Science

Proposed Appropriation Language

For Department of Energy expenses including the purchase, construction and acquisition of plant and capital equipment, and other expenses necessary for science activities in carrying out the purposes of the Department of Energy Organization Act (42 U.S.C. 7101 et seq.), including the acquisition or condemnation of any real property or facility or for plant or facility acquisition, construction, or expansion, and purchase of not to exceed **[**15**]** *four* passenger motor vehicles for replacement only, including not to exceed one ambulance, **[**$3,451,700,000**]** *$3,431,718,000* to remain available until expended. *(Energy and Water Development Appropriations Act, 2004.)*

[SEC. 130. DEPARTMENT OF ENERGY, ENERGY PROGRAMS, SCIENCE. For an additional amount for "Science", $50,000,000, to remain available until expended, is provided for the Coralville, Iowa, project, which is to utilize alternative energy sources.**]**

[SEC. 131. For an additional amount for the "Science" account of the Department of Energy in the Energy and Water Development Appropriations Act, 2004, there is appropriated $250,000, to remain available until expended, for Biological Sciences at DePaul University; $500,000, to remain available until expended; for the Cedars-Sinai Gene Therapy Research Program; and $500,000, to remain available until expended, for the Hartford Hospital Interventional Electrophysiology Project.**]**
(Division H, H.R. 2673 Consolidated Appropriations Bill, FY 2004.)

Explanation of Change

Changes are proposed to reflect the FY 2005 funding and vehicle request. No further funding is proposed for the Coralville, Iowa, project; Biological Sciences and DePaul University; the Cedars-Sinai Gene Therapy Research Program; or the Hartford Hospital Interventional Electrophysiology Project.

Science
Office of Science

Overview

Appropriation Summary by Program

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Science					
Basic Energy Sciences (BES	1,001,941	1,016,575	-5,984[a]	1,010,591	1,063,530
Advanced Scientific Computing Research (ASCR)	163,185	203,490	-1,198[a]	202,292	204,340
Biological & Environmental Research (BER)	494,360	592,000	+49,454[ab]	641,454	501,590
High Energy Physics (HEP)	702,038	737,978	-4,347[a]	733,631	737,380
Nuclear Physics (NP)	370,655	391,930	-2,307[a]	389,623	401,040
Fusion Energy Sciences (FES)	240,695	264,110	-1,555[a]	262,555	264,110
Science Laboratories Infrastructure (SLI)	45,109	54,590	-310[a]	54,280	29,090
Science Program Direction (SCPD)	137,425	147,053	+5,528[ac]	152,581	155,268
Workforce Development for Teachers and Scientists (WDTS)	5,392	6,470	-38[a]	6,432	7,660
Small Business Innovation Research/ Small Business Technology Transfer	100,172[d]	0	0	0	0
Safeguards and Security (S&S)	66,877	51,887	+10,441[ae]	62,328	73,315
Subtotal, Science	3,327,849	3,466,083	+49,684	3,515,767	3,437,323
Use of Prior Year Balances	0	-10,000	0	-10,000	0
Less security charge for reimbursable work	-5,605	-4,383	-1,215[f]	-5,598	-5,605
Total, Science	3,322,244	3,451,700	+48,469	3,500,169	3,431,718

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[a] Excludes $20,679,205 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003, as follows: BES $-5,984,276; ASCR $-1,197,753; BER $-3,795,588; HEP $-4,346,960; NP $-2,307,254; FES $-1,555,128; SLI $-310,110; SCPD $-864,126; WDTS $-37,736; and S&S $-280,274.

[b] Includes $53,250,000 provided by the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003.

[c] Includes $6,236,000 for the transfer in FY 2005 of 46 FTEs from the Office of Environmental Management (EM) to the Office of Science (SC) for the establishment of the Pacific Northwest Site Office (PNSO) and $1,100,000 for the transfer in FY 2005 of 10 FTEs from the National Nuclear Security Administration to SC for site office activities previously under Oakland Operations Office. Excludes $944,000 for the transfer in FY 2005 to the Office of Nuclear Energy, Science, and Technology of 7 FTEs associated with uranium management activities at Oak Ridge Operations Office.

[d] Includes $65,695,000 reprogrammed within the SC and $34,477,000 transferred from other DOE programs.

[e] Includes $10,721,000 for the transfer in FY 2005 of the newly established PNSO safeguards and security activities from EM to SC.

[f] Reflects security charges to reimbursable customers associated with the transfer in FY 2005 of the newly established PNSO safeguards and security activities from EM to SC.

Preface

The Office of Science (SC) requests $3,431,718,000 for the Fiscal Year (FY) 2005 Science appropriation, a decrease of $68,451,000 from FY 2004, 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. When $140,762,000 for FY 2004 Congressional earmarks are set aside, there is an increase of $72,311,000 in FY 2005.

Within the Science appropriation, the Office of Science has ten programs: Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, Nuclear Physics, Safeguards and Security, Science Laboratories Infrastructure, Workforce Development for Teachers and Scientists, and Science Program Direction.

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 also address the 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 program 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[a].

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).

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[a] The numbering scheme uses the following numbering convention: First 2 digits identify the General Goal (01 through 07); second two digits identify the GPRA Unit; last four digits are reserved for future use.

Mission

The mission of the Office of Science 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

The Office of Science plays five key roles in the U.S. research enterprise: *we support the missions of the Department of Energy*, delivering the scientific knowledge for solutions to our Nation's most critical energy and environmental challenges; *we are the Nation's leading supporter of the physical sciences*, which includes physics, chemistry and materials science; *we are the stewards of world-class scientific tools*, building and operating major research facilities for use by the world's scientific community; *we are the lead Federal agency for the creation of leadership class computational facilities for open science*, enabling solutions to problems in science and industry not attainable by simple extrapolation of existing architectures; and *we support a diverse set of researchers*, including those at more than 280 universities in every state in the Nation, scientists and technicians at the DOE national laboratories and in industry.

The Office of Science 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. The Office of Science has taken the lead on new research challenges for the Nation, such as launching the Human Genome Project in 1986.

Strategic 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 goals:

Energy Strategic Goal: To protect our national and economic security by reducing imports and promoting a diverse supply of reliable, affordable, and environmentally sound energy.

General Goal 4, Energy Security: Enhance energy security by developing technologies that foster a diverse supply of affordable and environmentally sound energy, improving energy efficiency, providing for reliable delivery of energy, exploring advanced technologies that make a fundamental change in our mix of energy options, and guarding against energy emergencies.

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; to 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 Goals 4 and 5 in the "goal cascade":

Program Goal 04.24.00.00/05.24.00.00: Bring the Power of the Stars to Earth — Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels a star.

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 elements in the Universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability, possessing radically different properties from known matter.

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

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

Program Goal 05.21.00.0: 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 alter the future of medical care and human health.

Contribution to General Goals

The *Fusion Energy Sciences (FES)* program contributes to General Goal 4 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 and will test the scientific and technical feasibility of fusion power. ITER is the penultimate step before a demonstration fusion power plant.

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

The *Advanced Scientific Computing Research (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, and 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. 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; 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 making interactions that used to take months happen almost instantaneously. ASCR will strengthen its contribution to Advanced Scientific Computing Research for SC in two main areas that specifically address ASCR's long term goals. First, we will 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, leading to leadership class machines. This critical investment will support the High End Computing Revitalization Task Force established by the Office of Science and Technology Policy, maintaining the Department's full participation in this interagency effort. Second, we will enhance ASCR's applied mathematics research to enable investigation of mathematics for modeling complex systems that will underpin SC's success in fields ranging from nanoscience to biology to global climate. This will develop the new area of "Atomic to Macroscopic Mathematics," also called *multiscale mathematics.* The new mathematical understanding of multiscale phenomena will engender the development of 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.

The *Basic Energy Sciences (BES)* program 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, 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, much shorter than the time of a chemical reaction or even the motion of molecule. With these tools, we will be able to understand how the composition of materials affects its properties, to watch proteins fold, to see chemical reactions, and to design for desired outcomes. Theory, modeling, and computer simulations will play a major role in achieving these outcomes and will be a companion to all of the experimental work. BES also supports basic research aimed at advancing hydrogen production, storage, and use for the coming hydrogen economy.

The *Biological and Environmental Research (BER)* program 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; in climate change, by including the development of models to predict climate over decades to centuries; by developing science-based methods for cleaning up environmental contaminants; in radiation biology, by providing regulators with a stronger scientific basis for developing future radiation protection standards; and in the medical sciences, by developing new diagnostic and therapeutic tools, technology for disease diagnosis and treatment, non-invasive medical imaging, and biomedical engineering such as an artificial retina that will restore sight to the blind.

The *Fusion Energy Sciences (FES)* program 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 Fusion Energy Sciences 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; 6) developing the cutting edge technologies that enable fusion facilities to achieve their scientific goals; and 7) advancing the science base for innovative materials to establish the economic feasibility and environmental quality of fusion energy.

The *High Energy Physics (HEP)* program contributes to General Goal 5 by advancing understanding of dark energy and dark matter, the lack of symmetry in the current universe, the basic constituents of matter, 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.

The *Nuclear Physics (NP)* program 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 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 provides for the nation's security, economic growth and opportunities, and improved quality of life.

Funding by General Goal

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Goal 4, Energy Security					
Program Goal 04.24.00.00, Fusion Energy..........	0	3,000[a]	7,000[b]	+4,000	+133.3%
General Goal 5, World-Class Scientific Research Capacity					
Program Goal 05.19.00.00, High Energy Physics ..	702,038	733,631	737,380	+3,749	+0.5%
Program Goal 05.20.00.00, Nuclear Physics..........	370,655	389,623	401,040	+11,417	+2.9%
Program Goal 05.21.00.00, Biological and Environmental Research..	494,360	641,454	501,590	-139,864	-21.8%
Program Goal 05.22.00.00, Basic Energy Sciences..	1,001,941	1,010,591	1,063,530	+52,939	+5.2%

[a] Reflects $3,000,000 in direct funding for ITER preparations. An additional $5,000,000 for ITER supporting activities is reflected within Goal 5, bringing the total Fusion program resources in preparation for ITER to $8,000,000 in FY 2004.

[b] Reflects $7,000,000 in direct funding for ITER preparations. An additional $31,000,000 for ITER supporting activities is reflected within Goal 5, bringing the total Fusion program resources in preparation for ITER to $38,000,000 in FY 2005.

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Program Goal 05.23.00.00, Advanced Scientific Computing Research	163,185	202,292	204,340	+2,048	+1.0%
Program Goal 05.24.00.00, Fusion Energy	240,695	259,555	257,110	-2,445	-0.9%
Total, General Goal 5, World-Class Scientific Research Capacity	2,972,874	3,237,146	3,164,990	-72,156	-2.2%
All Other					
Science Laboratories Infrastructure	45,109	54,280	29,090	-25,190	-46.4%
Program Direction	137,425	152,581	155,268	+2,687	+1.8%
Workforce Development for Teachers and Scientists	5,392	6,432	7,660	+1,228	+19.1%
SBIR/STTR	100,172	0	0	0	0.0%
Safeguards and Security	61,272	56,730	67,710	+10,980	+19.4%
Total, All Other	349,370	270,023	259,728	-10,295	-3.8%
Subtotal, General Goal 4 and 5, and All Other (Science)	3,322,244	3,510,169	3,431,718	-78,451	-2.2%
Use of Prior-Year Balances	0	-10,000	0	+10,000	+100.0%
Total, General Goal 4 and 5, and All Other (Science)	3,322,244	3,500,169	3,431,718	-68,451	-2.0%

R&D Investment Criteria

The President's Management Agenda identified the need to tie R&D investment to performance and well-defined practical outcomes. One criterion by which the Department's performance is measured involves using a framework in the R&D funding decision process and then referencing the use and outcome of the framework in budget justification material.

The goal is to develop highly analytical justifications for research portfolios in future budgets. This will require the development and application of a uniform cost and benefit evaluation methodology across programs to allow meaningful program comparisons.

The R&D Investment Criteria — *Quality, Relevance,* and *Performance* — help the Office of Science to take a portfolio approach to selecting the investments included in this budget request, in the recently released *Facilities for the Future of Science: a Twenty-Year Outlook*, and in the soon to be released *Office of Science Strategic Plan*. In addition, the business management practices and evaluation activities in the Office of Science remain focused on the principles of the Administration's R&D Investment Criteria. The R&D Program Assessment Rating Tool (PART) measures the degree to which the R&D Investment Criteria are implemented in the Office of Science.

Program Assessment Rating Tool (PART)

In addition to the use of R&D investment criteria, 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 that, when successfully completed, 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 2005 budget request, and the Department will take the necessary steps to continue to improve performance.

In its PART review, OMB assessed six Office of Science programs: Advanced Scientific Computing Research (ASCR), Basic Energy Sciences (BES), Biological and Environmental Research (BER), Fusion Energy Sciences (FES), High Energy Physics (HEP), and Nuclear Physics (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." This is a significant improvement from the FY 2004 PART review, which rated all SC programs as "Results Not Demonstrated" and scores ranged from 53-63%.

The improvements made by SC, based on the FY 2004 PART results and recommendations by OMB include the expanded use of Committees of Visitors (COVs) — outside experts who review a program's portfolio for quality and consistent application of business practices, a complete reworking of the long-term and annual performance measures in partnership with OMB, drafting of a new Office of Science Strategic Plan, developing some program-specific strategic plans with input from Advisory Committees, and improving the documentation of evidence.

OMB has identified other areas in the FY 2005 PART that SC will work to improve, including concerns about the degree of DOE's budget and performance integration and the comprehensiveness of the Department's Annual Performance Report. OMB also found that while the Department's Inspector General contracts with an outside auditor to check internal controls for performance reporting and periodically conducts limited reviews of performance measurement in the Office of Science, it is not clear that these audits check the credibility of performance data reported by DOE contractors. Although OMB is pleased with the SC commitment to COVs, answers to some questions, particularly in the Program Management section of the PART, will remain "No" until after COVs have reported positive reviews. In addition, a few program specific performance issues were raised in the Results section of the PART particularly in regard to the operation of some facilities. The full PARTs are available on the OMB website at http://www.whitehouse.gov/omb/budget/fy2005/pma.html

Significant Program Shifts

The FY 2005 budget request sets the Office of Science on the path toward addressing the challenges that face our Nation in the 21st Century. Our Strategic Plan, to be (published in February 2004), and a 20-Year Science Facilities Plan set an ambitious agenda for scientific discovery over the next decade that reflects national priorities set by the President and the Congress, our commitment to the missions of the Department of Energy, and the views of the U.S. scientific community. Pursuing the following research priorities will be challenging, but they hold enormous promise for the overall well-being of all of our citizens:

- *Fusion:* Develop a predictive understanding of fusion plasmas, including a burning plasma, for an enduring solution to our Nation's energy challenge.
- *Scientific Discovery and Innovation through Advanced Scientific Computing:* Expand the broad frontiers of scientific discovery and innovation through the power of advanced computation.
- *Nanoscale Science for New Materials and Processes:* Master the ability to construct revolutionary new materials and processes…atom-by-atom and build upon nature's self-assembling techniques.
- *Taming the Microbial World — the Next Revolution in Genomics:* Harness microbial genomes and the molecular machines of life for clean energy and a cleaner environment.
- *Dark Energy and the Search for the Genesis:* Illuminate the basic forces of creation and the origins of matter, energy, space and time.
- *Nuclear Matter at the Extremes:* Explore new forms of nuclear matter at high energy densities and at the extreme limits of stability.
- *Facilities for the Future of Science:* Pursue the required scientific tools that support the Nation's research in areas that are traditionally the responsibility of DOE.

The Office of Science is ready to meet the scientific challenges of our age. 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 have restructured our workforce and our business practices to achieve greater efficiencies and economies of scale that will improve the performance of the 10 national laboratories we manage. This FY 2005 budget request is a major step toward achieving our national goals energy independence, economic security, environmental quality, and intellectual leadership.

The Office of Science is proposing a restructuring and reengineering project, *OneSC*, and anticipates that this effort will result in functional consolidations, process reengineering, and elimination of skills imbalances throughout the organization. Full implementation of this realignment is expected to begin in FY 2004. This project reflects the changes envisioned by the President's Management Agenda (PMA) and directly supports the PMA objective to manage government programs more economically and effectively. The *OneSC* project will determine the best alternatives for obtaining essential services and support for the Office of Science field organizations. In addition, in response to the functional transfer within the Richland Operations Office from the Office of Environmental Management in support of the PNNL, the Office of Science will establish a Pacific Northwest Site Office (PNSO).

The *Advanced Scientific Computing Research* program will support planned research efforts in the Scientific Discovery through Advanced Computing (SciDAC) program — 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. In addition, the Next Generation Computer Architecture (NGA) effort will enable DOE and the Nation to evaluate the potential increases in delivered computing capability available to address the Office of Science mission through optimization of computer architectures to meet the special requirements of scientific problems. The NGA effort complements SciDAC and integrates advanced computer architecture researchers and engineers, application scientists, computer scientists, and applied mathematicians. The Laboratory Technology Research subprogram was brought to a successful conclusion in FY 2004, with the orderly completion of all existing CRADAs. The FY 2005 budget also includes funding for the new "Atomic to Macroscopic Mathematics" (AMM) research effort to provide the research support in applied mathematics needed to break through the current barriers in our understanding of complex physical processes that occur on a wide range of interacting length- and time-scales.

In the *Basic Energy Sciences* program, Project Engineering and Design (PED) and construction will proceed on four Nanoscale Science Research Centers (NSRCs) and funding will be provided for a Major Item of Equipment for the fifth and final NSRC. NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. They are designed to enable the nanoscale revolution by collocating multiple research disciplines, 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. The FY 2005 budget request includes new funding for activities that support the President's Hydrogen Fuel Initiative. This research program is based on the BES workshop report *Basic Research Needs for the Hydrogen Economy,* which highlights the enormous gap between our present capabilities and those required for a competitive hydrogen economy. The FY 2005 budget request also funds long-lead procurement activities for a revolutionary x-ray laser light source—located on the Stanford University campus—that would open entirely new realms of discovery in the chemical, materials, and biological sciences.

The *Biological and Environmental Research* program will support a facility for the Production and Characterization of Proteins and Molecular Tags, a facility that will help move the excitement of the Genomics: GTL program systems biology research to a new level by mass producing and characterizing proteins directly from microbial DNA sequences and creating affinity reagents — or "tags"— to identify, capture, and monitor the proteins from living systems. BER will focus its atmospheric sciences research on key uncertainties that currently limit our ability to accurately simulate and predict the direct and indirect effect of aerosols on climate. Aerosols play a significant but poorly understood role in climate.The Environmental Remediation subprogram will integrate research from a number of other programs (Environmental Management Science Program, Natural and Accelerated Bioremediation Research Program, Environmental Molecular Sciences Laboratory, Savannah River Ecology Laboratory) to perform "comprehensive" field studies. In FY 2005, BER will: (1) greatly increase our understanding of biological systems important to DOE's energy and environmental needs by increasing its rate of DNA sequencing to produce at least 20 billion base pairs of high quality DNA microbial and model organism genome sequence; (2) increase the accuracy (and more accurately depict the complexity) of climate models by including new information on the global cycling of carbon dioxide into and out of the atmosphere, atmospheric aerosols, and interactions between the climate system and the terrestrial biosphere; (3) improve our ability to treat environmental contamination by carrying out complex studies that span field sites, research laboratories, and computational models that can predict the behavior of contaminants in the environment; and (4) complete the testing on an artificial retina with 60 microelectrodes and insert this prototype device into a blind patient.

In the *Fusion Energy Sciences* program, the FY 2005 budget continues the redirection of the fusion program to prepare for participation in the ITER program, while also supporting many of the program priorities recommended by the Fusion Energy Sciences Advisory Committee and supported by the Secretary of Energy Advisory Board and the National Research Council. Assuming a successful outcome of ongoing ITER negotiations, in FY 2005 FES scientists and engineers will be supporting the technical R&D and the preparations to start project construction in FY 2006. Support will continue for the Scientific Discovery through Advanced Computing (SciDAC) program, which is being refocused on the physics of a burning plasma. The Inertial Fusion Energy research program will be redirected toward high energy density physics research based on recommendations of the recently established Interagency Task Force on High Density Physics. Fabrication of the National Compact Stellarator Experiment (NCSX) will also continue with a target of FY 2008 for the initial operation of this innovative new confinement system: the product of advances in physics understanding and computer modeling. In addition, work will be initiated on the Fusion Simulation Project — a joint effort with the Advanced Scientific Computing Research program — to provide an integrated simulation and modeling capability for magnetic fusion energy confinement systems over a 15-year development period.

To fully exploit their unique discovery potential, high priority in the *High Energy Physics* program will be given to the operations, upgrades, and infrastructure for the Tevatron at Fermi National Accelerator Laboratory and B-Factory at Stanford Linear Accelerator Laboratory. These include upgrades to the two accelerators to provide increased luminosity, detector component replacements to accommodate the higher intensities, and additional computational resources to support analysis of the anticipated larger volume of data. Planned accelerator and detector upgrades are scheduled for completion in 2006. Infrastructure spending is increased to improve Tevatron reliability and B-factory performance by installing new and upgraded diagnostic and feedback systems and by replacing outdated technology components. The FY 2005 budget request also supports engineering design activities for a new Major Item of Equipment, the BTeV ("B Physics at the TeVatron") experiment at Fermilab to enable new physics inaccessible to existing B-factories. This project is part of the 20-Year Science Facilities Plan.

In the *Nuclear Physics* program, the FY 2005 budget gives highest priority to exploiting the unique discovery potentials of the facilities at the RHIC and Continuous Electron Beam Accelerator Facility (CEBAF) by increasing operating time by 26% compared with FY 2004. Operations of the MIT/Bates facility will be terminated as planned, following three months of operations in FY 2005 to complete its research program. This facility closure follows the transitioning of operations of the Lawrence Berkeley National Laboratory 88-Inch Cyclotron in FY 2004 from a user facility to a dedicated facility for the testing of electronic circuit components for use in space (using funds from other agencies) and a small in-house research program. These resources have been redirected to better utilize and increase science productivity of the remaining user facilities and provide for new opportunities in the low-energy subprogram. Momentum will be maintained in exploiting the new opportunity presented with intense cold and ultra cold neutron sources at Los Alamos National Laboratory and at the Spallation Neutron Source. Funding for capital equipment will address opportunities identified in the recently completed 2002 Nuclear Science Advisory Committee Long Range Plan. R&D funding is provided for the proposed Rare Isotope Accelerator (RIA) and 12 GeV upgrade of CEBAF at Thomas Jefferson National Accelerator Facility.

Workforce Development for Teachers and Scientists will run Laboratory Science Teacher Professional Development activities at five or more DOE national laboratories with about 30 participating teachers, in response to the national need for science teachers who have strong content knowledge in the classes they teach. A new Faculty Sabbatical activity, proposed in FY 2005, will provide sabbatical opportunities for 12 faculty from minority serving institutions (MSIs). This proposed activity is an extension of the successful Faculty Student Teams (FaST) program where teams of faculty members and two or three undergraduate students, from colleges and universities with limited prior research capabilities, work with mentor scientists at a National Laboratory to complete a research project that is formally documented in a paper or presentation.

The purpose of the *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. In FY05, increased funding is primarily in cyber security and in the areas of protective forces and security systems for projected maintenance of elevated emergency security conditions (SECON) levels. The increases will enable continued self-assessment activities, full implementation of Integrated Safeguards and Security Management, and adequate support for the Foreign Visits and Assignments program.

Institutional General Plant Projects

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

IGPP projects at SC sites include the following:

- Building 1506 Renovation at Oak Ridge National Laboratory. This FY 2003 and FY 2004 effort includes structural upgrades to comply with DOE and international codes, greenhouse replacements, laboratory reconfigurations, and HVAC modifications. TEC: $3,000,000.
- East Campus Entry and Parking design and construction at Oak Ridge National Laboratory. This FY 2003 and FY 2004 effort includes construction of a new 25,000 ft^2 parking court for approximately 60 cars and a 20,000 ft^2 terrace area with seating and informal gathering areas. TEC: $2,725,000.
- Central Avenue Extension design and construction at Oak Ridge National Laboratory. The effort, initiated in FY 2002, will extend Central Avenue by approximately 680 feet to the east, from the current intersection at 6th Street, to improve traffic flow at the site. TEC: $1,725,000.

The following displays IGPP funding by site:

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Oak Ridge National Laboratory	6,000	6,000	3,000	-3,000	-50.0%
Pacific Northwest National Laboratory	0	1,000	3,500	+2,500	+250.0%
Total, IGPP	6,000	7,000	6,500	-500	-7.1%

Office of Science

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
President's Hydrogen Initiative	7,640	7,737	29,183	+21,446	+277.2%
Genomics: GTL	42,081	71,327	79,993	+8,666	+12.1%
Climate Change Science Program	118,060	133,275	134,169	+894	+0.7%
High Performance Computing and Communications	180,628	218,613	225,938	+7,325	+3.4%
Nanoscience Engineering and Technology	133,607	203,352	211,225	+7,873	+3.9%

Science
Office of Science

Funding by Site by Program

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Chicago Operations Office					
Ames Laboratory					
Basic Energy Sciences	17,970	18,310	16,547	-1,763	-9.6%
Advanced Scientific Computing Research	1,873	1,587	1,538	-49	-3.1%
Biological and Environmental Research	887	305	0	-305	-100.0%
Science Laboratories Infrastructure	0	150	150	0	0.0%
Safeguards and Security	395	409	505	+96	+23.5%
Total, Ames Laboratory	21,125	20,761	18,740	-2,021	-9.7%
Argonne National Laboratory – East					
Basic Energy Sciences	156,193	169,725	171,403	+1,678	+1.0%
Advanced Scientific Computing Research	12,413	11,394	10,682	-712	-6.2%
Fusion Energy Sciences	1,333	920	976	+56	+6.1%
High Energy Physics	9,539	8,926	9,512	+586	+6.6%
Nuclear Physics	20,829	17,720	19,098	+1,378	+7.8%
Biological and Environmental Research	25,048	26,423	24,454	-1,969	-7.5%
Science Laboratories Infrastructure	4,107	5,901	2,120	-3,781	-64.1%
Workforce Development for Teachers and Scientists	1,550	1,307	2,560	+1,253	+95.9%
Safeguards and Security	7,680	7,651	9,784	+2,133	+27.9%
Total, Argonne National Laboratory	238,692	249,967	250,589	+622	+0.2%
Brookhaven National Laboratory					
Basic Energy Sciences	65,782	67,649	80,382	+12,733	+18.8%
Advanced Scientific Computing Research	1,162	761	611	-150	-19.7%
High Energy Physics	36,342	22,022	19,884	-2,138	-9.7%
Nuclear Physics	146,721	147,861	155,892	+8,031	+5.4%
Biological and Environmental Research	18,638	18,531	17,960	-571	-3.1%
Science Laboratories Infrastructure	8,244	6,696	4,758	-1,938	-28.9%
Workforce Development for Teachers and Scientists	517	517	725	+208	+40.2%
Safeguards and Security	10,929	10,756	11,342	+586	+5.4%
Total, Brookhaven National Laboratory	288,335	274,793	291,554	+16,761	+6.1%

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Fermi National Accelerator Laboratory					
Advanced Scientific Computing Research .	226	115	146	+31	+27.0%
High Energy Physics	313,506	300,311	303,629	+3,318	+1.1%
Nuclear Physics	48	0	0	0	0.0%
Science Laboratories Infrastructure...........	362	233	125	-108	-46.4%
Workforce Development for Teachers and Scientists	50	70	98	+28	+40.0%
Safeguards and Security	2,805	2,837	3,067	+230	+8.1%
Total, Fermi National Accelerator Laboratory ...	316,997	303,566	307,065	+3,499	+1.2%
Chicago Operations Office					
Basic Energy Sciences	132,240	132,967	117,872	-15,095	-11.4%
Advanced Scientific Computing Research .	27,512	20,199	23,902	+3,703	+18.3%
Fusion Energy Sciences	50,484	120,796	123,308	+2,512	+2.1%
High Energy Physics	81,571	115,797	109,613	-6,184	-5.3%
Nuclear Physics	55,659	69,550	66,011	-3,539	-5.1%
Biological and Environmental Research.....	130,017	111,901	96,167	-15,734	-14.1%
Science Laboratories Infrastructure...........	1,007	0	1,520	+1,520	+100.0%
Science Program Direction	32,043	37,924	39,517	+1,593	+4.2%
SBIR/STTR	87,495	0	0	0	0.0%
Total, Chicago Operations Office	598,028	609,134	577,910	-31,224	-5.1%
Princeton Plasma Physics Laboratory					
Advanced Scientific Computing Research .	455	150	345	+195	+130.0%
Fusion Energy Sciences	62,230	70,454	67,977	-2,477	-3.5%
High Energy Physics	225	225	364	+139	+61.8%
Science Laboratories Infrastructure...........	545	980	0	-980	-100.0%
Workforce Development for Teachers and Scientists	90	80	110	+30	+37.5%
Safeguards and Security	3,489	1,855	1,945	+90	+4.9%
Total, Princeton Plasma Physics Laboratory	67,034	73,744	70,741	-3,003	-4.1%
Total, Chicago Operations Office	1,542,888	1,531,965	1,516,599	-15,366	-1.0%

(dollars in thousands)	FY 2003	FY 2004	FY 2005	$ Change	% Change
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory					
Basic Energy Sciences	1,911	1,045	1,494	+449	+43.0%
Fusion Energy Sciences	2,322	2,048	2,172	+124	+6.1%
Biological and Environmental Research	3,073	3,750	3,495	-255	-6.8%
Workforce Development for Teachers and Scientists	70	90	100	+10	+11.1%
Total, Idaho National Engineering and Environmental Laboratory	7,376	6,933	7,261	+328	+4.7%
Idaho Operations Office					
Biological and Environmental Research	4,805	5,456	1,135	-4,321	-79.2%
Total, Idaho Operations Office	12,181	12,389	8,396	-3,993	-32.2%
Livermore Site Office					
Lawrence Livermore National Laboratory					
Basic Energy Sciences	4,374	4,537	4,676	+139	+3.1%
Advanced Scientific Computing Research	5,965	5,313	3,023	-2,290	-43.1%
Fusion Energy Sciences	14,114	14,266	13,408	-858	-6.0%
High Energy Physics	1,531	650	436	-214	-32.9%
Nuclear Physics	823	690	500	-190	-27.5%
Biological and Environmental Research	22,351	24,426	23,645	-781	-3.2%
Science Laboratories Infrastructure	250	250	300	+50	+20.0%
Total, Lawrence Livermore National Laboratory	49,408	50,132	45,988	-4,144	-8.3%
Los Alamos Site Office					
Los Alamos National Laboratory					
Basic Energy Sciences	29,554	34,192	23,663	-10,529	-30.8%
Advanced Scientific Computing Research	3,990	3,448	3,030	-418	-12.1%
Fusion Energy Sciences	6,661	3,868	3,574	-294	-7.6%
High Energy Physics	964	695	825	+130	+18.7%
Nuclear Physics	9,678	8,963	9,107	+144	+1.6%
Biological and Environmental Research	24,091	21,134	19,600	-1,534	-7.3%
Total, Los Alamos National Laboratory	74,938	72,300	59,799	-12,501	-17.3%

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
NNSA Service Center/Albuquerque					
Golden Field Office					
Workforce Development for Teachers and Scientists	200	265	350	+85	+32.1%
National Renewable Energy Laboratory					
Basic Energy Sciences	5,598	5,705	4,562	-1,143	-20.0%
Advanced Scientific Computing Research	0	150	0	-150	-100.0%
Total, National Renewable Energy Laboratory	5,598	5,855	4,562	-1,293	-22.1%
NNSA Service Center/Albuquerque					
Biological and Environmental Research	850	850	850	0	0.0%
Total, NNSA Service Center/Albuquerque	6,648	6,970	5,762	-1,208	-17.3%
NNSA Service Center/Oakland					
Lawrence Berkeley National Laboratory					
Basic Energy Sciences	96,683	121,083	106,615	-14,468	-11.9%
Advanced Scientific Computing Research	55,348	56,020	54,886	-1,134	-2.0%
Fusion Energy Sciences	6,140	5,909	5,909	0	0.0%
High Energy Physics	43,507	39,339	38,323	-1,016	-2.6%
Nuclear Physics	20,435	16,407	17,955	+1,548	+9.4%
Biological and Environmental Research	66,885	66,946	64,207	-2,739	-4.1%
Science Laboratories Infrastructure	6,961	2,500	6,185	+3,685	+147.4%
Workforce Development for Teachers and Scientists	572	705	783	+78	+11.1%
Science Program Direction	0	0	50	+50	+100.0%
Safeguards and Security	4,649	4,689	5,165	+476	+10.2%
Total, Lawrence Berkeley National Laboratory	301,180	313,598	300,078	-13,520	-4.3%
NNSA Service Center/Oakland					
Basic Energy Sciences	29,487	0	0	0	0.0%
Advanced Scientific Computing Research	2,495	0	0	0	0.0%
Fusion Energy Sciences	69,520	4,644	0	-4,644	-100.0%
High Energy Physics	37,895	0	0	0	0.0%
Nuclear Physics	15,849	0	0	0	0.0%
Biological and Environmental Research	36,048	0	0	0	0.0%
SBIR/STTR	12,677	0	0	0	0.0%
Total, NNSA Service Center/Oakland	203,971	4,644	0	-4,644	-100.0%

(dollars in thousands)	FY 2003	FY 2004	FY 2005	$ Change	% Change
Stanford Linear Accelerator Center					
Basic Energy Sciences	45,313	43,629	85,218	+41,589	+95.3%
Advanced Scientific Computing Research	613	281	160	-121	-43.1%
High Energy Physics	160,033	168,982	169,175	+193	+0.1%
Biological and Environmental Research	5,450	3,675	3,200	-475	-12.9%
Science Laboratories Infrastructure	13	2,138	7,508	+5,370	+251.2%
Workforce Development for Teachers and Scientists	150	150	150	0	0.0%
Safeguards and Security	2,211	2,207	2,341	+134	+6.1%
Total, Stanford Linear Accelerator Center	213,783	221,062	267,752	+46,690	+21.1%
Total, NNSA Service Center/Oakland	706,257	539,304	567,830	+28,526	+5.3%
Oak Ridge Operations Office					
Oak Ridge Institute For Science and Education					
Basic Energy Sciences	2,130	1,069	872	-197	-18.4%
Advanced Scientific Computing Research	325	250	200	-50	-20.0%
Fusion Energy Sciences	896	1,002	919	-83	-8.3%
High Energy Physics	130	0	130	+130	+100.0%
Nuclear Physics	726	678	669	-9	-1.3%
Biological and Environmental Research	5,848	4,161	3,977	-184	-4.4%
Science Laboratories Infrastructure	0	0	565	+565	+100.0%
Workforce Development for Teachers and Scientists	1,217	1,132	1,340	+208	+18.4%
Science Program Direction	25	0	55	+55	+100.0%
Safeguards and Security	1,250	1,254	1,410	+156	+12.4%
Total, Oak Ridge Institute for Science and Education	12,547	9,546	10,137	+591	+6.2%
Oak Ridge National Laboratory					
Basic Energy Sciences	365,058	277,590	235,239	-42,351	-15.3%
Advanced Scientific Computing Research	34,894	20,677	21,833	+1,156	+5.6%
Fusion Energy Sciences	20,935	20,236	19,868	-368	-1.8%
High Energy Physics	663	200	623	+423	+211.5%
Nuclear Physics	18,188	19,484	20,423	+939	+4.8%
Biological and Environmental Research	46,204	43,360	39,431	-3,929	-9.1%
Science Laboratories Infrastructure	12,839	10,360	780	-9,580	-92.5%
Safeguards and Security	9,433	6,894	8,713	+1,819	+26.4%
Total, Oak Ridge National Laboratory	508,214	398,801	346,910	-51,891	-13.0%

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Office of Scientific Technical Information					
Advanced Scientific Computing Research	10	10	0	-10	-100.0%
Biological and Environmental Research	22	236	236	0	0.0%
Safeguards and Security	265	60	590	+530	+883.3%
Workforce Development for Teachers and Scientists	75	80	90	+10	+12.5%
Total, Office of Scientific Technical Information	372	386	916	+530	+137.3%
Thomas Jefferson National Accelerator Facility					
Advanced Scientific Computing Research	19	0	0	0	0.0%
High Energy Physics	10	0	0	0	0.0%
Nuclear Physics	80,060	81,601	86,345	+4,744	+5.8%
Biological and Environmental Research	1,080	775	525	-250	-32.3%
Science Laboratories Infrastructure	1,481	9,019	0	-9,019	-100.0%
Workforce Development for Teachers and Scientists	10	261	291	+30	+11.5%
Safeguards and Security	1,132	972	1,174	+202	+20.8%
Total, Thomas Jefferson National Accelerator Facility	83,792	92,628	88,335	-4,293	-4.6%
Oak Ridge Operations Office					
Biological and Environmental Research	464	373	371	-2	-0.5%
Science Laboratories Infrastructure	5,015	5,049	5,079	+30	+0.6%
Science Program Direction	44,116	48,556	50,134	+1,578	+3.2%
Safeguards and Security	11,593	11,688	15,872	+4,184	+35.8%
Total, Oak Ridge Operations Office	61,188	65,666	71,456	+5,790	+8.8%
Total, Oak Ridge Operations Office	666,113	567,027	517,754	-49,273	-8.7%

	FY 2003	FY 2004	FY 2005	$ Change	% Change
	(dollars in thousands)				
Richland Operations Office					
Pacific Northwest National Laboratory					
Basic Energy Sciences	13,115	13,821	11,648	-2,173	-15.7%
Advanced Scientific Computing Research	3,932	2,839	2,826	-13	-0.5%
Fusion Energy Sciences	1,436	1,365	1,384	+19	+1.4%
High Energy Physics	49	0	0	0	0.0%
Nuclear Physics	49	0	0	0	0.0%
Biological and Environmental Research	85,304	86,912	80,287	-6,625	-7.6%
Science Laboratories Infrastructure	0	1,979	0	-1,979	-100.0%
SLI — use of prior year balances	0	-3,950	0	+3,950	+100.0%
Workforce Development for Teachers and Scientists	748	838	931	+93	+11.1%
Science Program Direction	63	0	0	0	0.0%
Safeguards and Security	10,716	10,721	11,070	+349	+3.3%
Total, Pacific Northwest National Laboratory	115,412	114,525	108,146	-6,379	-5.6%
Richland Operations Office					
Workforce Development for Teachers and Scientists	25	0	0	0	0.0%
Total, Richland Operations Office	115,437	114,525	108,146	-6,379	-5.6%
Sandia Site Office					
Sandia National Laboratories					
Basic Energy Sciences	31,047	47,260	54,548	+7,288	+15.4%
Advanced Scientific Computing Research	9,735	9,318	8,572	-746	-8.0%
Fusion Energy Sciences	3,107	2,678	2,812	+134	+5.0%
Biological and Environmental Research	7,447	6,814	6,646	-168	-2.5%
Science Program Direction	163	0	0	0	0.0%
Total, Sandia National Laboratories	51,499	66,070	72,578	+6,508	+9.9%
Savannah River Site					
Westinghouse - Savannah River					
Fusion Energy Sciences	45	45	44	-1	-2.2%
Biological and Environmental Research	653	803	232	-571	-71.1%
Total, Westinghouse – Savannah River	698	848	276	-572	-67.5%
Savannah River Site Office					
Biological and Environmental Research	6,800	7,599	7,776	+177	+2.3%
Total, Savannah River Site	7,498	8,447	8,052	-395	-4.7%

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Headquarters					
Basic Energy Sciences	5,486	72,009	148,791	+76,782	+106.6%
Advanced Scientific Computing Research	2,218	69,780	72,586	+2,806	+4.0%
Fusion Energy Sciences	1,472	14,324	21,759	+7,435	+51.9%
High Energy Physics	16,073	76,484	84,866	+8,382	+11.0%
Nuclear Physics	1,590	26,669	25,040	-1,629	-6.1%
Biological and Environmental Research	2,395	207,024	107,396	-99,628	-48.1%
Workforce Development for Teachers and Scientists	118	937	132	-805	-85.9%
Science Laboratories Infrastructure	4,285	12,975	0	-12,975	-100.0%
Science Program Direction	61,015	66,101	65,512	-589	-0.9%
Safeguards and Security	330	335	337	+2	+0.6%
Total, Headquarters	94,982	546,638	526,419	-20,219	-3.7%
Subtotal, Science	3,327,849	3,515,767	3,437,323	-78,444	-2.2%
Use of Prior Year Balances	0	-10,000	0	+10,000	+100.0%
Less Security Charge for Reimbursable Work	-5,605	-5,598	-5,605	-7	-0.1%
Total, Science	3,322,244	3,500,169	3,431,718	-68,451	-2.0%

Site Description

Ames Laboratory

Introduction

Ames Laboratory is a Multiprogram Laboratory located on 10 acres of land owned by the University of Iowa, in Ames, Iowa. The laboratory consists of 10 buildings (320,000 gross square feet of space) with the average age of the buildings being 39 years.

The laboratory was built on the campus of Iowa State University during World War II to emphasize the purification and science of rare earth materials. Ames conducts fundamental research in the physical, chemical, and mathematical sciences associated with energy generation and storage. Ames 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. It 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 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.

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 National Laboratory

Introduction

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on 1,700 acres in suburban Chicago. The laboratory consists of 106 buildings (4.6 million gross square feet of space) with the average age of the buildings being 32 years. ANL has a satellite site located in Idaho Falls, Idaho.

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, the Intense Pulsed Neutron Source, and the Electron Microscopy Center for Materials Research.

The **Advanced Photon Source** (APS) 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** (IPNS) 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** (EMC) 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 collaboratory pilot projects as well as supporting an advanced computing research testbed and participates on a number of the SciDAC teams. It also focuses on testing and evaluating leading edge research computers and participates in Integrated Software Infrastructure Center activities that focus on specific software challenges confronting users of terascale computers.

Fusion Energy Sciences

Argonne contributes to a variety of enabling R&D program activities. It has a lead role internationally in analytical models and experiments for liquid metal cooling in fusion devices. Studies of coatings for candidate structural alloy materials are conducted in a liquid lithium flow loop. Argonne's capabilities in the engineering design of fusion energy systems have contributed to the design of components, as well as to analysis supporting the studies of fusion power plant concepts.

High Energy Physics

HEP supports a program of physics research and technology R&D, using unique capabilities of the laboratory in the areas of advanced accelerator and computing techniques.

Nuclear Physics

The major ANL activity is the operation and research program at the ATLAS national user facility. Other activities include a Medium Energy group which carries out a program of research at TJNAF, Fermilab, RHIC and DESY in Germany; R&D directed towards the possible Rare Isotope Accelerator (RIA) facility; a Nuclear Theory group, which carries out theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy and Low Energy physics; and data compilation and evaluation activities as part of the National Nuclear Data Program.

The **Argonne Tandem Linac Accelerator System (ATLAS)** facility provides variable energy, precision beams of stable ions from protons through uranium, at energies near the Coulomb barrier (up to 10 MeV per nucleon) using a superconducting linear accelerator. Most work is performed with stable heavy-ion beams; however, about 6% of the beams are exotic (radioactive) beams. The ATLAS facility features a wide array of experimental instrumentation, including a world-leading ion-trap apparatus, the 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 is a world leader in superconducting linear accelerator technology, with particular application to the possible Rare Isotope Accelerator (RIA) facility. The combination of versatile beams and powerful instruments enables the ~230 users annually at ATLAS to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies.

Biological and Environmental Research

ANL operates a high-throughput national user facility for protein crystallography at the Advanced Photon Source. 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 ARM sites. Research is conducted to understand the molecular control of genes and gene pathways in microbes. In conjunction with ORNL and PNNL and six universities, ANL co-hosts the terrestrial carbon sequestration research consortium, Carbon Sequestration in Terrestrial Ecosystems (CSiTE).

Science Laboratories Infrastructure

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

Brookhaven National Laboratory

Introduction

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on 5,200 acres in Upton, New York. The laboratory consists of 371 buildings (4.1 million gross square feet of space) with the average age of the buildings being 34 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** is among the largest and most diverse scientific user facilities in the world. The NSLS, commissioned in 1982, has consistently operated at >95% reliability 24 hours a day, seven days a week, with scheduled periods for maintenance and machine studies. Adding to its breadth is the fact that the NSLS consists of two distinct electron storage rings. The x-ray storage ring is 170 meters in circumference and can accommodate 60 beamlines or experimental stations, and the vacuum-ultraviolet (VUV) storage ring can provide 25 additional beamlines around its circumference of 51 meters. Synchrotron light from the x-ray ring is used to determine the atomic structure of materials using diffraction, absorption, and imaging techniques. Experiments at the VUV ring help solve the atomic and electronic structure as well as the magnetic properties of a wide array of materials. These data are fundamentally important to virtually all of the physical and life sciences as well as providing immensely useful information for practical applications. The petroleum industry, for example, uses the NSLS to develop new catalysts for refining crude oil and making by-products like plastics.

Advanced Scientific Computing Research

BNL has a computing capability for Quantum Chromodynamics (QCD) simulations and participates on one of the SciDAC teams. It also participates in Integrated Software Infrastructure Center activities that focus on specific software challenges confronting users of terascale computers.

High Energy Physics

HEP supports a program of physics research and technology R&D, using unique capabilities of the laboratory, including the Accelerator Test Facility and its capability for precise experimental measurement.

Nuclear Physics

Research activities include use of polarized protons in the Relativistic Heavy Ion Collider (RHIC) to understand the internal “spin” structure of the protons, the Laser Electron Gamma Source (LEGS) group, that uses a unique polarized photon beam to carry out a program of photonuclear spin physics at the National Synchrotron Light Source (NSLS), research primarily in the area of relativistic heavy ion physics, an important role in the research program at the Sudbury Neutrino Observatory (SNO) that is measuring the solar neutrino flux, and the National Nuclear Data Center (NNDC) that is the central U.S. site for national and international nuclear data and compilation efforts.

The Relativistic Heavy Ion Collider (RHIC) Facility, completed in 1999, is a major new and unique international facility used by about 1,100 scientists from 19 countries. RHIC uses the Tandem Van de Graaff, Booster Synchrotron, and Alternating Gradient Synchrotron (AGS) accelerators in combination to inject beams into two rings of superconducting magnets of almost 4 km circumference with 6 intersection regions where the beams collide. It can accelerate and collide a variety of heavy ions, including gold beams, up to an energy of 100 GeV per nucleon. RHIC will search for the predicted "quark-gluon plasma," a form of nuclear matter thought to have existed microseconds after the "Big Bang."

The **Alternating Gradient Synchrotron (AGS)** provides high intensity pulsed proton beams up to 33 GeV on fixed targets and secondary beams of kaons, muons, pions, and anti-protons. The AGS is the injector of (polarized) proton and heavy-ion beams into RHIC, and its operations are supported by the Heavy Ion subprogram as part of the RHIC facility. Operation of the AGS for fixed targets and secondary beams for medium energy physics experiments was terminated in FY 2003; however, the AGS will still be utilized to produce beams for tests of proton radiography for NNSA and for radiation damage studies 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 as a Work-for-Others project completed in FY 2003. Operational costs for this facility are being 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 that maintains the U.S. expertise in low- and intermediate-energy nuclear physics by providing evaluated nuclear data for the user community. The NNDC is assisted in carrying out this responsibility by other Nuclear Data program funded scientists at U.S. National Laboratories and universities.

Biological and Environmental Research

BNL operates the 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.

The radiotracer chemistry, radiopharmaceutical technology, and magnetic resonance imaging research and development programs support applications of novel techniques for imaging brain function in normal and diseased states, and to study the biochemical basis of disease.

Climate change research 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, providing special expertise in atmospheric field campaigns and aerosol research. BNL scientists play a leadership role in the development of, and experimentation at, the Free-Air Carbon Dioxide Enhancement (FACE) facility at the Duke Forest used to understand how plants respond to elevated carbon dioxide concentrations in the atmosphere.

Science Laboratories Infrastructure

The SLI program enables the conduct of Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure and the cleanup and removal of excess facilities. The laboratory also provides Payments in Lieu of Taxes (PILT) to local communities around the laboratory.

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 Operations Office

Chicago 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, 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--Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, and Ames Laboratory; and New Brunswick Laboratory, a government-owned and government-operated Federal laboratory. Chicago serves as SC's grant center, administering grants to universities as determined by the DOE-SC Program Offices as well as non-SC offices.

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 337 buildings (2.2 million gross square feet of space) with the average age of the buildings being 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, in the world. About 2,500 scientific users, scientists from universities and laboratories throughout the U.S. and around the world, use Fermilab for their research. Fermilab's mission is the goal of high-energy physics: to learn what the universe is made of and how it works.

Advanced Scientific Computing Research

Fermilab conducts research in networking and collaboratories.

High Energy Physics

Fermilab operates the Tevatron accelerator and colliding beam facility, which consists of a four-mile ring of superconducting magnets and two large multi-purpose detectors, and is capable of accelerating protons and antiprotons to an energy of one trillion electron volts (1 TeV). The Tevatron is the highest energy proton accelerator in the world, and will remain so until the LHC begins commissioning in 2007. With the shutdown of the LEP machine at CERN in Switzerland in 2000, the Tevatron became the only operating particle accelerator at the energy frontier. The Tevatron complex also includes the Booster and the Main Injector, pre-accelerators to the Tevatron. The Main Injector is also used to produce antiprotons for the Tevatron and will be used independently of the Tevatron for a 120 GeV fixed target program, including 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 and SLAC are the principal experimental facilities of the DOE High Energy Physics program.

Science Laboratories Infrastructure

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

Safeguards and Security

S&S program efforts are directed at maintaining protective force staffing and operations to protect personnel and the facility, and toward continuing the cyber security, 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 National Engineering and Environmental Laboratory

Introduction

Idaho National Environmental and Engineering Laboratory (INEEL) 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, operated by Bechtel, B&W Idaho for the U.S. Department of Energy.

Basic Energy Sciences

INEEL supports studies to understand and improve the life expectancy of material systems used in engineering such as welded systems and to develop new diagnostic techniques for engineering systems.

Fusion Energy Sciences

Since 1978, INEEL 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 INEEL focuses on the safety aspects of magnetic fusion concepts for existing and planned domestic experiments and developing further our domestic safety database using existing collaborative arrangements to conduct work on international facilities. In addition, with the shutdown of the Tritium Systems Test Assembly (TSTA) facility at LANL, INEEL will expand their research and facilities capabilities to include tritium science activities. In FY 2003, INEEL will complete a small tritium laboratory (Safety and Tritium Applied Research Facility).

Biological and Environmental Research

Using unique DOE capabilities such as advanced software for controlling neutron beams and calculating dose, INEEL 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. Research is also supported into the analytical chemistry of complex environmental and biological systems using the technique of mass spectrometry.

Lawrence Berkeley National Laboratory

Introduction

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. The laboratory consists of 107 buildings (1.68 million gross square feet of space) with the average age of the buildings being 34 years. LBNL is dedicated to performing leading-edge research in the biological, physical, materials, chemical, energy, and computer sciences.

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 BES supported user facilities -- the Advanced Light Source (ALS) and the National Center for Electron Microscopy (NCEM).

The **Advanced Light Source** began operations in October 1993 and now serves over 1,000 users as one of the world's brightest sources of high-quality, reliable vacuum-ultraviolet (VUV) light and long wavelength (soft) x-rays. Soft x-rays and VUV light are used by the researchers at the ALS as high-resolution tools for probing the electronic and magnetic structure of atoms, molecules, and solids, such as those for high-temperature superconductors. The high brightness and coherence of the ALS light are particularly suited for soft x-ray imaging of biological structures, environmental samples, polymers, magnetic nanostructures, and other inhomogeneous materials. Other uses of the ALS include holography, interferometry, and the study of molecules adsorbed on solid surfaces. The pulsed nature of the ALS light offers special opportunities for time resolved research, such as the dynamics of chemical reactions. Shorter wavelength 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 collaboratory tools. It participates in several scientific application and collaboratory pilot projects and participates on a number of the SciDAC teams. LBNL manages the Energy Sciences Network (ESnet). ESnet is one of the 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 Integrated Software Infrastructure Center activities that focus on specific software challenges confronting users of terascale computers.

Fusion Energy Sciences

The laboratory's current mission is to study and apply the physics of heavy ion beams and to advance related accelerator technologies. LBNL, LLNL, and PPPL work together in advancing the physics of heavy ion drivers through the Heavy Ion Fusion Virtual National Laboratory.

High Energy Physics

LBNL supports a program of physics research and technology R&D, using unique capabilities of the laboratory primarily in the areas of superconducting magnet R&D, world-forefront expertise in laser driven particle acceleration, expertise in design of advanced electronic devices, and design of modern, complex software codes for acquisition and analysis of data from HEP experiments.

Nuclear Physics

The Low Energy (LE) subprogram has supported operations and the research program of the 88-Inch Cyclotron, whose operations are transitioning in FY 2004 to a dedicated in-house facility. Other activities include the development of a next-generation gamma-ray detector system, GRETINA; the development of the STAR detector, and a smaller activity directed towards development of the ALICE detector within the heavy ion program at the Large Hadron Collider at CERN; the implementation and operation of the Sudbury Neutrino Observatory (SNO) detector in Canada and the KamLAND detector in Japan that are performing neutrino studies; a program with emphasis on the theory of relativistic heavy ion physics; 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.

Biological and Environmental Research

LBNL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high-throughput DNA sequencing techniques and studies on the biological functions associated with newly sequenced human DNA. The laboratory also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on the use of model organisms to understand and characterize the human genome. LBNL operates beam lines for determination of protein structure at the Advanced Light Source for use by the national and international biological research community, research into new detectors for x-rays, and research into the structure of proteins, including membrane proteins. The nuclear medicine program supports research into novel radiopharmaceuticals for medical research and studies of novel instrumentation for imaging of living systems for medical diagnosis. LBNL also supports the Natural and Accelerated Bioremediation Research (NABIR) program and the geophysical and biophysical research capabilities for NABIR field sites.

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. The carbon cycle field experiment at the ARM Southern Great Plains site is maintained and operated by LBNL.

Science Laboratories Infrastructure

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

Safeguards and Security

The S&S program provides 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.

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 positron materials science, superplasticity in alloys, adhesion and bonding at interfaces, and kinetics of phase transformations in welds; and 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 Advanced Scientific Computing research and SciDAC efforts. It also participates in Integrated Software Infrastructure Center activities that focus on specific software challenges confronting users of terascale computers.

Fusion Energy Sciences

LLNL works with LBNL on the physics of heavy ion beam. The LLNL program also includes collaborations with General Atomics on the DIII-D tokamak, operation of an innovative concept experiment, the Sustained Spheromak Physics Experiment (SSPX) at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D. It carries out research in the simulation of turbulence and its effect on transport of heat and particles in magnetically confined plasmas. LLNL, LBNL, and PPPL work together in advancing the physics of heavy ion drivers through the Heavy Ion Fusion Virtual National Laboratory.

High Energy Physics

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

Nuclear Physics

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

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. 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 understand and improve climate models. Virtually every climate modeling center in the world participates in this unique program.

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

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 Integrated Software Infrastructure Center activities that focus on specific software challenges confronting users of terascale computers.

Fusion Energy Sciences

LANL supports the creation of computer codes for modeling the stability of plasmas, as well as work in diagnostics, innovative fusion plasma confinement concepts such as Magnetized Target Fusion, and the removal of the remainder of the recoverable tritium from and completion of the stabilization of the Tritium Systems Test Assembly facility prior to turning the facility over to the Office of Environmental Management for Decontamination and Decommissioning at the end of FY 2003.

High Energy Physics

HEP supports a program of physics research and technology R&D at LANL, using unique capabilities of the laboratory primarily in the area of theoretical studies, experimental research, and development of computational techniques for accelerator design.

Nuclear Physics

NP supports a broad program of research including: a program of neutron beam research that utilizes beams from the LANSCE facility to make fundamental physics measurements, such as the development of an experiment to search for the electric dipole moment of the neutron; a relativistic heavy ion effort using the PHENIX detector at the Relativistic Heavy Ion Collider (RHIC); research directed at the study of the quark substructure of the nucleon in experiments at Fermilab, and at the "spin" structure of nucleons at RHIC using polarized proton beams; the development of the Sudbury Neutrino Observatory (SNO) and MiniBooNE research programs measuring neutrino; 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.

Biological and Environmental Research

LANL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high-throughput DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. 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 Los Alamos Neutron Science Center for use by the national biological research community and research into new techniques for determination of the structure of proteins.

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

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, for example on overcoming semiconductor doping limits, novel and ordered semiconductor alloys, and theoretical and experimental studies of properties of advanced semiconductor alloys for prototype solar cells. It also supports research addressing the fundamental understanding of solid-state, artificial photosynthetic systems. This research includes the preparation and study of novel dye-sensitized semiconductor electrodes, characterization of the photophysical and chemical properties of quantum dots, and study of charge carrier dynamics in semiconductors.

Oak Ridge Institute for Science and Education

Introduction

The Oak Ridge Institute for Science and Education (ORISE), operated by Oak Ridge Associated Universities (ORAU), is located on a 150-acre site in Oak Ridge, Tennessee. Established in 1946, ORAU is a consortium of 88 colleges and universities. The institute undertakes national and international programs in education, training, health, and the environment. ORISE is an academic and training facility providing specialized scientific and safety training to DOE and other institutions. ORISE is an international leader in radiation-related emergency response and epidemiological studies.

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 Oak Ridge National Laboratory. 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.

Fusion Energy Sciences

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

High Energy Physics

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

Nuclear Physics

ORISE supports the Holifield Radioactive Ion Beam Facility (HRIBF) and its research program.

Biological and Environmental Research

ORISE coordinates research fellowship programs. 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.

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

Oak Ridge National Laboratory (ORNL) 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 335 buildings (3 million gross square feet of space) with the average age of the buildings being 33 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 clear, abundant energy; restore and protect the environment; and contribute to national security.

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) and the Radiochemical Engineering Development Center (REDC). ORNL also is the site of the Spallation Neutron Source (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.

The **Radiochemical Engineering Development Center**, located adjacent to HFIR, provides unique capabilities for the processing, separation, and purification of transplutonium elements.

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 (ACRTs) 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.

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. Computer codes developed at the laboratory are also used to model plasma processing in industry. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies. ORNL is also a leader in stellarator theory and design and is a major partner with PPPL on the NCSX. It leads the advanced fusion structural materials science program, contributes to research on all materials systems of fusion interest, coordinates experimental collaborations for two U.S.-Japan programs, and coordinates fusion materials activities.

High Energy Physics

A small research effort using unique capabilities of ORNL primarily in the area of particle beam shielding calculations is supported. Through the Scientific Discovery through Advanced Computing (SciDAC) program, ORNL will support an effort to model the physics processes that drive supernova explosions.

Nuclear Physics

The major effort at ORNL is the research and operations of the Holifield Radioactive Ion Beam Facility (HRIBF) that is operated as a national user facility. Also supported are a relativistic heavy ion group that is involved in a research program using the PHENIX detector at RHIC; the development of the fundamental newtron physics beam line at the Spallation Newtron Source; 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 (HRIBF)** is the only radioactive nuclear beam facility in the U.S. to use the isotope separator on-line (ISOL) method and is used annually by about 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..

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 the newest FACE experiment. 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 NABIR program, providing special leadership in microbiology applied in the field. ORNL also manages the NABIR Field Research Center, a field site for developing and testing bioremediation methods for metal and radionuclide contaminants in subsurface environments. ORNL, in conjunction with ANL and PNNL and six universities, co-hosts a terrestrial carbon sequestration research consortium, CSiTE.

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

Science Laboratories Infrastructure

The SLI program enables the conduct of Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure and the cleanup and removal of excess facilities. The program also supports SC landlord responsibilities for the 36,000 acre Oak Ridge Reservation, and for Federal facilities in the city of Oak Ridge. The laboratory also provides Payments in Lieu of Taxes (PILT) to local communities around the laboratory.

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 Safeguards and Security programs.

Oak Ridge Operations Office

Introduction

Oak Ridge supports almost every major Departmental mission in science, defense, energy resources, and environmental quality. Oak Ridge provides world-class scientific research capacity while advancing scientific knowledge through such major Departmental initiatives as the Spallation Neutron Source, the Supercomputing program, and in Nanoscience research. Research is conducted at facilities at the Oak Ridge National Laboratory and Thomas Jefferson National Accelerator Facility. In the defense mission area, programs include those which protect our 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 for the implementation of domestic and international policy aimed at reducing threats, both internal and external, to the U.S. from weapons of mass destruction. Oak Ridge also supports various Energy Efficiency and Renewable Energy programs and facilitates the R&D on energy efficiency and renewable energy technologies. All of the missions under Oak Ridge management are supported through centralized administrative and specialized technical personnel in the financial, legal, procurement, personnel, security, and various other support organizations.

Science Laboratories Infrastructure

The Oak Ridge Landlord subprogram provides for centralized Oak Ridge Operations Office (ORO) infrastructure requirements and general operating costs for activities on the Oak Ridge Reservation

(ORR) outside plant fences and activities to maintain a viable operations office, including maintenance of roads and grounds, 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 Oak Ridge National Laboratory. This includes protection of a category 1 Special Nuclear Material Facility, Building 3019. Other small activities include security systems, information security, and personnel security.

Office of Scientific and Technical Information

The Office of Scientific and Technical Information (OSTI) is located on an 8-acre site in Oak Ridge, Tennessee. The 133,000 square foot OSTI facility houses both Federal and contractor staff and over 1.2 million classified and unclassified documents dating from the Manhattan Project to the present. The large collection represents a critical component of the OSTI mission 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.

Pacific Northwest National Laboratory

Introduction

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The laboratory consists of 40 government-owned buildings (900,000 gross square feet of space) with the average age of the buildings being 33 years. PNNL conducts research in the area of environmental science and technology and carries out related national security, energy, and human health programs.

Basic Energy Sciences

PNNL supports research in interfacial chemistry of water-oxide systems, near-field optical microscopy of single molecules on surfaces, inorganic molecular clusters, and direct photon and/or electron excitation of surfaces and surface species. Programs in analytical chemistry and in applications of theoretical chemistry to understanding surface catalysis are also supported. Geosciences research includes theoretical and experimental studies to improve our understanding of phase change phenomena in microchannels. Also supported is research on molecularly tailored nanostructured materials, stress corrosion and corrosion fatigue, interfacial dynamics during heterogeneous deformation, irradiation assisted stress corrosion cracking, bulk defect and defect processing in ceramics, chemistry and physics of ceramic surfaces and interfacial deformation mechanisms in aluminum alloys.

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.

Fusion Energy Sciences

PNNL is focused on research on materials that can survive in a fusion neutron environment. The available facilities used for this research include mechanical testing and analytical equipment, including state-of-the-art electron microscopes, that are either located in radiation shielded hot cells or have been adapted for use in evaluation of radioactive materials after exposure in fission test reactors. Experienced scientists and engineers at PNNL provide leadership in the evaluation of ceramic matrix composites for fusion applications and support work on vanadium, copper and ferritic steels as part of the U.S. fusion materials team. It also plays a leadership role in a fusion materials collaboration with Japan, with Japanese owned test and analytical equipment located in PNNL facilities and used by both PNNL staff and up to ten Japanese visiting scientists per year.

Biological and Environmental Research

PNNL is home to the William R. Wiley **Environmental Molecular Sciences Laboratory** (EMSL). PNNL scientists, including EMSL scientists, play important roles in performing research for NABIR. 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 lead scientist for the Environmental Meteorology Program, 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, in conjunction with ANL and ORNL and six universities, co-hosts a terrestrial carbon sequestration research consortium: CSiTE. PNNL also conducts research on the integrated assessment of global climate change.

Science Laboratories Infrastructure

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

Science Program Direction

PNNL conducts assessments of trends in R&D and the development of science management tools, for R&D portfolio and outcome analyses; and provides expert assistance in state-of-the-art science communications. As part of the organizational restructuring of PNNL from an Environmental Management Site to an SC Site, a Pacific Northwest Site Office is being established.

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 Plasma Physics Laboratory

Introduction

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. The laboratory consists of 35 buildings (700,000 gross square feet of space) with the average age of the buildings being 28 years.

Advanced Scientific Computing Research

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

Fusion Energy Sciences

PPPL is the only U.S. Department of Energy (DOE) laboratory devoted primarily to plasma and fusion science. It hosts experimental facilities used by multi-institutional research teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. It 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 in the U.S. and the large JET (Europe) and JT-60U (Japan) tokamaks abroad. This research is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. It 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, through its association with Princeton University, provides high quality education in fusion-related sciences, having produced more than 175 Ph.D. graduates since it’s founding in 1951. PPPL, LBNL, and LLNL currently work together in advancing the physics of heavy ion drivers through the heavy ion beams Fusion Virtual National Laboratory.

High Energy Physics

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

Science Laboratories Infrastructure

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

Safeguards and Security

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

Richland Operations Office

Richland is responsible for and manages all environmental cleanup and science and technology development at the 560 square mile Hanford Site, coordinating closely with contractor companies hired to manage and complete the work of the world's largest cleanup project.

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 Integrated Software Infrastructure Center activities that focus on specific software challenges confronting users of terascale computers.

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. 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.

Biological and Environmental Research

SNL provides the site manager for the North Slope of Alaska ARM site. The chief scientist for the ARM-UAV program is at SNL, and SNL takes the lead role in coordinating and executing ARM-UAV missions. The laboratory conducts advanced research and technology development in robotics, smart medical instruments, microelectronic fabrication, and computational modeling of biological systems.

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

Science Program Direction

SNL carries out research in areas of technical program planning and merit review practices. This activity includes assessments of best practices in R&D organizations.

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

The Savannah River Site supports the Savannah River Ecology Laboratory (SREL), a research unit of the University of Georgia operating at the site for over forty years. The SREL conducts research aimed at reducing the cost of environmental cleanup and remediation while ensuring biodiversity to the restored environment. It supports the SREL through a cooperative agreement with the University of Georgia.

Stanford Linear Accelerator Center

Introduction

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 (1.8 million gross square feet of space) with the average age of 27 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, the SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third generation synchrotron sources.

Basic Energy Sciences

SLAC is the home of the **Stanford Synchrotron Radiation Laboratory** (SSRL) and peer-reviewed research projects associated with SSRL. Over the years, the SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third generation synchrotron sources. The facility is 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.

High Energy Physics

SLAC operates the B-factory and its detector, BaBar, and a small program of fixed target experiments. The B-factory, a high energy electron-positron collider, was constructed to support a search for and high-precision study of CP symmetry violation in the B meson system. All of these facilities make use of the two-mile long linear accelerator, or linac. SLAC and Fermilab are the principal experimental facilities of the HEP program.

Biological and Environmental Research

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

Science Laboratories Infrastructure

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

Safeguards and Security

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

Thomas Jefferson National Accelerator Facility (TJNAF)

Introduction

Thomas Jefferson National Accelerator Facility (TJNAF) is a laboratory operated by the Nuclear Physics program located on 162 acres in Newport News, Virginia. The laboratory consists of 65 buildings (500,000 gross sq. ft. of space) with the average age of the buildings being 12 years. Constructed over the period FY 1987-1995 at a cost of $513,000,000, TJNAF began operations in FY 1995.

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 that has a user community of ~1200 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, to measure the weak charge of the proton, is being developed by a collaboration of laboratory and university groups in partnership with the National Science Foundation.

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.

Science Laboratories Infrastructure

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

Safeguards and Security

TJNAF has a guard force 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

The Office of Science 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 High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences and Advanced Scientific Computing Research. In addition, Federal staff responsible for management, policy, personnel, and technical/administrative support activities in budget, finance, grants, contracts, information technology, construction management, safeguards, security, environment, safety, 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.

All Other Sites

The Office of Science funds 272 colleges/universities located in all 50 states and Puerto Rico.

Basic Energy Sciences

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

Advanced Scientific Computing Research

The ASCR program funds research at 71 colleges/universities located in 24 states supporting approximately 126 principal investigators.

Fusion Energy Sciences

The FES program funds research at more than 50 colleges and universities located in approximately 30 states. It also funds the DIII-D tokamak experiment and related programs at General Atomics, an industrial firm located in San Diego, California.

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 NP program funds 185 research grants at 85 colleges/universities located in 35 states. Among these is a cooperative agreement with the Massachusetts Institute of Technology (MIT) for the operation of the Bates Linear Accelerator Center as a national user facility used by about 110 scientists; the Triangle Universities Nuclear Laboratory (TUNL); Texas A&M (TAMU) Cyclotron; the Yale Tandem Van de Graaff; and the University of Washington Tandem Van de Graaff. 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, the premier international center for new initiatives and collaborations in nuclear theory research.

Biological and Environmental Research

The 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

Funding Profile by Subprogram

	(dollars in thousands)				
	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
High Energy Physics					
Proton Accelerator-Based Physics	383,787	399,494	-8,934[ab]	390,560	412,092
Electron Accelerator-Based Physics	137,933	159,486	-13,774[b]	145,712	150,890
Non-Accelerator Physics	44,309	43,000	+6,401[ab]	49,401	42,936
Theoretical Physics	44,792	42,256	+5,367[b]	47,623	49,630
Advanced Technology R&D	71,375	81,242	+6,667[b]	87,909	81,081
Subtotal, High Energy Physics	682,196	725,478	-4,273[a]	721,205	736,629
Construction	19,842	12,500	-74[a]	12,426	751
Subtotal, High Energy Physics	702,038	737,978	-4,347[a]	733,631	737,380
Use of Prior Year Balances	0	-1,205	0	-1,205	0
Total, High Energy Physics	702,038[cd]	736,773	-4,347[a]	732,426	737,380

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 and their interactions, thereby underpinning and advancing DOE missions and objectives through the development of key cutting-edge technologies and trained manpower that provide unique support to these missions.

[a] Excludes a rescission of $4,346,960 in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H. Rpt. 108-401, dated November 25, 2003, as follows: Proton Accelerator-Based Physics ($2,648,210); Non-Accelerator Physics ($1,625,000); and Construction ($73,750).

[b] Reflects reallocation of funding within High Energy Physics in accordance with H. Rpt. 108-212, accompanying the FY 2004 Energy and Water Development Appropriations Act, HR 2754, as follows: Proton Accelerator-Based Physics ($-6,286,000); Electron Accelerator-Based Physics ($-13,774,000); Non-Accelerator Physics ($+8,026,000); Theoretical Physics ($+5,367,000); and Advanced Technology R&D ($+6,667,000).

[c] Excludes $14,984,000 which was transferred to the SBIR program and $899,000 which was transferred to the STTR program.

[d] Excludes $4,697,019 rescinded in accordance with the Consolidated Appropriations Resolution, FY 2003.

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 cosmology. Research advances in any one of these fields often have a strong impact on research directions in another. These fields also share a common technological infrastructure, ranging from particle accelerators and detectors to data acquisition and computing. Technology that was developed in response to the demands of high energy physics 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.

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 HEP program supports the following goals:

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, to advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences, and to 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 understanding of dark energy and dark matter, the lack of symmetry in the universe, the basic constituents of matter, 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; explains how everything came to have mass; and illuminates 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. Our goals in FY 2005 address all of these challenges. The FY 2005 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 at the Fermi National Accelerator Laboratory (Fermilab) and the Stanford Linear Accelerator Center (SLAC), to produce maximum scientific data to address these fundamental questions. In FY 2005 we also expect to begin engineering design of a new Major Item of Equipment, the BTeV ("B Physics at the TeVatron") experiment at Fermilab that will extend current investigations aimed at an explanation of the absence of antimatter in the universe.

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 very roughly to current research priorities, but 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 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 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 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 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.	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.	Deliver data as planned within 20% of the baseline estimate (390 pb-1) to CDF and D-Zero detectors at the Tevatron.
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.	Deliver data as planned within 20% of baseline estimate (50 fb-1) to the BaBar detector at the SLAC B-factory.
Construction					
		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 upgrades and new major 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., National Science Foundation (NSF), 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 High Energy Physics (HEP) program has incorporated feedback from OMB into the FY 2005 Budget Request and has taken, or will take, the necessary steps to continue to improve performance.

In the PART review, OMB gave the High Energy Physics (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. HEP will work to develop a resource-loaded project plan for Fermilab's Run II effort and will submit that plan to OMB by June 2004. The Particle Physics Project Prioritization Panel (P5) will continue its work and submit a final report in FY 2004. Although HEP is establishing 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, this committee has not yet met. Once the COV issues a report, HEP will develop an action plan to respond to the findings and recommendations within 30 days. The assessment found that HEP has developed a limited number of adequate performance measures. However, OMB noted concerns regarding the collection and reporting of performance data. To address these concerns, HEP will work with its Advisory Committee to develop research milestones for the long-term performance goals, will include the long term research goals in grant solicitations, will work to improve performance reporting by grantees and contractors, and will work with the CFO to improve HEP sections of the Department's performance documents. HEP's role in providing scientific research facilities is strongly supported by the Administration. Funding is provided in FY 2005 to operate the program's two large facilities at 93 percent of maximum capacity.

Reviews of the program are conducted by HEPAP. Also, the Office of High Energy Physics conducts annual reviews, using independent consultants, of the HEP programs at five major laboratories. However, it was called out that the program does not currently have regular reviews of its research portfolio and processes by ad hoc panels of outside technical experts.

As a result of the above findings, the High Energy Physics program has taken the following actions. The program has worked further to reform its performance measures and goals while being sensitive to the problems that basic research programs face in attempting to predict future scientific progress. Also, the FY 2004 budget focused resources on addressing construction and upgrade activities at Fermilab while simultaneously operating the laboratory at 82 percent of maximum capacity (compared to 87 percent in FY 2003 and 78 percent in FY 2002). The program has formed a committee, called the Particle Physics Project Prioritization Panel (P5), to prioritize its medium and large ($50-600M TEC) construction projects and MIEs within the program that have not yet reached the full construction phase. The committee was charged in January 2003 to study and prioritize three proposed projects; and a response was received from the committee in September 2003. In addition, the program has instituted a process for reviewing its research portfolio by a formal committee of visitors every three years. The first review is tentatively scheduled for the 2nd quarter in 2004.

Funding by General and Program Goal

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
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	383,787	390,560	412,092	+21,532	+5.5%
Electron Accelerator-Based Physics	137,933	145,712	150,890	+5,178	+3.6%
Non-Accelerator Physics	44,309	49,401	42,936	-6,465	-13.1%
Theoretical Physics	44,792	47,623	49,630	+2,007	+4.2%
Advanced Technology R&D	71,375	87,909	81,081	-6,828	-7.8%
Construction	19,842	12,426	751	-11,675	-94.0%
Total, Program Goal 5.19.00.00, Explore the Fundamental Interactions of Energy, Matter, Time and Space	702,038	733,631	737,380	+3,749	+0.5%
Use of Prior Year Balances	0	-1,205	0	+1,205	+100.0%
Total, High Energy Physics	702,038	732,426	737,380	+4,954	+0.7%

Overview

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

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

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

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

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

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

Major Advances

Since the Department of Energy and its predecessors began supporting research in this field around 1950, our understanding of the fundamental nature of matter has deepened profoundly, generating a stream of Nobel Prizes that are a source of national pride, prestige, and scientific leadership. The most recent example is the 2002 Nobel Prize in Physics, shared by Raymond Davis, Jr., of Brookhaven National Laboratory (BNL) for his groundbreaking experiment that demonstrated the existence of neutrinos coming from the sun and conclusively proved that the sun shines via thermonuclear reactions.

Many of the Nobel Prizes awarded for research in high energy physics have been tied to the development of the "Standard Model," a comprehensive theoretical description of all the fundamental particles and their interactions (except gravity). The success of the Standard Model in predicting and explaining a wide variety of experimental data with impressive precision and economy has made it the theoretical gold standard over the last half-century. A major role in establishing the Standard Model is one of the proudest accomplishments of the HEP program supported by the DOE and its predecessor agencies.

Major Questions

Though the Standard Model has been subjected to an array of rigorous tests for many years -- and has survived all of them at the particle energies we have been able to explore -- important questions remain. It is known that the Standard Model is incomplete at TeV energies. At energies above 1 TeV, the electromagnetic and weak interactions are unified into a single electroweak force, and the W and Z bosons that carry the weak interaction have zero mass (like the photon, which carries the electromagnetic interaction). This situation is dramatically changed as the energy falls through 1 TeV, with the W and Z acquiring large masses (nearly a hundred times the mass of a proton). The Standard Model accommodates this effect via a hypothetical (not yet observed) field called the Higgs, but does not explain *why* the symmetry is broken. Furthermore, estimates of the Higgs boson mass are unnaturally sensitive to quantum mechanical corrections that must be finely tuned to avoid driving the calculated mass far above the TeV scale. New physics is needed to stabilize the calculation and provide sensible results.

A theory called supersymmetry is one possible example of such new physics. It predicts one new particle for each particle that is known today, and their contributions to quantum corrections of the Higgs boson mass cancel others, stabilizing the mass. Moreover, supersymmetry may help us to understand how the separate forces we see today in the universe “unify” into a coherent whole. The investigation of unification phenomena is one of the central thrusts of the HEP research program.

Another powerful insight, emphasized by both the HEPAP long-range plan and the recent National Research Council study entitled “Connecting Quarks with the Cosmos,” is that cosmological questions are intimately connected with fundamental particles and forces. The study of elementary particles is necessary to answer questions about the origin, evolution, and fate of the universe, and precise observations of the universe can yield clues to the nature of the particles and forces. The study of these “cosmic connections” between the very large and the very small forms another major research thrust of the HEP program.

The key scientific questions that are now being asked about the universe at its two extremes – the very large and the very small – are inextricably intertwined. These questions define the major scientific goals of the program:

- Can we realize Einstein’s dream of a unified description of fundamental particles and forces in the universe?
- Where is the fundamental particle that endows all other particles with their masses?
- Are there additional or “hidden” dimensions of space-time?
- What are the masses of the neutrinos, and what is their role in the universe?
- Why is there more matter than anti-matter in the universe?
- What are dark matter and the dark energy, which together make up more than 95% of the universe?

Major Experimental Tools

Obtaining definitive answers to these questions require – as with all scientific research – conduct of controlled experiments to test hypotheses. The HEP program has developed, in collaboration with the NSF, NASA, and other U.S. funding agencies, as well as international research partners, a coordinated experimental program that seeks to address these questions:

- Einstein's dream of unification will be pursued experimentally by the CDF and D-Zero experiments at the Fermilab Tevatron that will investigate particles and forces at the current energy frontier. With these experiments, we will also be directly searching for evidence of supersymmetry, extra space-time or quantum dimensions, particle candidates for dark matter, and for other new phenomena beyond the Standard Model.
- Extending the energy frontier, the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) and its associated experiments, A Toroidal LHC Apparatus (ATLAS) and Compact Muon Solenoid (CMS), will begin operations later this decade. This higher energy scale will lead us to a deeper understanding of the unification of forces and should provide the crucial evidence for the mechanism causing all particles to have masses.
- Evidence for additional space-time dimensions as well as supersymmetry and the source of mass will be sought at the Tevatron and the LHC. These investigations would be further enhanced by a high-energy electron linear collider that can map the nature, shapes and sizes of these other dimensions and precisely measure the properties of new particles. A hadron collider, with its rich abundance of particles, is a discovery machine for new physics, while an electron collider can focus sharply on a precise energy and make very clean measurements of the properties of new particles. Working in tandem, the two instruments provide an extremely powerful tool to explore the TeV energy scale which is sure to be a fertile ground for new physics. This is the main reason for our continued support of a vigorous program of accelerator R&D leading towards higher energy accelerators.
- That neutrinos have mass and transform themselves among their different types was recently discovered and confirmed. In order to investigate these elusive particles in detail experimentally, a powerful neutrino source is needed. The world's highest intensity neutrino beam, Neutrinos at the Main Injector (NuMI), has been constructed at Fermilab and will begin operations in 2005.
- The question of why the universe is predominantly made of matter rather than a balance of matter and antimatter is inextricably tied to the phenomenon of "CP violation." This small imbalance observed in particle interactions is being investigated for b-quarks with electron collisions at the SLAC B-factory, while planning is underway for the next-generation of B-particle experiments at Fermilab, called BTeV. The possibility of investigation of this phenomenon in neutrinos is also being explored.
- Confirming earlier spectacular discoveries, many independent measurements, including the Sloan Digital Sky Survey, now show that the expansion of the universe is accelerating due to "Dark Energy," which apparently comprises 70 percent of the energy density of the universe. The proposed SuperNova Acceleration Probe (SNAP) is one option for a space-based Joint Dark Energy Mission (JDEM) with NASA, designed to measure the expansion history of the universe and uncover the nature of dark energy. The overwhelming evidence for the mysterious Dark Energy was chosen the 2003 "Breakthrough of the Year" by the editors of *Science.*

- "Dark Matter," that was recently determined to comprise about 25 percent of the energy density of the universe, is another great mystery. Searches for the particles that make up dark matter are underway or planned not only at the Tevatron and LHC, but also in experiments that do not use accelerators.

The U.S. HEP program takes advantage of the unique tools that have been developed both here and abroad to answer these fundamental questions, using both man-made and cosmic accelerators, and a wide variety of particle detection technologies. Cross-cutting the entire program are activities in theoretical physics and advanced technology development, which help define the right questions to be asked and provide new tools for answering them.

Theoretical Research

Theoretical research in high energy physics seeks to comprehend elementary particles and forces in a mathematical framework that enables calculation of particle properties and interactions. The theory may also predict new phenomena. One recent exciting development in theoretical research is the prospect that neutrinos may be involved in the explanation of the matter-antimatter asymmetry in the universe.

A promising, if challenging, theoretical approach is string theory that represents elementary particles as "musical notes" of tiny loops of string. There are several string theory models, and all require extra dimensions of space-time. These could have such small extent that we don't perceive them, but might explain why gravity is so much weaker than the other basic forces: perhaps its effect is spread among more than three dimensions. These tiny, rolled-up spatial dimensions may not only exist but also may be observable at the Tevatron and the LHC.

String theories also offer the possibility of combining the forces that govern the behavior of particles with the force of gravity. Gravity has been best explained by the general theory of relativity that defines it as a curvature of space-time. As a fundamental force of nature, it stands alone, but with string theory, it may someday be unified with other forces, fulfilling Einstein's dream. This would extend the current Standard Model of particles and interactions in a very important way. At the same time, recently available precision results in particle astrophysics and cosmology are leading to the development of a "Standard Model" for cosmology.

Some theoretical problems also require massive computing resources. For example, the theory of strong interactions (called "Quantum Chromodynamics" or QCD) can only be calculated to high precision by using advanced, high-performance computers. These high-precision calculations are needed to allow improvement in the measurements of a number of phenomena, e.g., CP-violation measurements at B-factories. Development of suitable computing resources for experiment and theory is supported by the program and additional resources are provided through the *Scientific Discovery through Advanced Computing* (SciDAC) program (see below).

Advanced Technology R&D

High energy physics experiments involve precise measurements of phenomena buried in a background of noise or conventional physics processes. A typical experiment will record multiple interactions of many (10-100) extremely high-energy particles occurring in a very short period of time (10-100 nanoseconds). Such research demands particle beams of great intensities and high energies; and robust detectors with high sensitivity and careful selectivity. The HEP program supports advanced technology research and development aimed at developing higher energy and more intense particle accelerators and more sophisticated, high-performance detectors.

Operating in these extreme domains requires substantial time and expense to design, build, maintain, operate, and upgrade the complex and technically advanced research apparatus. A new accelerator or colliding beam device now requires 10 to 20 years of intensive research and development work to bring it to the point of cost effective construction, and a similar effort is required for detectors and computing systems. The R&D programs to sustain a forefront science program are unavoidably costly and long-term. Since few of the core technologies for these devices are marketable, industry has little motivation to research, develop, or manufacture the key technical items, except as (usually expensive) special procurements. Consequently, in order to advance the science, it is essential for the universities and national laboratories engaged in high energy physics to develop the cutting edge technologies that are needed for their research. Fortuitously, it is from this technology R&D that many of the spin-offs to other sciences and the marketplace originate. See *Benefits to Other Sciences and Citizens* below for examples.

Current research in these areas includes studies in nonlinear dynamics of particle beam optics, applications of chaos theory to the behavior of particle beams, new computational techniques, and computer modeling of accelerator and detector systems. An essential part of the research is looking for new accelerator and detector concepts and methods. Excellent progress has been made in the use of lasers and plasmas for the acceleration of electrons and positrons, the exploration of alternate radio frequency acceleration techniques the industrial availability of very high current superconductors, the operation of record magnetic fields in experimental superconducting magnets, and the development of new types of semiconductor-based particle detectors.

Benefits to Other Sciences and to Citizens

High energy physics is profoundly connected to nuclear physics and to astrophysics and cosmology. Research advances in any one of these fields often have a strong impact on research directions in another: a good example is the recent discovery of “Dark Energy” by teams of high energy physicists and astronomers that overturned the conventional picture of cosmology and led to the SNAP research proposal. These fields also share a common technological infrastructure, ranging from particle accelerators and detectors to data acquisition and computing.

Technology that was developed in response to the demands of high energy physics 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:

- Synchrotron light sources, an outgrowth of electron accelerators and storage rings, have become invaluable tools for materials science, structural biology, chemistry, environmental science, and medical science. All of the current “light sources” in the Basic Energy Sciences program are based on this enabling technology. Synchrotron radiation is also used in the semiconductor industry to study structures on silicon surfaces at the nanometer level, and in studies of molecular structures that promise to provide new tools for drug design and disease prevention.

- Accelerators are used for radiation therapy and to produce isotopes for medical imaging. Moreover, many medical imaging technologies rely on detectors and techniques developed for research in high energy and nuclear physics, including computerized axial tomography (CAT scans), single photon emission computerized tomography (SPECT) and positron emission tomography (PET scans). In U.S. hospitals, one patient in three benefits from a diagnostic or therapeutic nuclear medicine procedure.

- The amount of superconducting wire and cable required to build the Fermilab Tevatron in the 1970's was far beyond the capacity of what industrial vendors had ever been asked to supply. By placing an order that required tons of material rather than pounds and working closely with industry, Fermilab helped to create the large-scale manufacturing techniques needed, and thereby created an industry with the capability to supply a commercial market. By the 1980's the market existed, through demand for a powerful new medical diagnostic tool: Magnetic Resonance Imaging or MRI. Today this is a billion-dollar worldwide market. In the words of one industry veteran: "Every program in superconductivity that there is today owes itself in some measure to the fact that Fermilab built the Tevatron and it worked."

- The World Wide Web was invented by high energy physicists to transport large bodies of data among international collaborators and has brought about a worldwide revolution in communications and commerce. The next phase in this development is the "Data Grid," a worldwide network of connected computing resources that can be seamlessly accessed and optimally used by individual physicists, just as the electrical grid powers our everyday life. HEP experimenters and computer scientists are developing and using prototype "grids" today to analyze data from current experiments (e.g., BaBar and D-Zero), and preparing larger and more robust versions to cope with the flood of data expected from the LHC at the end of this decade. Many players in the computing industry are watching these developments closely.

While it is not possible to predict which technologies developed in support of HEP research today will impact the broader scientific community and society at large over the next 20 years, it can be expected that the technologies we are investing in will, as they have in the past, make notable contributions. One area is continued development of advanced superconducting wire and cable for use in high-field superconducting magnets, necessary for upgrades to the LHC or construction of any future proton accelerator. The development of niobium-tin and niobium-aluminum, as well as the application of the newer high temperature superconductors, is done in collaboration with U.S. industry through direct grants and the Small Business Innovation Research (SBIR) program. Another significant effort is development of compact microwave and radiofrequency (RF) power sources and accelerating structures that are needed for technically feasible and cost-effective linear collider designs. Many years of R&D into high-resolution, radiation-hard silicon pixel detectors have paid off in the first working detectors for HEP applications, and will be installed in the LHC.

Finally, an important product of the HEP program is the corps of graduate students trained at universities in the large variety of scientific and engineering skills required to support this discipline. This is a group of highly talented people, well versed in scientific methods and state-of-the-art technologies, and skilled at working in large teams. More than half of them ultimately go into careers in high-tech industries, contributing to our country's economic strength in a multitude of ways.

How We Work

The High Energy Physics program coordinates and funds high energy physics research. In FY 2003, the DOE HEP program provided about 90% of the federal support for high energy physics research in the nation. The National Science Foundation (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, the Department of Energy and its national laboratories actively seek external input using a variety of advisory bodies.

The ***High Energy Physics Advisory Panel (HEPAP)*** provides advice to the Department of Energy and the National Science Foundation on a continuing basis regarding the direction and management of the national high energy physics research program. HEPAP regularly meets to advise the agencies on their research programs, assess their scientific productivity, and evaluate the scientific case for new facilities. HEPAP also undertakes special studies and planning exercises in response to specific charges from the funding agencies.

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), that 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 as *Connecting Quarks with the Cosmos*.

As noted above, the central scientific questions identified in both the recent HEPAP Long Range Plan and the NRC "Quarks to Cosmos" report form the major goals of the HEP research program.

Laboratory directors seek advice from ***Program Advisory Committees (PACs)*** to determine the allocation of a scarce scientific resource—available beam time. Committee members, mostly external to the laboratory, are appointed by the director. PACs review research proposals requesting time at the facilities and technical resources; judging each proposal's scientific merit, technical feasibility, and manpower requirements and recommending whether the proposal should be approved, conditionally approved, deferred, or rejected.

Non-accelerator-based research proposals to DOE and NSF often do not receive review by laboratory PACs; instead, they are reviewed by a special advisory committee called the ***Scientific Assessment Group for Experiments in Non-Accelerator Physics (SAGENAP),*** which assesses the scientific merit of such proposals.

Review and Oversight

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

The program also conducts annual in-depth reviews of the high energy physics program at each ***laboratory***, using a panel of external technical experts. These on-site reviews examine the institutional health of the laboratory, its high energy physics research program, and, as appropriate, the state of its user facilities. The results are used in setting priorities both at the laboratory and within the national program. In addition, the HEP program will begin in FY 2004 to conduct regular, dedicated reviews of operations and infrastructure at its major user facilities in order to maintain high standards of performance and reliability. HEPAP generally meets once a year at one of the major high energy physics laboratories and devotes one-third of its time to a review of that laboratory's program. Findings and recommendations are transmitted to DOE. In addition, the HEP program participates in the annual SC Institutional Reviews for each of its laboratories and semi-annual reviews of each of its ongoing construction projects conducted by the Construction Management Support Division in SC.

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 review. 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 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 is tentatively scheduled for the 2nd quarter in 2004.

Planning and Priority Setting

One of the most important functions of HEPAP is development of long-range plans that express community-wide priorities for future research. The most recent such plan was submitted in January 2002 and presented a "roadmap" for the field, laying out the physics opportunities they envision as possibilities for the next twenty years. As part of this roadmap, the panel recommended that the highest priority of the U.S. program be a high energy, high-luminosity electron-positron linear collider to be built as a fully international effort.[*] 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 recommended a new mechanism to update the roadmap and set priorities across the program. This recommendation has been implemented in the form of the Particle Physics Project Prioritization Panel ("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. The recommendations of this report have been implemented in this budget submission 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 High Energy Physics budget has five major components by function. About 51% of the FY 2005 budget request is provided to the two major HEP laboratories (Fermilab and SLAC) for facility operations; a total of 25% is provided to laboratories, including multipurpose laboratories, in support of their HEP research activities; 15% is provided for university-based research; 3% for infrastructure improvements (construction plus GPP and GPE); and 6% for other activities (including Small Business Innovative Research [SBIR] and Small Business Technology Transfer [STTR]). The FY 2005 budget request is focused on facility operations and upgrades at Fermilab and SLAC to advance research with the CDF and D-Zero detectors at the Tevatron and the BaBar detector at the B-factory.

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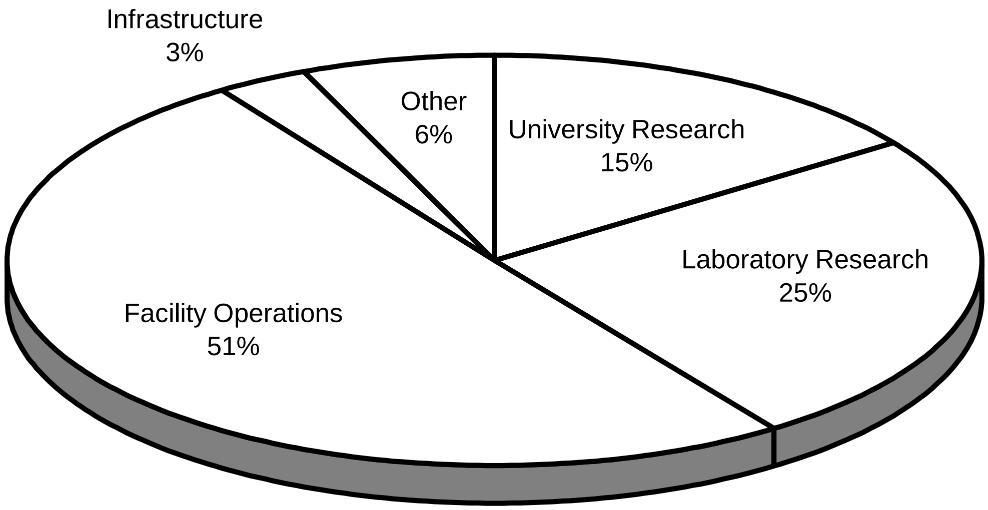
[*] A U.S. Linear Collider Steering Group has been formed, comprised of eminent scientists in the field, to coordinate U.S. efforts toward a linear collider. This group is working closely with the recently formed International Linear Collider Steering Committee to develop an international strategy and formally organize an international R&D collaboration (See detailed justification for Advanced Technology R&D below).

High Energy Physics Budget Allocation
FY 2005



Research

The DOE High Energy Physics 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 9 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 particle 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 up slightly compared to FY 2004 in order to support 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 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 2003, the DOE High Energy Physics program supported approximately two-thirds of the nation's university researchers and graduate students engaged in fundamental high energy physics research. Typically, about 120 Ph.D. degrees are granted annually to students for research supported by the program.

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

- ***National Laboratory Research:*** The High Energy Physics program supports research groups at the Fermi, Lawrence Berkeley, Lawrence Livermore, Argonne, Brookhaven, Oak Ridge, and Los Alamos National Laboratories, Princeton Plasma Physics Laboratory, and the Stanford Linear

Accelerator Center. The directions of laboratory research programs are driven by the needs of the Department and are tailored to the major scientific facilities at the laboratories. Laboratory researchers collaborate with academic users of the facilities and are important for developing and maintaining the large experimental detectors and computing facilities for data analysis.

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

Significant Program Shifts

- To fully exploit their unique discovery potential, the highest priority is given to the operations, upgrades and infrastructure for the Tevatron and B-factory. These include upgrades to the two accelerators to provide increased luminosity, detector component replacements to accommodate the higher intensities, and additional computational resources to support analysis of the anticipated larger volume of data. Planned accelerator and detector upgrades are scheduled for completion in 2006. Infrastructure spending is increased to improve Tevatron reliability and B-factory performance by installing new and upgraded diagnostic and feedback systems and by replacing outdated technology components.
- The Tevatron has recovered from its poor start after the commissioning of the Main Injector ("Run II"). While luminosities have nearly reached the level planned for in the initial Main Injector construction project, Fermilab continues to face technical and management challenges in meeting more aggressive luminosity goals developed in the last few years. The laboratory has developed a detailed, resource-loaded plan for accelerator operations and improvements that should result in more reliable luminosity projections; SC has reviewed that plan, and is actively engaged in tracking its progress.
- The D-Zero and CDF Detector Upgrade projects have been descoped, canceling the silicon tracker replacements. The original detector upgrade plans proposed in the FY 2002 budget called for replacement of both silicon tracker subsystems in two large Tevatron collider experiments, CDF and D-Zero. At the time, the Tevatron luminosity upgrade plan was much more aggressive, projecting much larger integrated luminosities by the end of Run II than the current plan. Such large integrated luminosities would have delivered an unacceptably large radiation load, or dose, to the inner silicon tracking systems of the two detectors, leading to their failure before the end of data-taking. With the revised luminosity projections, replacement of the silicon tracker systems is not required, and is in fact detrimental to the overall Run II physics goals, because of the long shutdown required to extract the existing detectors and replace them.
- The U.S. LHC projects will be about 97% complete in FY 2005. To insure the greatest benefit from the investment made, strong support of the U.S. LHC research program will be provided in the areas of pre-operations of U.S.-built systems, development of software and computing for physics analysis, and accelerator R&D related to the LHC machine.
- An exciting and expanding partnership with NASA continues in the area of Particle Astrophysics and Cosmology. Fabrication of the Large Area Telescope (LAT) for the NASA Gamma-ray Large Area Space Telescope (GLAST) mission will be complete in 2005, while the Alpha Magnetic Spectrometer (AMS) will be in pre-operations testing. There will be a significant increase in the U.S.

scope of the GLAST/LAT effort in FY 2005 because of the default of one of the international partners in the experiment. DOE and NASA are sharing the cost of this scope increase to maintain the scientific reach of the LAT. GLAST is scheduled for launch in 2006 and AMS in 2007.

- There is also an exciting new potential for an interagency experiment to explore the nature of the recently-discovered "Dark Energy" that is causing an accelerating expansion of the universe. NASA has a Dark Energy probe in its research program starting in FY 2004 and is developing mission concepts. R&D for the SuperNova Acceleration Probe (SNAP) will be continued as a possible option for an interagency experiment on the Joint Dark Energy Mission (JDEM). These experiments, and others that may be proposed, will provide important new information about the birth, evolution and ultimate fate of the universe that will in turn lead to a better understanding of dark matter, dark energy, and the original Big Bang.
- In FY 2005 we will begin engineering design of a new Major Item of Equipment, the BTeV ("B Physics at the TeVatron") experiment at Fermilab, subject to successful independent cost and technical reviews of the project to take place in 2004. This is a dedicated experiment that will run at the Tevatron after the conclusion of Collider Run II at the end of this decade. This experiment will study CP violation and search for new phenomena in the B meson system with much higher statistics than is possible at the B-factories, including studies of B meson species that are inaccessible to the B-factories. The importance of the physics addressed by BTeV has been endorsed by HEPAP and recognized in the Office of Science's Report, "*Facilities for the Future: A Twenty Year Outlook*."
- The construction of the Neutrinos at the Main Injector (NuMI) project is proceeding well, and completion is expected within the projected cost and schedule in FY 2005, followed by the operations of these facilities to provide neutrino beams for the next generation of neutrino experiments.

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.

More details on HEP contributions to SciDAC and the FY 2005 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 two major high energy physics facilities: the Tevatron at Fermilab, and the B-factory at the SLAC. These facilities provided a total of 9,250 hours of beam time in FY 2003 for a research community of about 2,200 U.S. scientists in HEP and related fields. A comparable number of users come from foreign countries, testifying to the fact that these are unique, world-leading experimental facilities. The FY 2005 Congressional Budget Request will support facility operations that will provide ~8,740 hours of beams for research. This plan will increase above the FY 2004 level at Fermilab and a decrease at SLAC associated with required shutdown for facility modification and upgrades and expected increases in power costs.

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

	FY 2003	FY 2004	FY 2005 Request
Tevatron Collider at Fermilab			
Maximum hours = 5,400			
Scheduled Hours	4,440	3,960	4,320
Unscheduled Downtime	15%	<20%	<20%
Number of Users = 2,160			
B-factory at SLAC			
Maximum hours = 5,850			
Scheduled hours	4,810	4,810	4,420
Unscheduled Downtime	10%	<20%	<20%
Number of Users = 1,100			

In FY 2003, the operation of fixed target experiments using the SLAC linac at End Station A concluded its program of High Energy Physics research.

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

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005 Request
Major milestones completed or committed to	Completed D-Zero Run II upgrade at Fermilab				
	Completed U.S. Compact Muon Solenoid (CMS) hadron calorimeter absorber and delivered to CERN	Completed construction of U.S. A Toroidal LHC Apparatus (ATLAS) tile calorimeter sub-modules	Completed first inner triplet quadrupole magnet for LHC accelerator	Complete U.S. ATLAS Transition radiation tracker module production Complete U.S. CMS Hadron calorimeter readout test	Complete U.S. contribution to LHC machine Complete Phase I of US ATLAS and U.S. CMS fabrication
		Completed fabrication of first half of Main Injector Neutrino Oscillation (MINOS) experiment	Completed Neutrinos at the Main Injector (NuMI) excavation	Complete NuMI civil construction	Complete NuMI/MINOS construction
			Completed fabrication of MINOS far detector.		
				Complete CDMS II project fabrication Complete Pierre Auger project fabrication	
					Complete LAT fabrication Complete Run IIb detector upgrades of CDF and D-Zero.

Construction and Infrastructure

Funding for construction is down significantly compared to FY 2004 as several projects are completed or ramping down. Funding for capital equipment increases as engineering design begins for the new BTeV experiment at Fermilab; and other capital equipment funding at SLAC and Fermilab to address accelerator and detector complex reliability and performance issues is significantly increased. Similarly, funding for general plant projects (GPP) is significantly 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 slightly at SLAC and Fermilab relative to FY 2004, as accelerator upgrade projects designed to increase the rate of physics data delivered at both laboratories begin to ramp down.

Workforce Development

The High Energy Physics program supports development of the R&D workforce through support of graduate students working toward a doctoral degree and post-doctoral associates developing their research and management skills. The R&D workforce developed under this program not only provides new scientific talent in areas of fundamental research, but also provides talent for a wide variety of technical, medical, and industrial areas that require the finely honed thinking and problem solving abilities and computing and technical skills developed through an education and experience in a fundamental research field. Scientists trained as High Energy Physicists can be found in such diverse areas as hospitals (radiation therapy, medical imaging, and medical physics), national security, space exploration, software and computing, telecommunications, finance, and many more fields.

About 1,200 post-doctoral associates and graduate students supported by the High Energy Physics program in FY 2003 were involved in a large variety of theoretical and experimental research, including advanced technology R&D. About one-fifth are involved in theoretical research. Those involved in experimental research utilize a number of scientific accelerator facilities (~90%) supported by the DOE, NSF, and foreign countries as well as participating in non-accelerator research (~10%).

Details of the High Energy Physics manpower are given below. These numbers include people employed by universities and laboratories. The University grants include Physics Research and Accelerator Technology grants. In FY 2003, there were 140 University grants with an average funding of $850,000 per year. Most of these are multi-task grants with an average of three tasks. The duration of the grants is three years. The number of laboratory groups is an estimate of the number of distinct HEP research groups (experiment, theory, accelerator R&D) at the laboratories, which is a collection of single and multi-task efforts.

Human Resources (Full-Time Equivalent) in High Energy Physics at Laboratories and Universities, DOE Supported

	FY 2002	FY 2003	FY 2004 est.	FY 2005 est.
University Grants	140	140	140	140
Lab Groups	51	50	50	50
Ph.D.'s with permanent positions	1,255	1,255	1,255	1,255
Postdoctoral Associates	565	565	565	565
Graduate Students	605	610	610	610
# Ph.D.'s awarded	120	120	120	120

In addition, there is a joint DOE/HEP and NSF research-based physics education project ("QuarkNet") aimed at professional development for high school teachers. In this project, active researchers in high energy physics serve as mentors for the 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 to follow.

Facilities Summary

Fermilab

In FY 2005, Fermilab plans 4,320 hours of running to achieve a performance goal of 390 inverse picobarns $(pb)^{-1}$ of data delivered to the major Tevatron experiments (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). 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 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 four years requires a series of performance enhancements to the accelerator and the CDF and D-Zero detectors. These efforts are proceeding in parallel with current Tevatron operations and research and are more fully described in the Detailed Justification sections that follow.

Tevatron operations also include the running of the Tevatron complex in fixed target mode in parallel with Tevatron collider operation. This will be for the physics data taking of the MiniBooNE experiment (8 GeV protons extracted from Booster ring) and MINOS experiment (120 GeV protons extracted from

Main Injector to NuMI beamline) and for test beam runs (120 GeV protons extracted from Main Injector). During FY 2005, the MiniBooNE experiment will be operating its beam line and detector to collect data until NuMI begins operations. Test beam runs will be scheduled as needed. These functions are non-interfering with the high-priority Tevatron collider operations.

SLAC

In FY 2005, SLAC plans 4,420 hours of running to achieve a performance goal of 50 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 2005. The collected data will provide a significant enhancement to the BaBar dataset for precision studies of CP violation in the B-meson system, as described above.

Fully achieving the physics goals of the B-factory program has required a series of performance enhancements to the accelerator and the BaBar detectors. Plans to improve the collision luminosity to an ultimate value of $3x10^{34}cm^{-2}s^{-1}$, an order of magnitude greater than the design value have been carried out since FY 2002 and are expected to be completed in FY 2005. These efforts are proceeding in parallel with current B-factory operations and research and are more fully described in the Detailed Justification sections that follow.

Operations of the fixed target experimental program using the SLAC linac and End Station A were terminated in FY 2003.

HEP facilities operations funding and running weeks are summarized in the table below for the Tevatron and B-factory:

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Tevatron Operations	184,933	196,926	193,665
Tevatron Improvements[a]	44,583	42,185	69,826
Total, Tevatron	229,516	239,111	263,491
Running Hours	4,440	3,960	4,320
B-factory Operations	95,095	96,913	100,290
B-factory Improvements[b]	15,709	20,665	21,770
Total, B-factory.	110,804	117,578	122,060
Running Hours	4,810	4,810	4,420

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

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

Proton Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Proton Accelerator-Based Physics					
Research	76,016	73,295	74,048	+753	+1.0%
Facilities	307,771	317,265	338,044	+20,779	+6.5%
Total, Proton Accelerator-Based Physics	383,787	390,560	412,092	+21,532	+5.5%

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 Department of Energy'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 the high energy proton collider facilities. This experimental research will determine whether the Standard Model correctly predicts the mechanism that generates mass for all fundamental particles and search for the first evidence of new physics beyond the Standard Model.

The Proton Accelerator subprogram also consists of accurate, controlled measurements of basic neutron properties, including neutrino oscillations at the accelerator-based neutrino facilities. These measurements will provide important clues and constraints to the theory of matter and energy beyond the Standard Model. These research thrusts are aligned with the key unification and cosmology questions identified under Program Mission.

Supporting Information

The most immediate concern of the unification goal on the particle physics roadmap is fully understanding 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 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 should 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 interactions.

The energy frontier is the primary thrust of the Proton Accelerator subprogram. In FY 2005 the energy frontier remains at the Tevatron at Fermilab. The CDF and D-Zero experiments will pursue these questions of electroweak unification with direct searches for the Higgs Boson, supersymmetry, and hidden dimensions. There will also be precision measurements of known particles, like the mass of W boson and the top quark – 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 that will allow a serious study of its mass, spin, and couplings. These types of precision measurements give indirect but useful information about the major theories on electroweak unification, and that information can guide and constrain the direct searches. When the LHC at CERN is operational, the energy frontier will move there and the CMS and ATLAS experiments will take over the program begun at the Tevatron.

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

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

A variety of B meson studies will be done, including independent confirmation of CP violation, that has been observed at the B-factories at SLAC and in Japan. Other processes, inaccessible to the B-factories, can also be measured. Recently, a proposal for a dedicated collider experiment at the Tevatron that can significantly advance this research has been reviewed and endorsed by the community. These measurements provide vital pieces of the theoretical framework used to explain CP violation, and an explanation of CP violation is necessary to understand why matter (and not antimatter) is what makes up the universe we live in. A precision measurement of mass of the W boson and detailed studies of the charm quarks will also be carried out.

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

The major activities under the Proton Accelerator subprogram are the broad research programs using the CDF and D-Zero detectors at the Tevatron at Fermilab; the neutrino research program using the NuMI/MINOS and MiniBooNE facilities at Fermilab and at the Soudan Mine site in Minnesota; the LHC program; engineering design for the proposed "BTeV" experiment at Fermilab; 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 and MiniBooNE programs 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 insure that the U.S. high energy physics research program will be one of the key players at the next energy frontier. The proposed BTeV experiment will extend the measurements of the current B-factories to explain the absence of antimatter in the universe. There are much smaller specialized efforts involving the HERA accelerator machine at DESY in Germany, and the KEK proton accelerator in Japan.

Research and Facilities

The Research category in the Proton Accelerator subprogram supports the university and laboratory based scientists performing experimental research at proton accelerator facilities in the U.S. and abroad. Experimental research activities are collaborative efforts by research groups from Argonne National Laboratory (ANL), 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 subprogram supports the maintenance and operations of, and technical improvements to, proton accelerator facilities in the U.S. In addition, this category supports the U.S. share of 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; providing computing hardware and software infrastructure to support the experiments and the accelerators, and provide platforms for data analysis; and directed R&D for accelerator and detector enhancements and performance improvements. Since physicists are often involved in these activities as well as research activities, some are partially supported by both categories of funding where appropriate.

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

Highlights

Most recent research highlights reflect milestones in completion, initial operations of, or preparation for, 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 more data in Run II of the Tevatron collider than all of Run I (1992-1996). The collaborations published their first papers and have presented a larger number new of results at conferences. These detectors have much greater sensitivity than before and will make numerous 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. Data taking is continuing and results are expected in 2005.
- The MINOS far detector in the Soudan mine has been completed ahead of schedule. Commissioning with cosmic rays is progressing.
- A formal program has been initiated to develop, design and implement a computing system to process, store and support the analysis of the huge amount of data anticipated after the LHC begins commissioning in FY 2007. A parallel effort to test, commission, and eventually operate the U.S.-supplied systems that are part of the LHC detectors has also been initiated, and significant pre-operations activities will begin in FY 2004.

The major planned research efforts in FY 2005 are:

- *The research program using the Tevatron/CDF Facility at Fermilab*. This research program is being carried out by a collaboration including 750 scientists from Fermilab, ANL, LBNL, 25 U.S. universities, and institutions in 10 foreign countries. The physics issues to be addressed include searches for the Higgs boson, supersymmetry or other new phenomena; B meson studies including CP violation; and precision measurements of the top quark and the W boson properties.

- *The research program using the Tevatron/D-Zero Facility at Fermilab*. This research program is being carried out by a collaboration including 650 scientists from Fermilab, BNL, LBNL, 33 U.S. universities and institutions in 16 foreign countries. The physics issues to be addressed include searches for the Higgs boson, supersymmetry or other new phenomena; B meson studies including CP violation; and precision measurements of the top quark and the W boson properties.

- *The research program using the MiniBooNE and NuMI/MINOS Facilities at Fermilab and the Soudan Mine*. These research programs are being carried out by a collaboration including 250 scientists from Fermilab, ANL, BNL, LANL, LLNL, 26 U.S. universities, and institutions in 5 foreign countries. This research is also supported in part through the DOE Nuclear Physics program. The major efforts in FY 2005 will be data taking and analysis (MiniBooNE) and detector commissioning, developing computing tools, and cosmic ray data analysis (MINOS).

- *Planning and preparation for the U.S. portion of the research program of the LHC*. A major effort in FY 2005 will continue to be the design and implementation of the U.S. data handling and computing capabilities needed for full participation in the LHC research program. Pre-operations of U.S.-supplied detectors for LHC experiments will begin at CERN.

The major planned facilities efforts in FY 2005 are:

- *Operations of the Tevatron at Fermilab*. Fermilab plans 4,320 hours of running to achieve a performance goal of 390 pb^{-1} of data delivered to the major Tevatron experiments. 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.
- *Preparation for Tevatron/CDF/D-Zero performance enhancements*. The Run II Tevatron program utilizes a series of performance enhancements to the accelerator and the CDF and D-Zero detectors that will be completed in FY 2006. This effort begins to roll off in FY 2005, which as discussed above, proceeds in parallel with current Tevatron operations and research.
- *Operation of the MiniBooNE and MINOS facilities at Fermilab and the Soudan Mine*. The MiniBooNE experiment will be operating its beam line and detector to collect data. The MINOS far-detector at Soudan Mine will make the first measurements that can separate atmospheric neutrinos from atmospheric antineutrinos, while construction of the NuMI beamline is completed.
- *Fabrication and support for the U.S. portion of the LHC project*. The fabrication of the U.S. portion of the ATLAS and CMS detector components will continue along with the support for these detector activities. The production of the U.S. portion of the LHC accelerator components will be completed in FY 2005.
- *Engineering design for the BTeV experiment at Fermilab*. BTeV is a dedicated experiment that will run at the Fermilab Tevatron after the conclusion of Collider Run II. This experiment will study matter-antimatter asymmetries and search for new phenomena in the B meson system with much higher statistics than is possible at the B-factories, including studies of B meson species that are inaccessible to the B-factories. Assuming successful completion of independent cost and technical reviews in 2004, detailed engineering design would begin in FY 2005.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Research	**76,016**	**73,295**	**74,048**
▪ **University Research**	**46,069**	**46,000**	**46,625**

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; the MINOS and MiniBooNE experiments at Fermilab and the Soudan Mine; and the HERA accelerator complex at DESY in Germany.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

In FY 2005, the overall level of support is basically 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 activities on the LHC experiments, CMS and ATLAS, during FY 2005. 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 2003	FY 2004	FY 2005
▪ **National Laboratory Research**	**28,507**	**26,208**	**26,023**

The national laboratory research program consists of groups at several laboratories participating in experiments at proton accelerator facilities. These groups participate in all phases of the experiments, with the focus of the physics program being similar to that of the university groups described above. Although they lack the specific educational mission of their colleagues at universities, they are imbedded in the laboratory structure, and therefore they provide invaluable service to the research program in detector design, construction, and operations. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers. Proton accelerator activities concentrate on experiments at the Tevatron complex at Fermilab; the Large Hadron Collider, under construction at CERN; and to a much smaller degree at the HERA accelerator complex at DESY in Germany.

In FY 2005, the national laboratory research program is basically unchanged. Full participation of national laboratory physicists is needed to exploit the physics potential of the very active program at the Tevatron during FY 2005. 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 in the FY 2002-4 collider run; pre-operations of the MINOS detector and preparation for neutrino beam from NuMI; data taking with the MiniBooNE detector; support for the fabrication of the ATLAS and CMS detectors for the LHC; and for physicists working on preparation for U.S. participation in the LHC Research Program.

The Fermilab research program ($8,283,000) includes data taking and analysis of the CDF, D-Zero, and MiniBooNE experiments, the CMS research and computing program, and commissioning of the MINOS detector. Being imbedded at the host laboratory, these activities provide the close linkages between the Research and the Facilities categories in the Proton Accelerator subprogram.

Research activities at LBNL ($5,350,000) will include data taking and analysis of the CDF and D-Zero experiments, and the ATLAS research and computing program.

Activities by the BNL research group ($7,840,000) will cover data taking and analysis of the D-Zero experiment, the ATLAS research and computing program, analysis of BNL Alternating Gradient Synchrotron (AGS) experiments from the last data-taking run and preparation for future NSF-funded experiments, and a small effort on the MINOS experiment.

	FY 2003	FY 2004	FY 2005

(dollars in thousands)

The research group at ANL ($4,550,000) will be working on data taking and analysis of the CDF experiment, the ATLAS research and computing program, commissioning of the MINOS detector, and data taking and analysis of the ZEUS experiment at HERA.

	FY 2003	FY 2004	FY 2005
▪ **University Service Accounts**	**1,440**	**1,087**	**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.

	FY 2003	FY 2004	FY 2005
Facilities	**307,771**	**317,265**	**338,044**

	FY 2003	FY 2004	FY 2005
Facilities			
Tevatron Operations	184,933	196,926	193,665
Tevatron Improvements	44,583	42,185	69,826
Large Hadron Collider Project	59,210	48,800	32,500
Large Hadron Collider Support	7,300	15,400	29,400
AGS Operations/Support	625	0	0
Other Facilities	11,120	13,954	12,653
Total, Facilities	307,771	317,265	338,044

	FY 2003	FY 2004	FY 2005
▪ **Tevatron Operations**	**184,933**	**196,926**	**193,665**

Operations at Fermilab will include operation of the Tevatron accelerator complex in collider mode and operations of two collider detectors for about 4,320 hours. This will be a major physics run with the higher intensity available from the Main Injector and with the D-Zero and CDF detectors. 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 recovered from its poor start after the commissioning of the Main Injector ("Run II"). While luminosities have nearly reached the level planned for in the initial Main Injector construction project, Fermilab continues to face technical and management challenges in meeting more aggressive luminosity goals developed in the last few years. The laboratory has developed a detailed, resource-loaded plan for accelerator operations and improvements that will result in more reliable luminosity projections; SC has reviewed that plan and is actively engaged in tracking its progress, with a follow-up review scheduled for early 2004. The FY 2005 budget for Tevatron Operations is consistent with that plan. Funding for associated luminosity improvements are discussed below under Tevatron Improvements.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

The extra resources needed to meet Tevatron Run II luminosity goals are mostly the efforts of accelerator and experimental staff at Fermilab. SLAC, LBNL and BNL accelerator physicists with specialized expertise relevant to Run II problems have been recruited to help as well. Enhancements to Tevatron reliability are discussed under Tevatron Improvements below.

Tevatron operations also include the running of the Tevatron complex in fixed target mode in parallel with Tevatron collider operation. This running mode will be primarily for the physics data taking of the MiniBooNE experiment (8 GeV proton extracted from Booster ring). Final installation and commissioning of the NuMI beam line will also take place in 2005 in preparation for the beginning of NuMI/MINOS operations.

Tevatron Operations

	(in hours)		
	FY 2003	FY 2004	FY 2005
Tevatron Operations	4,440	3,960	4,320

- **Tevatron Improvements** **44,583** **42,185** **69,826**

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. The funding will also provide the cost for the various utility improvement projects to operate the entire Fermilab site with higher reliability and efficiency. The category also includes funding for R&D and engineering design for a proposed new experiment, “B Physics at the TeVatron” (BTeV).

Plans for luminosity upgrades involve several steps toward increasing the number of antiprotons in the Tevatron, since that is the factor that limits luminosity. In FY 2005, this effort will be concentrating on the commissioning of the new Recycler ring that will allow for much larger (~twice as big) “bunches” of antiprotons to be injected into the Tevatron. With a larger rate of antiprotons, the rate of collisions between protons and antiprotons, and thus physics productivity, will increase by a similar rate. Funding for this particular effort is comparable to FY 2004, following the planned profile of the luminosity upgrade plan.

Detector upgrades are also needed to cope with the larger data rates that will be provided by the Tevatron. Funding for these upgrades will be completed in FY 2005 and the detector systems will be fully installed by 2006. The scope of the upgrades includes data acquisition, trigger, and computing systems for the collider experiments that will allow a greater amount of data to be recorded and analyzed.

The detector upgrade plan had been significantly descoped as noted above (under “*Significant Program Shifts*”). The revised plan for the detector upgrades includes phase out the silicon replacement activities, including measurement and documentation of the characteristics of the

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

silicon prototypes, and bringing to publication the research results which have advanced state-of-the-art silicon detector technology. The revised funding profile includes these closeout costs for the silicon replacements, and has been reviewed and approved via standard procedures. Cost savings realized from the descoping of these projects has been applied to Run II luminosity upgrades and operations.

Funding in the amount of $21,745,000 is included for the program to increase the Tevatron luminosity, fabricate Run IIb CDF and D-Zero detector improvements and provide the computing capability needed to analyze the data collected. This is a decrease of $5,870,000 from FY 2004. This includes capital equipment for continuation of the two projects including closeout silicon tracker replacement for both the CDF Detector ($1,732,000; TEC of $10,374,000) and the D-Zero Detector ($3,708,000; TEC of $12,502,000). The TEC of the two Run IIb detector upgrade projects has been reduced and is now final as an outcome of the baseline review in fall 2003. The scope and funding profile for the Run IIb accelerator upgrades was reviewed in July 2003, and it is anticipated that the accelerator upgrades will have a baseline established prior to the next planned DOE/HEP review in February 2004.

Funding in the amount of $37,281,000 is included for Other Tevatron Improvement activities (other than those specified above). This is a significant increase of $24,711,000 from FY 2004. Activities in this category include: specific accelerator improvement projects (AIP) aimed at improving Tevatron reliability (+$6,800,000); support for ongoing Tevatron accelerator (+$9,403,000) and detector (+$2,359,000) operations, not directly related to identified upgrades, including: accelerator and detector maintenance activities, repair and replacement of failing or obsolescent components, and minor improvements and upgrades to existing systems. Increased support for these critical infrastructure areas was identified by independent reviews in 2003 as being crucial to the success of the luminosity upgrade plan. Also included in this funding category is R&D for approved accelerator upgrades (+$3,890,000), including projects to improve the throughput of antiprotons in the Tevatron complex and to mitigate the long-range interactions between the proton and antiproton beams that tend to disrupt them before they reach collision; and general complex operations support (+$345,000). GPP funding is also significantly increased to $8,544,000 (+$1,914,000) to assist with urgent ES&H and infrastructure needs.

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

MINOS is the detector part of the NuMI project that will provide a major new capability for neutrino research. Capital equipment for the MINOS Detector is included at $550,000 (TEC $44,510,000). This is reduced from FY 2004 by $1,450,000 following the planned profile.

In FY 2005 we will begin engineering design of a Major Item of Equipment, the BTeV experiment at Fermilab, subject to successful independent cost and technical reviews of the project to take place in 2004. This is a dedicated experiment that is proposed to run at the Fermilab Tevatron after the conclusion of Collider Run II at the end of this decade. This

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

experiment will study CP violation and search for new phenomena in the B meson system with much higher statistics than is possible at the B-factories, including studies of B meson species which are inaccessible to the B-factories.

The importance of the physics addressed by BTeV has been endorsed by HEPAP and recognized in the Office of Science's Report, "*Facilities for the Future: A Twenty Year Outlook*." BTeV is one of the high-priority new projects described in the Outlook which could begin fabrication in the next few years. In addition, the Particle Physics Project Prioritization Panel (P5), a subpanel of the HEPAP, reviewed BTeV along with other projects at Fermilab. HEPAP endorsed the P5 report that supported the fabrication of BTeV as the highest priority new project at Fermilab after completion of the Run II upgrades, subject to constraints within the HEP budget.

The BTeV experiment will have scientific competition from a dedicated B-physics experiment at the CERN LHC, so timely completion of BTeV is important. Thus we are pursuing an aggressive schedule of R&D ($3,500,000) and engineering design ($6,750,000) in FY 2005 to be ready to begin fabrication in FY 2006. Resources for this effort will come from re-direction of other elements of the Fermilab program but will not impact the highest-priority efforts on Tevatron Run II. The Total Estimated Cost range of estimate is $190,000,000 to $230,000,000 and will be refined upon completion of detailed engineering design in FY 2005.

Funding for pre-conceptual R&D leading up to the BTeV proposal was previously funded under the Detector Development category (in the *Advanced Technology R&D* subprogram) so that category shows a corresponding decrease in FY 2005, as the R&D effort is now captured here.

▪ **Large Hadron Collider Project**	**59,210**	**48,800**	**32,500**

The funding requested follows the profile approved in FY 2003, that is a revision from the original profile. Changes have been made to better match the funding profile to the funding needs of (1) the three U.S. LHC fabrication projects based on their current fabrication plans and schedules, and (2) the updated LHC construction schedule as determined by CERN. This funding 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 April 2007.

The detailed schedules of the three U.S. LHC projects have been reviewed in the context of this schedule revision by CERN. The U.S. LHC Accelerator Components Project will go forward without modification and will be 100% complete in FY 2005. The U.S. detector projects (ATLAS and CMS) will complete ~95% of their planned work by the previously scheduled end-date (4^{th} quarter FY 2005), but for each a small amount of work is intimately tied to the late stages of the CERN schedule. This is primarily work directly related to the final assembly, testing, and installation of the full detectors, as well as purchase of computing hardware for data acquisition. Under the current schedule, this work will occur in 2006 and 2007, changing the final project completion date. The increased costs arising from the delay are modest and will be contained within the projects contingency allowances. The result of these changes is a stretch out of the

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

planned U.S. contributions to the LHC detectors by two years. The FY 2005 funding for the detectors is reduced and the funds rescheduled in FY 2006 and FY 2007 accordingly. The final cost of each detector is unchanged.

CERN initiated the LHC project in FY 1996. This will consist of a 7 on 7 TeV proton-proton colliding beams facility to be constructed in the existing Large Electron-Positron Collider (LEP) machine tunnel (LEP will be removed). The LHC will have an energy 7 times that of the Tevatron at Fermilab, thus opening up substantial new frontiers for scientific discovery.

Participation by the U.S. in the LHC program is extremely important to U.S. High Energy Physics program goals. The LHC will become the foremost high energy physics research facility in the world when it begins commissioning in 2007. With the LHC at the next energy frontier, American scientific research at that frontier depends on participation in LHC. The High Energy Physics Advisory Panel (HEPAP) Subpanel on Vision for the Future of High Energy Physics strongly endorsed participation in the LHC, and this endorsement has been restated by HEPAP on several occasions.

The physics goals of the LHC include a search for the origin of mass as represented by the “Higgs” particle, exploration in detail of the structure and interactions of the top quark, and the search for totally unanticipated new phenomena. LHC has strong potential for answering the question of the origin of mass. The LHC energies are sufficient to test theoretical arguments for a totally new type of matter. In addition, history shows that major increases in the particle energy nearly always yield unexpected discoveries.

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

Participation in the LHC project (accelerator and detectors) at CERN primarily takes the form of the U.S. accepting responsibility for designing and fabricating particular subsystems of the accelerator and of the two large detectors. Thus, much of the funding goes to U.S. laboratories, university groups, and industry for fabrication of subsystems and components that will become part of the LHC accelerator or detectors. A portion of the funds is being used to pay for purchases by CERN of material needed for construction of the accelerator from U.S. vendors.

The agreement provides for a U.S. DOE contribution of $450,000,000 to the LHC accelerator and detectors (with an additional $81,000,000 being provided by the NSF). The DOE contribution is broken down as follows: detectors $250,000,000; accelerator $200,000,000 (including $90,000,000 for direct purchases by CERN from U.S. vendors and $110,000,000 for fabrication of components by U.S. laboratories).

The total cost of the LHC on a basis comparable to that used for U.S. projects is estimated at about $6,000,000,000. (The LHC cost estimates prepared by CERN, in general, do not include the cost of permanent laboratory staff and other laboratory resources used to construct the project.)

Neither the proposed U.S. DOE $450,000,000 contribution nor the estimated total cost of $6,000,000,000 include support for the European and U.S. research physicists working on the LHC program.

The agreement negotiated with CERN provides for U.S. involvement in the management of the project through participation in key management committees (CERN Council, CERN Committee of Council, LHC Board, etc.). This will provide an effective base from which to monitor the progress of the project, and will help ensure that U.S. scientists have full access to the physics opportunities available at the LHC. The Office of Science has conducted a cost and schedule review of the entire LHC project and similar reviews of the several proposed U.S. funded components of the LHC. All of these reviews concluded the costs are properly estimated and that the schedule is 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 already begun. Over 600 U.S. scientists have joined the U.S.-ATLAS detector collaboration, the U.S.-CMS detector collaboration, or the U.S.-LHC accelerator consortium, and are hard at work helping to design the initial physics research program to be carried out at the LHC, helping to specify the planned physics capabilities of the LHC accelerator and detectors, and helping to design and fabricate accelerator and detector components and subsystems.

U.S. LHC Accelerator and Detector Funding Profile

(dollars in thousands)

Fiscal Year	Department of Energy			National Science Foundation[a] (Detector)
	Accelerator	Detector	Total	
1996[b]	2,000	4,000	6,000	0
1997[b]	6,670	8,330	15,000	0
1998[b]	14,000	21,000	35,000	0
1999	23,491	41,509	65,000	22,150
2000	33,206	36,794	70,000	15,900
2001	27,243	31,627	58,870	16,370
2002	21,303	27,697	49,000	16,860
2003	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 2003	FY 2004	FY 2005
LHC			
Accelerator Systems			
Operating Expenses	800	1,000	100
Capital Equipment	7,900	5,130	2,820
Total, Accelerator Systems	8,700	6,130	2,920
Procurement from Industry	12,610	23,200	18,527
ATLAS Detector			
Operating Expenses	7,282	4,280	3,076
Capital Equipment	10,134	4,710	2,413
Total, ATLAS Detector	17,416	8,990	5,489
CMS Detector			
Operating Expenses	10,290	4,450	2,054
Capital Equipment	10,194	6,030	3,510
Total, CMS Detector	20,484	10,480	5,564
Total, LHC	59,210	48,800	32,500

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 2003, and updated planning based on the FY 2003 experience.

In FY 2005, funding will be used for completion of the fabrication of accelerator magnets and equipment; and 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 2003	FY 2004	FY 2005
• **Accelerator Systems**	**8,700**	**6,130**	**2,920**

In FY 2005, funding will support completion of production of quadrupole magnets, cryogenic/ electrical power feedboxes, and beam absorbers for the LHC beam interaction regions. Production testing of superconducting wire and cable for the LHC main magnets will be completed. Funding is reduced by $3,210,000 as production activities conclude.

• **Procurement from Industry**	**12,610**	**23,200**	**18,527**

In FY 2005, final funding will be provided to support reimbursement to CERN for purchases from U.S. industry including superconducting wire, cable, cable insulation materials, and other technical components. This figure reflects the latest information on the planned expenditure profile. Funding is decreased by $4,673,000 to complete the currently estimated schedule of actual CERN payments to U.S. industrial suppliers.

• **ATLAS Detector**	**17,416**	**8,990**	**5,489**

In FY 2005, funding will support continued production of detector hardware and electronics and the installation of U.S.-supplied equipment at CERN. Installation of the transition radiation tracker barrel, the silicon inner tracker and the muon drift test chambers, and fabrication of the detector trigger and data acquisition system will continue. Funding is decreased by $3,501,000 to follow the ramp-down of detector fabrication.

• **CMS Detector**	**20,484**	**10,480**	**5,564**

In FY 2005, funding will support continued production of detector hardware and electronics and the assembly and installation of U.S.-supplied equipment at CERN. Assembly of the hadron calorimeter 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 in the U.S. Funding is decreased by $4,916,000 to follow the ramp-down of detector fabrication.

▪ **Large Hadron Collider Support**	**7,300**	**15,400**	**29,400**

In FY 2005, LHC Support work will concentrate on the preparation for U.S. participation in the LHC research program. The main use of the resources will be for LHC software and computing, and pre-operations for the U.S.-built systems that are part of the LHC detectors. The U.S. LHC effort is one of the high priority components of the HEP program and has been repeatedly endorsed by HEPAP. Significant increases in this area are planned for FY 2005 to meet the urgent and growing need for LHC support activities in advance of LHC turn-on in 2007.

The LHC software and computing effort will enable U.S. physicists to analyze the vast quantity of LHC data in a transparent manner, and empower them to take a leading role in exploiting the physics opportunities presented by the LHC. In FY 2005, the U.S. software efforts will be focused on “data challenges” where a significant fraction (~10%) of the hardware needed for full LHC data

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		

analysis will be tested with professional-quality software on simulated data. These systems need to grow rapidly from prototypes, capable of handling a few percent of the eventual data in 2002, to fully-functional 10%-scale systems in 2005.

Funding for pre-operations and operations of the LHC detector subsystems built by U.S. physicists will also ramp-up significantly in FY 2005 as LHC turn-on approaches. U.S. CMS collaborators will be performing vertical integration tests of the major detector subsystems that they built, using functional prototypes of the final data acquisition system, in advance of their final installation in the underground cavern. U.S. ATLAS collaborators will be performing testing and commissioning of most detector subsystems. U.S. LHC Accelerator Research Program will be conducting R&D towards possible future LHC accelerator upgrades. A small effort focused on R&D for specific possible LHC detector upgrades will continue.

LHC computer and networking increments will support U.S. leadership in the physics analysis phase by developing a distributed computing environment (the Grid) that will allow researchers remote from CERN full access to data and CPU needed to analyze the large and complex LHC dataset.

	FY 2003	FY 2004	FY 2005
▪ **AGS Operations/Support**	**625**	**0**	**0**

Operations at BNL for HEP experiments using the AGS facility were terminated at the end of FY 2002 with some close out costs remaining in FY 2003.

	FY 2003	FY 2004	FY 2005
▪ **Other Facilities**	**11,120**	**13,954**	**12,653**

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 2003	FY 2004	FY 2005
Total, Proton Accelerator-Based Physics	**383,787**	**390,560**	**412,092**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Research	
▪ In University Research, an increase of $625,000 provides additional support for university groups participating in Tevatron Run II operations and data analysis	+625
▪ In National Laboratory Research, a decrease of $185,000 is taken in partial support of high-priority facilities operations	-185

	FY 2005 vs. FY 2004 ($000)
▪ In University Service Accounts, an increase of $313,000 provides additional equipment and services for university groups.	+313
Total, Research	+753
Facilities	
▪ In Tevatron Operations, a reduction of $3,261,000 is taken in funding for operations of the Tevatron complex, as effort shifts to Tevatron Improvements (see below). This includes continued implementation of the Run II luminosity upgrades in Tevatron running according to the planned profile, as well as installation and commissioning for the NuMI/MINOS program using the Main Injector in fixed-target mode.	-3,261
▪ In Tevatron Improvements, an additional $27,641,000 is provided for Tevatron complex support and Technology R&D support projects. This includes $10,250,000 to complete conceptual R&D and initiate detailed engineering design for the BTeV experiment (previously funded under Detector Development, Advanced Technology R&D subprogram); and $24,711,000 for AIP, GPP, operations and R&D support to continue a major effort to improve operational reliability across the complex. This is offset by a decrease of $1,450,000 in capital equipment for the MINOS project as reflected in the approved profile and a decrease of $5,870,000 in the Run II upgrades of the Tevatron complex, following the planned funding profile.	+27,641
▪ In the Large Hadron Collider project, a decrease of $16,300,000 follows the revised funding profile that reflects the changes to the CERN LHC completion date and its impact on the U.S. portions of the LHC detector sub-projects. The total project cost is unchanged. The U.S. LHC accelerator funding ramps down as that project completes...	-16,300
▪ In Large Hadron Collider Support, an increase of $14,000,000 is provided in part for significantly increased effort in providing the computing systems and networks needed to effectively handle and process the large volume of LHC data. The support for the detector pre-operations is also significantly increased, as detector testing and commissioning activities are ramping up quickly in 2005. A small accelerator R&D effort focused on LHC machine improvements also increases.	+14,000
▪ In Other Facilities, a decrease of $1,866,000 in funds held pending completion of peer review and/or programmatic review is offset by an increase of $565,000 in GPP at LBNL to address urgent infrastructure needs	-1,301
Total, Facilities	+20,779
Total Funding Change, Proton Accelerator-Based Physics	**+21,532**

Electron Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Electron Accelerator-Based Physics					
Research	27,129	28,134	28,830	+696	+2.5%
Facilities	110,804	117,578	122,060	+4,482	+3.8%
Total, Electron Accelerator-Based Physics	137,933	145,712	150,890	+5,178	+3.6%

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 Department of Energy'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 constituent 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.

Currently, SLAC's electron B-factory established and is precisely measuring 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.

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

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

Research and Facilities

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

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

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

Highlights

Recent accomplishments include:

- In 2003, physicists using the BaBar detector at the SLAC B-factory obtained new, improved measurements of CP violation in the B-meson system. American physicists also participated in the BELLE experiment at the Japanese KEK laboratory that reported similar measurements. The two sets of results are largely consistent with each other, and with their earlier results announced in 2002, though interesting (and possibly significant) discrepancies remain to be resolved. The BaBar experiment also reported evidence for a new subatomic particle that appears to be an unexpected configuration of a charm quark and a strange anti-quark; the CLEO experiment at CESR subsequently confirmed this result and found a related particle, and BELLE has recently confirmed these results. Data collected to date are mostly consistent with the current Standard Model description of CP violation. Data collection continues at a high rate to improve the precision of the results, look for evidence in new modes, and resolve any discrepancies.

The major planned research efforts in FY 2005 are:

- *The research program at the B-factory/BaBar Facility at SLAC*. This research program is being carried out by a collaboration of approximately 550 physicists including scientists from LBNL, LLNL, Oak Ridge National Laboratory (ORNL), SLAC, 35 U.S. universities, and institutions from 7 foreign countries.
- *The research program at other electron accelerator facilities*. This program complements the B-factory/BaBar efforts and consists of a group of experimental research activities using the 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.

The major planned facilities efforts in FY 2005 are:

- *Operations of the B-factory at SLAC*. SLAC plans 4,420 hours of running to achieve a performance goal of 50 fb^{-1} of data delivered to the BaBar experiment. Approximately 450 people are involved in day-to-day B-factory operations.
- *Planning and preparation for B-factory/BaBar performance enhancements*. Fully achieving the physics goals of the B-factory program over the next few years requires a series of performance enhancements to the accelerator and the BaBar detectors. These efforts are proceeding in parallel with current B-factory operations and research.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Research...	**27,129**	**28,134**	**28,830**
▪ **University Research**.......................................	**16,871**	**16,800**	**16,965**

The university program consists of groups at about 40 universities doing experiments at electron accelerator facilities. These university groups plan, build, execute, analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; and train graduate students and post-docs. The current Electron Accelerator subprogram is focused on the study of charm and bottom quarks and the tau lepton 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 will pursue a broad program of physics studies on particles containing bottom or charm quarks with CP violation measurements being its highest priority, but other measurements that support or complement the CP violation program will also be pursued.

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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

The university program also supports nine groups that work at the Cornell Electron Storage Ring at Cornell University; and four groups that work at the KEK-B accelerator complex at KEK in Japan. The CLEO-C experiment at the Cornell Electron Storage ring is concentrating on certain precision measurements of particles containing charmed quarks 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 run the accelerators and detectors and do the data analysis leading to physics results that are more precise than they would be otherwise. University-based research efforts will be selected based on peer review.

In FY 2005, the university program is slightly increased for those universities that support analysis of the unprecedented amount of physics data generated by the B-factory and other electron accelerators. To the extent possible, the detailed funding allocations will take into account the involvement of university based research groups in the targeted physics research activities. These include research efforts related to the high priority experiments such as BaBar.

	FY 2003	FY 2004	FY 2005
▪ **National Laboratory Research**	**10,045**	**11,075**	**11,555**

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 2005, the laboratory experimental physics research groups will be focused mainly on data-taking with the BaBar detector, analysis of data taken in earlier runs, and planning for detector enhancements needed for future runs. The laboratory research program is increased slightly for those groups that support analysis of the unprecedented amount of physics data generated by the B-factory and other electron accelerators.

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

The experimental research group from SLAC ($8,210,000) participates in all phases of the experiments. Because they are imbedded in the laboratory structure, they provide invaluable service in the design, construction, and calibration, and operations of the detector, as well as the reconstruction and analysis of the data.

The experimental research group at LBNL ($3,040,000) has broad responsibilities on the BaBar experiment. They were responsible for constructing and commissioning significant portions of the charged particle tracking detectors and their electronics. Now they contribute to operating, maintaining and calibrating the detector. They also make significant contributions to the computing system used to control the detector and acquire the data, and the computing system used to reconstruct the data into physics quantities used for analysis.

The efforts from LLNL ($305,000) are much smaller, limited to only a handful of scientists working on the BaBar experiment.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **University Service Accounts**	**213**	**259**	**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.

Facilities	**110,804**	**117,578**	**122,060**
▪ **B-factory Operations**	**95,095**	**96,913**	**100,290**

Funding for operations supports running the accelerator for 4,420 hours, the operation of the BaBar detector for data collection, and computing support to analyze the collected data. This will be the priority research program at SLAC in FY 2005. It is anticipated that the collected data will be slightly more than the total collected in FY 2004, despite fewer hours of operations. With a modest funding increase, the total scheduled running hours decreases due to the expected increases in power costs. The expected increase in cost per kilowatt-hour arises because SLAC's current contract for electrical power expires in FY 2004.

The fixed target research program in End Station A was terminated in FY 2003, due to overall budget constraints and the high priority assigned to B-factory operations.

SLAC Operation

	(in hours)		
	FY 2003	FY 2004	FY 2005
Fixed Target[a]	(1,040)	(0)	(0)
B-factory Operation	4,810	4,810	4,420
Total, SLAC Operation	4,810	4,810	4,420

▪ **B-factory Improvements**	**15,709**	**20,665**	**21,770**

An important component of the FY 2005 SLAC program will be continuation of the accelerator R&D aimed at improving the luminosity and operational efficiency of the B-factory complex. Particular attention will be paid to finding ways to continue to improve the collision luminosity to an ultimate value of $3x10^{34}cm^{-2}s^{-1}$, an order of magnitude greater than the design value. The planned improvements include additional RF acceleration systems, improvements to the vacuum pumping system, and improvements to the beam control systems.

Funding in the amount of $10,085,000 is included for the projects to upgrade the B-factory, the BaBar detector, and the SLAC computing facilities needed to process the BaBar data. This is a decrease of $3,015,000 relative to FY 2004. The projects include: upgrades to B-factory vacuum and

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

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		

acceleration systems, replacement of failing elements of the BaBar muon detector system; upgrade of Instrumented Flux Return (IFR Upgrade) by installing additional brass absorber to enhance the performance of the muon detector system ($1,200,000; TEC of $4,900,000), and continuous enhancement of computing capabilities to keep pace with the flood of data the B-factory provides.

Activities in this category also include support for ongoing B-factory accelerator and detector operations, not related to identified upgrades (+$4,120,000), including: accelerator and detector maintenance activities, repair and replacement of failing or obsolescent components, and minor improvements and upgrades to existing systems. Most of the increase relative to FY 2004 is directed at GPP funding (+$1,982,000) to assist with urgent ES&H and infrastructure needs.

	FY 2003	FY 2004	FY 2005
Total, Electron Accelerator-Based Physics	**137,933**	**145,712**	**150,890**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Research	
▪ In University Research, an additional $165,000 is provided for maintaining effort on the BaBar research program.	+165
▪ In National Laboratory Research, an additional $480,000 is provided for maintaining effort on the BaBar research program.	+480
▪ In University Service Accounts, an increase of $51,000 provides additional equipment and services to university groups.	+51
Total, Research	+696
Facilities	
▪ In B-factory Operations, an additional $3,377,000 is provided for operation of the B-factory complex to help address projected increases in power costs and meet performance targets.	+3,377
▪ In B-factory Improvements, an increase of $2,877,000 is provided in part for increased effort on the computing upgrade and for GPP funding to assist with urgent ES&H and infrastructure needs. This is offset by a decrease of $1,772,000 as the B-factory accelerator and detector upgrades begin to roll-off, following their planned funding profile.	+1,105
Total, Facilities	+4,482
Total Funding Change, Electron Accelerator-Based Physics	**+5,178**

Non-Accelerator Physics

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Non-Accelerator Physics					
University Research	11,564	11,500	11,565	+65	+0.6%
National Laboratory Research	16,020	14,363	10,420	-3,943	-27.5%
Projects	15,925	20,636	18,051	-2,585	-12.5%
Other	800	2,902	2,900	-2	-0.1%
Total, Non-Accelerator Physics	44,309	49,401	42,936	-6,465	-13.1%

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 Department of Energy'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 idea 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.

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 and the Gamma-ray Large Area Space Telescope (GLAST) Mission.

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, 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, and the Gran Sasso Laboratory in Italy. Other operations include the ground-based facilities laboratories for fabrication and operation of the Gamma-ray Large Area Space Telescope (GLAST) Large Area Telescope (LAT) at SLAC and for the Alpha Magnetic Spectrometer (AMS) at Massachusetts Institute of Technology (MIT).

Highlights

Recent accomplishments include:

- The Pierre Auger Project in Argentina to observe ultra-high energy cosmic rays completed an engineering array in FY 2002 consisting of 40 air-shower detectors and 2 resonance fluorescence detectors. The full array of 1600 air-shower detectors and 4 fluorescence detectors will be completed in 2005 by an international collaboration, but physics measurements commenced in 2002 with the engineering array, and will continue with increasing fractions of the full array as they are completed.
- The Cryogenic Dark Matter Search (CDMS II) experiment completed and installed its first two towers of silicon and germanium detectors in the Soudan Mine in Minnesota. Data taking began in June 2003. The second tower will be installed in December 2003. The final three towers will be installed in 2004, and the full experiment will run until the end of 2005. The prototype experiment (CDMS-I) in a shallow site (10.6 meters below the Stanford University campus) at the Stanford Underground Facility has completed its measurements, already setting the best limits in the world to date on detection of dark matter particles.
- In December 2002, after six months of running, KamLAND's first results were announced, showing a deficit in the expected flux of anti-neutrinos coming from a number of reactors to a detector located in the Kamiokande mine in Japan. Further corroborating results were released in June 2003. This result indicates that neutrinos have mass and are not stable in time, apparently oscillating into other types of neutrinos. The KamLAND results make the case for oscillations and mass of solar neutrinos seemingly inescapable, and are in accord with other results from experiments on neutrinos coming from the sun.

The major planned efforts in FY 2005 are:

- *Fabrication of the GLAST/LAT Telescope*. DOE and NASA are partners on the LAT, which uses particle physics detector technology and is the primary instrument to be flown on the NASA space-based GLAST Mission, scheduled to complete fabrication in late 2005 and to be launched in late 2006. Its goals are to observe and understand the highest energy gamma rays observed in nature and yield information about extreme particle accelerators in space, including 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.
- *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. There is particular interest in gamma rays from poorly-understood astronomical sources such as Active Galactic Nuclei and Gamma Ray Bursters, and searches for signatures of supersymmetric dark matter. The experimental technique was developed by the DOE/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 will begin in FY 2004 on Kitt Peak in Arizona and will be completed in three years.
- *Operation of the Pierre Auger Observatory*. The Pierre Auger Observatory is a very large area cosmic ray detector, covering about 3,000 square kilometers in Argentina, whose goal is to observe, understand and characterize the very highest energy cosmic rays. The southern array is under construction on the pampas of Mendosa, Argentina, but physics analysis has already begun based on results from the partially completed array. This research program is being carried out by an international collaboration including scientists from U.S. universities, Fermilab, and institutions from 19 foreign countries. The U.S. part of the project is funded jointly with NSF and a significant contribution from the University of Chicago. Fermilab provides the project management team.
- *Operation of the Cryogenic Dark Matter Search (CDMS).* CDMS-II is the most sensitive direct search for super-symmetric dark matter undertaken to date. It consists of specially developed cryogenic silicon and germanium detectors with dual ionization and phonon signal capabilities. These detectors must operate at very low temperature (25 milliKelvin) in a cryostat located deep underground at the Soudan Mine Laboratory in Northern Minnesota. This research program is being carried out by a collaboration including scientists from U.S. universities and Fermilab. The project is funded jointly with NSF and Fermilab provides the project management team.
- *Prepare to launch the Alpha Magnetic Spectrometer (AMS).* AMS is an international consortium experiment, led by Massachusetts Institute of Technology (MIT), to be placed on the International Space Station in 2007. 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 proposed Supernova Acceleration Probe (SNAP) Experiment 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 2003	FY 2004	FY 2005
University Research	**11,564**	**11,500**	**11,565**

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 2005, the university program in Non-Accelerator Physics will provide support for those universities involved in projects that may yield exciting new physics at about the level of FY 2004, as several new experiments (e.g., CDMS II, AMS) have completed their fabrication phase and moving into detector operations and datataking. To the extent possible, the detailed funding allocations will take into account the discovery potential of the proposed research. One notable example is the AMS experiment, whose goal is to detect sources of extra-galactic antimatter, using an instrument attached to the International Space Station. In FY 2005, the AMS collaboration will enter preparations for the planned 2007 launch. This project is led by scientists at MIT and consists of a collaboration of NASA, multiple U.S. universities, and numerous international institutions.

Other research efforts that will be continuing in this subprogram include: KamLAND, an underground neutrino oscillation detector which detects reactor-produced neutrinos in Japan; Super-Kamiokande, a proton decay, solar and atmospheric neutrino detector located in the Kamioka Underground Laboratory in Japan; CDMS-II in the Soudan Mine in Minnesota; Pierre Auger Project in Argentina; VERITAS in Arizona; and AMS, GLAST/LAT and SNAP in space.

National Laboratory Research	**16,020**	**14,363**	**10,420**

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.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

In FY 2005, the laboratory experimental physics research groups (including groups at LBNL, LLNL, Fermilab and SLAC) will be focused mainly on supporting the fabrication of the GLAST/LAT telescope and analysis of previous experimental data (SLAC); analysis of data from the Auger engineering array, the CDMS-II detector and the Sloan Digital Sky Survey (Fermilab); and research and development for the proposed SNAP experiment proposal and continued analysis of data from KamLAND (LBNL). The apparent reduction in this category FY 2005 is mainly due to redirection of effort at SLAC to enhance support of GLAST/LAT fabrication, and is captured in the Projects category below.

Projects	**15,925**	**20,636**	**18,051**

In FY 2005, this effort will be focused mainly on completing fabrication of the GLAST/LAT telescope, continuing deployment of the full Auger array, installation of the Phase-I CDMS detector, R&D for the proposed SNAP experiment, and initial fabrication of VERITAS.

The FY 2005 GLAST/LAT program ($8,421,000; TEC of $42,000,000) will focus on completing the fabrication of the LAT instrument in preparation for integration and launch on the GLAST mission in late in 2006, and development of the data processing and analysis capability at SLAC. The project was rebaselined in FY 2003, and as a result, the DOE TEC has been increased by $5,000,000.

The FY 2005 program for VERITAS ($2,050,000; TEC of $4,799,000) will continue the fabrication phase for the full telescope array.

The FY 2005 SNAP program ($7,580,000) will focus on finalizing the research and development for technology needed for the JDEM mission. Funding is maintained at about the same level to provide the significant resources needed to continue the detailed design and prototyping phase. This effort is consistent with the 2002 HEPAP Long Range Planning Subpanel and 2003 HEPAP New Facilities panel recommendation that the physics of SNAP (the "dark energy" phenomenon) is exciting and of central importance to HEP, and that the R&D effort should be supported. It is also consistent with the recent National Research Council report ("Connecting Quarks with the Cosmos") which identified this interdisciplinary research area as a high priority for an interagency initiative. DOE is actively engaged with NASA on JDEM. DOE funding for SNAP takes into account expected contributions from NASA towards JDEM.

Other	**800**	**2,902**	**2,900**

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	**44,309**	**49,401**	**42,936**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
University Research	
An increase of $65,000 for universities active in Non-Accelerator research projects...........	+65
National Laboratory Research	
A decrease of $3,943,000 is taken in this activity. This includes a decrease of $3,843,000 in this category as effort is redirected to completion of the GLAST/LAT project (see below); and a decrease of $100,000 in funds held pending completion of peer review and/or programmatic review.	-3,943
Projects	
A decrease of $2,585,000 is taken to the Projects activity. This includes a decrease of $676,000 for the SNAP R&D program during transition to the Joint Dark Energy Mission collaboration with NASA; a decrease to equipment funding reflecting the completion of the Auger (-$1,000,000) and CDMS-II (-$550,000) projects in FY 2004; and a decrease of $1,330,000 in funds held pending completion of peer review and/or programmatic review.	
These are offset by: an increase of $450,000 to continue fabrication of VERITAS according to the planned profile; and an increase of $521,000 for the GLAST/LAT project in FY 2005, consistent with the profile in the approved Baseline Change Proposal...	-2,585
Other	
A minor decrease in Other	-2
Total Funding Change, Non-Accelerator Physics...	**-6,465**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Theoretical Research					
University Research	23,336	23,300	23,694	+394	+1.7%
National Laboratory Research	15,018	14,998	15,062	+64	+0.4%
SciDAC	4,785	4,600	6,600	+2,000	+43.5%
Other	1,653	4,725	4,274	-451	-9.5%
Total, Theoretical Physics	44,792	47,623	49,630	+2,007	+4.2%

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 Department of Energy'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 to a new plane of physical phenomena and how 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, in order to illuminate the origin and evolution of the universe.

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 especial importance for the experimental program. Major themes are symmetry and unification in the description of diverse phenomena.

Research at Universities and National Laboratories

The University and National Laboratory categories of the Theoretical Physics subprogram support scientists performing research in theoretical high energy physics and related areas of theoretical physics. The research groups are based at approximately 75 colleges and universities and at 6 DOE High Energy Physics and multiprogram laboratories (Fermilab, SLAC, BNL, ANL, LBNL, 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 more informal than the efforts required mounting 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 High Energy Physics Office 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). After 18 months, 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:

- Recent 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.

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 2005:

- *Lattice QCD*. Quantum Chromodynamics (QCD) is a very successful theory that describes the strong interactions between quarks and gluons. Although the equations that define this theory are in principle exact, none of the analytical methods that are so successful elsewhere in theoretical physics are adequate to analyze it. The reason that QCD is so intractable is that it is a strongly-coupled gauge field theory. The lack of precision in current QCD calculations is now limiting the understanding of many experimental results. It has long been known that QCD can be analyzed to any desired precision by numerical methods, given enough computational power. Recent advances in numerical algorithms coupled with the ever-increasing performance of computing have now made a wide variety of QCD calculations feasible with relatively high precision (errors of a few percent). Some of the computational tools for this effort are provided through the SciDAC program, and there will be a major effort to fabricate the necessary computer hardware.
- *Neutrino Phenomenology*. The accumulating evidence that neutrinos have mass raises a host of fundamental and timely questions: whether neutrinos might be their own anti-particles; whether there might be CP violation, or even CPT violation (the combination of CP-and Time-invariance violation), in the neutrino sector; the role of neutrinos in supernova explosions; and whether neutrinos might be the origin of the matter-antimatter asymmetry in the universe. In turn these questions have strong connections to astrophysics, cosmology, and other sectors of particle physics, so that new developments have wide-ranging impacts. New theories of neutrinos are being developed, and the active world-wide program of neutrino experiments can be expected to clarify this interesting domain of elementary particles.
- *New Ideas*. Theoretical physicists are speculating on whether there might be additional space dimensions that are normally hidden from us. It is even possible that some of these dimensions and their consequences are accessible to experiment, perhaps manifesting themselves in the production of mini-black holes at the LHC. Perhaps they can explain the nature of dark matter, or dark energy, or even suggest new cosmologies explaining the history and evolution of the universe.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
University Research...	**23,336**	**23,300**	**23,694**

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 2005, 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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

frontier, and the SLAC B-factory experiments studying CP violation and the matter - antimatter asymmetry, as described in previous sections. To the extent possible, the detailed funding allocations will take into account the involvement of university based research groups in these targeted physics research activities.

National Laboratory Research	**15,018**	**14,998**	**15,062**

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 2005, the laboratory theoretical research groups will address problems across the full range of theoretical physics research, including the analysis and interpretation of the new data expected from both the Tevatron Collider detectors, CDF and D-Zero, and the B-factory's detector, BaBar.

SciDAC	**4,785**	**4,600**	**6,600**

Following upon the successful completion and installation of the uniform software environment on two types of parallel computer platforms being developed for this program, in FY 2005 there will be two principal SciDAC efforts. A program of the most important and accessible research computations begun on the prototype QCDOC ("QCD On a Chip") computer at BNL will continue and, assuming technical milestones are met, R&D for more powerful computers of this kind will proceed. The FY 2005 increment of $2,000,000 is provided to begin fabrication of a ~3 teraflop prototype hardware platform. In addition, further R&D will be undertaken on the optimization of commercial cluster computers for Fermilab. The goal of this R&D effort is to provide an efficient design for a large QCD computing cluster based on commercial components to address the hardware challenges of lattice QCD computing, as noted above. Both the customized and the commercial component approaches are viewed as important and useful in addressing the magnitude of the QCD computational problem; however, if both R&D efforts are successful, only the most cost-effective option will be pursued.

Other	**1,653**	**4,725**	**4,274**

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

This category also includes support for the QuarkNet education project. This project takes place in QuarkNet "centers" which are set up at universities and laboratories around the country. Each center has two physicist mentors and, over three years, goes through several stages to a full operating mode with twelve high school teachers. The project began in 1999 with an initial complement of 12 centers starting

	FY 2003	FY 2004	FY 2005
(dollars in thousands)			

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.

	FY 2003	FY 2004	FY 2005
Total, Theoretical Physics	**44,792**	**47,623**	**49,630**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
University Research	
An increase of $394,000 is provided to maintain support for university researchers	+394
National Laboratory Research	
An increase of $64,000 is provided to maintain support for laboratory researchers	+64
SciDAC	
An increase of $2,000,000 is provided for the SciDAC program for the QCDOC initial prototype hardware complement of a multi-teraflop computer.	+2,000
Other	
A decrease of $451,000 is taken reflecting a reduction in funds held pending completion of peer review and/or programmatic review.	-451
Total Funding Change, Theoretical Physics	**+2,007**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Advanced Technology R&D					
Accelerator Science	22,170	22,423	26,250	+3,827	+17.1%
Accelerator Development	37,245	38,384	32,936	-5,448	-14.2%
Other Technology R&D	11,960	9,713	4,412	-5,301	-54.6%
SBIR/STTR	0	17,389	17,483	+94	+0.5%
Total, Advanced Technology R&D	71,375	87,909	81,081	-6,828	-7.8%

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 Department of Energy's strategic goals for science.

Benefits

The 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 existing.

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 and storage rings. 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 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 Department of Energy and the National Science Foundation on a continuing basis regarding the direction and management of the national high energy physics research program. Their 2002 long range planning report 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, the Office of Science prepared a list of essential science facilities required 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 the Office of Science in the midterm.

The emphasis on exploiting current unique opportunities through full operations of HEP facilities in the U.S. for physics research has required a reduction of funding in important areas of accelerator and detector R&D in 2005 particularly at Fermilab. These are reflected in the reductions shown for general accelerator R&D and Other R&D (Detector R&D is contained in this category). Details are provided in the following sections.

The Advanced Technology (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 topic, Other Technology R&D, describes 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 and the proposed ORION facility at SLAC.

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 largest 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, over twice the field strength of comparable SSC magnets. 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.
- 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 250 MeV 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 2005 are:

- *The Accelerator Science Research Program*. This program supports studies in scientific topics such as laser and radiofrequency driven acceleration, plasma-based accelerators, alternative radiofrequency (RF) accelerating structures, ionization cooling of muon beams, superconducting material development and applications, and nonlinear dynamics and chaos. This research is performed at some 25 universities and 6 DOE national laboratories (ANL, BNL, LANL, LBNL, Princeton Plasma Physics Laboratory (PPPL), and SLAC). The programs of research at the universities and national laboratories are complementary and collaboration between the national laboratories and the university research groups is strongly encouraged.

- *The Research and Development Program in General Technology R&D.* A component of the technology R&D at BNL, Fermilab, LBNL, and SLAC is focused on "reduction 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 16 Tesla and quadrupole fields approaching 300 Tesla per meter, RF acceleration systems for gradients above 75 megavolts per meter, new beam instrumentation, 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 the U.S. High Energy Physics Advisory Panel (HEPAP), as an essential international facility to extend particle physics research beyond what is feasible at the LHC. A U.S. National Collaboration, including SLAC, Fermilab, LBNL, LLNL, and BNL, is funded to develop new technologies that enable a higher performance, lower cost machine, focusing on systems engineering, value engineering and risk analysis studies of applicable technologies.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Accelerator Science...	**22,170**	**22,423**	**26,250**
▪ **University Research**....................................	**9,103**	**9,060**	**9,665**

In FY 2005, funding will provide for a program of accelerator physics and related technologies at some 25 universities at about the same level of effort as FY 2004. 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 will be 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**..................	**11,714**	**11,843**	**14,843**

There are areas of Accelerator Science research that require the more extensive or specialized research facilities located at DOE national laboratories. Funding for this work is provided to six national laboratories, ANL, BNL, LANL, LBNL, PPPL, and SLAC. National laboratory research efforts are selected based on review by appropriate peers, laboratory program advisory committees, and special director-appointed review committees. Measurement of progress is by these means, the annual HEP Program review supported by well-qualified peers, and publications in professional journals and participation in conferences and workshops. Part of the funding previously allocated to the Muon Accelerator R&D effort ($2,400,000) is redirected to this area to support R&D into high-

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

power target studies required for possible future neutrino facilities, including e.g., possible upgrades to the NuMI beam and into support of muon ionization cooling and alternate accelerating methods for muons.

BNL ($3,360,000) is the home of a very successful user facility, the Accelerator Test Facility (ATF), supporting research that HEP funds at universities and in industry (particularly through the SBIR Program). In FY 2005, 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 ($3,943,000) is supported in FY 2005 for research in laser-driven plasma acceleration, advanced radiofrequency 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.

An advanced accelerator R&D program is supported at SLAC ($4,000,000) in FY 2005 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 colliders concepts, and theoretical studies in advanced beam dynamics methods and new computer computation and simulation codes. Much of the work on advanced accelerator concepts at SLAC is done in collaboration with universities funded by the ATRD subprogram.

Other activities supported in FY 2005 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 maintenance and development of standard accelerator, storage ring, and beam optics computer codes at the Accelerator Code Group at LANL, which also maintains an online encyclopedia of accelerator-related computer codes developed throughout the U.S.

▪ **Other**	**1,353**	**1,520**	**1,742**

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.

Accelerator Development.................................	**37,245**	**38,384**	**32,936**
▪ **General Accelerator Development**	**14,032**	**15,550**	**13,736**

This research includes R&D to bring new concepts to a stage of engineering readiness wherein they can be incorporated into existing facilities, used in upgrading existing facilities, or applied to the design of new facilities. The work is almost entirely done at BNL, Fermilab, LBNL and SLAC. The major areas of R&D are superconducting magnet and related materials technology, high-powered radiofrequency acceleration systems; instrumentation; stochastic and electron cooling technologies; beam dynamics, both linear and nonlinear; and development of large simulation programs. In FY 2005 this general research area continues to be funded at a reduced level in order to support the high priority operations for high physics productivity. Part of the funding previously allocated to the

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

Muon Accelerator R&D effort ($1,200,000) is redirected to this area to support R&D into high-power target studies required for possible future neutrino facilities, including e.g., possible upgrades to the NuMI beam, and demonstration experiments to validate muon ionization cooling.

Work at BNL in FY 2005 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 2005 will address a broad spectrum of technology needs for that facility, including 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 2005 includes work on very high field superconducting magnets using niobium-tin and possibly niobium-aluminum, on development of superconducting wire and cable for their magnet R&D, on new beam instrumentation for use at Fermilab and SLAC, and on an extensive beam dynamics and simulation studies program with particular emphasis on electron cloud and related efforts in proton and electron colliders. The FY 2005 program at SLAC encompasses high-powered RF systems, beam instrumentation, generic electron-positron collider R&D, and advanced beam dynamics and machine simulation code development. Simulation codes for modeling radiofrequency system components and high-powered microwave tubes will receive special R&D focus.

	FY 2003	FY 2004	FY 2005
▪ **Linear Collider**	**19,600**	**19,200**	**19,200**

The need for an electron-positron linear collider as a complement to and precision augmentation of the research program that will be carried out at the LHC now under construction at CERN 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 physics questions central to high-energy physics.

The result of the international R&D Program is that there are now two principal, viable technical approaches to constructing a high energy linear collider. One of these approaches, developed by a collaboration led by the German high energy physics laboratory, Deutsches Elektronen-Synchrotron (DESY), is based on the use of a superconducting radiofrequency acceleration system cooled to approximately 452 degrees Fahrenheit below zero. The other approach, developed by a U.S. - Japan collaboration, led in the U.S. by SLAC and including BNL, Fermilab, LBNL and LLNL and in Japan by the high energy physics laboratory, KEK, is based on a room temperature RF accelerating system similar in principle to the one used successfully in the original (100 GeV) SLAC Linear Collider in the early 1990's.

In FY 2005, the U.S. linear collider collaboration will continue the systems engineering, value engineering, risk analysis, and cost studies that have been used to guide the R&D. A particular focus in FY 2005 will be on completing an operational run for at least 2,000 hours of a prototype accelerator section, including RF power source, pulse compressor, and eight accelerating structures. In addition work will continue with KEK on the injection damping ring technology using the

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

prototype ring built at KEK and on design of the electron and positron sources and final focus beam optics systems.

In 2003, a Linear Collider Steering Group was formed by the U.S. HEP community as the U.S. component of a proposed future international collaboration. Similar regional groups were formed in Europe and Asia. About the same time the International Committee on Future Accelerators, ICFA, a long-standing group whose membership is made up of the Directors of all of the world's leading high energy physics laboratories, sponsored the formation of an International Linear Collider Steering Committee (ILCSC) whose membership is drawn from the three regional groups. The ILCSC has set up several groups to address issues relative to the possible construction of an international linear collider. The International Technology Recommendation Panel (ITRP) is charged with deciding whether a cold or warm accelerator technology can better meet the needs of the experimental physics program. Another committee is reviewing the issues involved in setting up a central, international team to coordinate and manage the first phase of a truly international R&D effort directed at the design of an international facility based on the technology recommended by the ITRP. These two committees are to provide their recommendations to ICFA by the fall of 2004.

▪ **Muon Accelerators**.......................................	**3,613**	**3,634**	**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.

The requirements for muon accelerators rely on new technologies that do not yet exist. The two principal technology areas are ultra-high-intensity beam targets that are applicable to any future neutrino research program, and transverse and longitudinal phase-space cooling to reduce beam size. Consequently, the R&D program has been split into the Accelerator Science ($2,400,000) and the General Accelerator Development ($1,200,000) categories. System studies will be continued as part of both activities as necessary to guide the research. The specific activities assigned to each are included in the descriptions of the FY 2005 R&D provided above.

Other Technology R&D.....................................	**11,960**	**9,713**	**4,412**
▪ **Advanced Detector Research**......................	**743**	**990**	**500**

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

▪ **Detector Development**	**11,217**	**8,530**	**3,043**

New experiments frequently depend on advancements in technologies. This funding supports detector development work at the national laboratories to advance these technologies to a point where there is reasonable chance that an experiment can adopt the technology successfully. Technology choices are based on the needs of foreseen experiments. In FY 2005, this research area

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

is further reduced in order to meet high-priority needs for facility operations. In addition, funding for pre-conceptual R&D leading up to the BTeV proposal was previously provided under this category (and is now reported under *Tevatron Improvements*).

	FY 2003	FY 2004	FY 2005
▪ **Other**	**0**	**193**	**869**

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

	FY 2003	FY 2004	FY 2005
SBIR/STTR	**0**	**17,389**	**17,483**

The two activities funded are the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) set asides mandated by Congress. The High Energy Physics Program manages four technical topics related to accelerator science and technology and two topics related to detector science and technology in the annual procurement solicitation. The contents of each topic are 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 programs concerning areas of mutual interest. The organization of the topics and the annual solicitations for suggestions for R&D to be included in the annual solicitation are treated as an important and integral component of the advance accelerator R&D program and selections of grants are made 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 2003, $14,984,000 was transferred to the SBIR program and $899,000 was transferred to the STTR program.

	FY 2003	FY 2004	FY 2005
Total, Advanced Technology R&D	**71,375**	**87,909**	**81,081**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Accelerator Science	
An increase of $3,827,000 provides increased support for long-term R&D efforts at universities and small laboratories focused on developing new particle acceleration techniques, including a redirection of $2,400,000 from the Muon Accelerator R&D category, to focus on ionization cooling R&D.	+3,827
Accelerator Development	
▪ A decrease is taken in General Accelerator Development R&D of $3,014,000 to support high-priority facility operations at Fermilab and SLAC, partially offset by $1,200,000 transferred from the Muon Accelerator R&D to focus on high-power target development for future neutrino sources.	-1,814

	FY 2005 vs. FY 2004 ($000)
▪ The Muon Accelerator R&D effort is redirected as described above…………………..	-3,634
Total, Accelerator Development	-5,448
Other Technology R&D	
A decrease of $5,301,000 is taken primarily in Detector Development, reflecting a transfer of BTeV R&D effort ($4,000,000) to Tevatron Improvements; and also reduced R&D efforts on future experiments ($1,977,000), to maintain support for high-priority facility operations and is partially offset by an increase of $676,000 in the funds held pending completion of peer review and/or program considerations......................................	-5,301
SBIR/STTR	
An increase of $94,000 for the SBIR and STTR programs.	+94
Total Funding Change, Advanced Technology R&D..	**-6,828**

Construction

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Neutrinos at the Main Injector............	19,842	12,426	751	-11,675	-94.0%

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 2003	FY 2004	FY 2005
Neutrinos at the Main Injector (NuMI)...........	**19,842**	**12,426**	**751**
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.			
Total, Construction	**19,842**	**12,426**	**751**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Neutrinos at the Main Injector (NuMI)	
▪ Funding needs decrease as project completes in FY 2005...	-11,675
Total Funding Change, Construction	**-11,675**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Plant Projects............................	9,453	14,330	18,791	+4,461	+31.1%
Accelerator Improvements Projects........	5,263	24,700	21,665	-3,035	-12.3%
Capital Equipment	81,285	61,114	71,790	+10,676	+17.5%
Total, Capital Operating Expenses.........	96,001	100,144	112,246	+12,102	+12.1%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2003	FY 2004	FY 2005	Unapprop-riated Balance
98-G-304 Neutrinos at the Main Injector	109,168	76,149	19,842	12,426	751	0

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2003	FY 2004	FY 2005	Accept-ance Date
Large Hadron Collider — Machine[a]	90,652	74,802	7,900	5,130	2,820	FY 2005
Large Hadron Collider — ATLAS Detector[b]	54,099	34,398	10,134	4,710	2,413	FY 2008
Large Hadron Collider — CMS Detector[b, c]	71,789	47,905	10,194	6,030	3,510	FY 2008
MINOS	44,510	36,520	5,440	2,000	550	FY 2005
GLAST/LAT[d]	42,000	16,769	8,910	7,900	8,421	FY 2006
Cryogenic Dark Matter Search (CDMS)	4,908	3,568	790	550	0	FY 2004
Auger	3,230	1,000	1,230	1,000	0	FY 2004
Alpha Magnetic Spectrometer (AMS) Upgrade	5,506	4,006	1,500	0	0	FY 2004
Run IIb D-Zero Detector[e]	12,502	3,460	2,792	2,542	3,708	FY 2007
Run IIb CDF Detector[f]	10,374	3,460	3,509	1,673	1,732	FY 2007

[a] The TEC has increased by $4,980,000 to reflect the need to increase funding for certain high risk, state-of-of-art pieces of hardware, such as the IR quads, which are part of the LHC accelerator MIE project. The total amount of funding for the LHC program does not change, rather there is a shift between the operating and capital equipment distribution.

[b] At the end of FY 2005 approximately 95% of the U.S. ATLAS and U.S. CMS 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 will continue, consistent with all DOE project management policies and practices. Based on CERN's current schedule, it is anticipated that the remaining work will be completed by the end of FY 2008, with no change in the total estimated costs of the project.

[c] The TEC has increased by $4,738,000 to reflect the need to cover additional needs associated with the detector installation, currently underway at CERN. Based on the favorable experience on operating costs compared to original conservative estimates, FY 2004 operating funds were converted to equipment funds. The total amount of funding for the U.S. CMS program does not change, rather there is a shift between the operating and capital equipment distribution.

[d] The TEC for this project has increased by $5,000,000 to cover the scope of one international partner's default. The Total Project Cost of $133.4M is being funded jointly by DOE ($42M), NASA ($90M) and Japan ($1.4M).

[e] The TEC for this project has been decreased by $8,119,000 from the baseline established in 2002. This is based on the decision made in the September 2003 to reduce the scope of the project in recognition of the lower integrated luminosity projection in outyears.

[f] The TEC for this project has been decreased by $14,613,000 from the baseline established in 2002. This is based on the decision made in the September 2003 to reduce the scope of the project in recognition of the lower integrated luminosity projection in outyears.

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2003	FY 2004	FY 2005	Accept-ance Date
VERITAS……………………..	4,799	0	0	1,600	2,050	FY 2006
BaBar Instrumented Flux Return (IFR) Upgrade[a]............	4,900	0	0	3,000	1,200	FY 2006
BTeV[b]......................................	TBD	0	0	0	6,750	FY 2010
Total, Major Items of Equipment................................		225,888	52,399	36,135	33,154	

[a] New MIE to replace and upgrade failing elements of the BaBar detector. Congressional approval will be requested to initiate fabrication in FY 2004.

[b] TEC range of estimate is $190,000,000 to $230,000,000. Estimate will be refined upon completion of detailed engineering design in FY 2005.

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

(Changes from FY 2004 Congressional Budget Request are denoted with a vertical line [|] in the left margin.)

Significant Changes

The cost estimate for the building increases due to the amount of a competitively bid, fixed-price subcontract for construction of service buildings and outfitting of the tunnels and halls.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1998 Budget Request *(A-E and technical design only)*	1Q 1998	4Q 1998	N/A	N/A	5,500	6,300
FY 1999 Budget Request (Preliminary Estimate)	--	3Q 1999	1Q 1999	4Q 2002	75,800	135,300
FY 2000 Budget Request	3Q 1998	2Q 2000	3Q 1999	2Q 2003	76,200	136,100
FY 2001 Budget Request	3Q 1998	2Q 2000	3Q 1999	2Q 2004	76,200	138,600
FY 2001 Budget Request (Amended)	3Q 1998	2Q 2000	3Q 1999	4Q 2003	76,200	138,400
FY 2002 Budget Request	3Q 1998	4Q 2000	3Q 1999	4Q 2003	76,149	139,390
FY 2003 Budget Request	3Q 1998	4Q 2000	3Q 1999	4Q 2005	109,242	171,442
FY 2004 Budget Request	3Q 1998	4Q 2000	3Q 1999	4Q 2005	109,242	171,442
FY 2005 Budget Request	3Q 1998	4Q 2000	3Q 1999	4Q 2005	109,168[a]	171,368[a]

[a] TEC and TPC were decreased by $73,750 based on the Consolidated Appropriations Act, 2004, as reported in conference report H. Rpt. 108-401, dated November 25, 2003.

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design & Construction			
1998	5,500	5,500	1,140
1999	14,300	14,300	5,846
2000	22,000	22,000	15,089
2001	22,949	22,949	19,752
2002	11,400	11,400	21,489
2003	19,842[a]	19,842	24,000
2004	12,426[b]	12,426	13,926
2005	751	751	7,926

3. Project Description, Justification and Scope

The project provides for the design, engineering and construction of new experimental facilities at Fermi National Accelerator Laboratory in Batavia, Illinois and at the Soudan Underground Laboratory at Soudan, Minnesota. The project is called NuMI which stands for Neutrinos at the Main Injector. The purpose of the project is to provide facilities that will be used by particle physicists to study the properties of neutrinos, which are fundamental elementary particles. In the Standard Model of elementary particle physics there are three types of neutrinos that are postulated to be massless and to date, no direct experimental observation of neutrino mass has been made. However, there are compelling hints from experiments that study neutrinos produced in the sun and in the earth's atmosphere that indicate that if neutrinos were capable of changing their type it could provide a credible explanation for observed neutrino deficits in these experiments.

The primary element of the project is a high flux beam of neutrinos in the energy range of 1 to 40 GeV. The technical components required to produce such a beam will be located on the southwest side of the Fermilab site, tangent to the Main Injector accelerator at the MI-60 extraction region. The beam components will be installed in a new tunnel of approximately 1.5 km in length and 6.5 m diameter. The beam is aimed at two detectors (MINOS), which will be assembled in two new experimental halls located along the trajectory of the neutrino beam. One such detector will be located on the Fermilab site, while a second will be located in the Soudan Underground Laboratory. Two similar detectors in the same neutrino beam and separated by a large distance are an essential feature of the experimental plan. The FY 2005 funding is to complete the installation and commissioning of the neutrino beam line and the detector in the underground facility at Fermilab.

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[a] The FY 2003 original appropriation amount was $20,093,000. The revised appropriation excludes $121,000 for the share of the Science general reduction and $129,819 rescinded in accordance with the Consolidated Appropriations Resolution, FY 2003.

[b] The FY 2004 original appropriation amount was $12,500,000. The revised appropriation excludes $73,750 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003.

The experiments that are being designed to use these facilities will be able to search for neutrino oscillations occurring in an accelerator produced neutrino beam and hence determine if neutrinos do have mass. Fermilab is the only operational high energy physics facility in the U.S. with sufficiently high energy to produce neutrinos which have enough energy to produce tau leptons. This gives Fermilab the unique opportunity to search for neutrino oscillations occurring between the muon and the tau neutrino. Additionally, the NuMI facility is designed to accommodate future enhancements to the physics program that could push the search for neutrino mass well beyond the initial goals established for this project.

4. Details of Cost Estimate[a]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs	7,150	7,150
Design Management costs (0.0% of TEC)	10	10
Project Management costs (0.0% of TEC)	20	20
Total, Engineering design inspection and administration of construction costs (6.6% of TEC)	7,180	7,180
Construction Phase		
Buildings	15,965	12,265
Special Equipment	20,923	20,902
Other Structures	40,184	40,184
Construction Management (8.6% of TEC)	9,379	9,379
Project Management (4.1% of TEC)	4,430	4,430
Total, Construction Costs	90,881	87,160
Contingencies		
Construction Phase (10.2% of TEC)	11,107	14,902
Total, Contingencies (10.2% of TEC)	11,107	14,902
Total, Line Item Cost (TEC)	109,168	109,242

5. Method of Performance

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

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

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 2003	FY 2004	FY 2005	Total
Project Cost					
Facility Cost					
Design	7,180	0	0	0	7,180
Construction	56,136	24,000	13,926	7,926	101,988
Total, Line item TEC	63,316	24,000	13,926	7,926	109,168
Other Project Costs					
Capital equipment [a]	31,414	9,443	2,000	1,653	44,510
R&D necessary to complete construction [b]	1,768	0	0	0	1,768
Conceptual design cost [c]	1,928	0	0	0	1,928
Other project-related costs [d]	11,828	983	800	383	13,994
Total, Other Project Costs	46,938	10,426	2,800	2,036	62,200
Total Project Cost (TPC)	110,254	34,426	16,726	9,962	171,368

[a] Costs to fabricate the near detector at Fermilab and the far detector at Soudan. Include systems and structures for both near detector and far detector, active detector elements, electronics data acquisition, and passive detector material.

[b] This provides for project conceptual design activities, for design and development of new components, and for the fabrication and testing of prototypes. R&D on all elements of the project to optimize performance and minimize costs will continue through early stages of the project. Specifically included are development of active detectors and engineering design of the passive detector material. Both small and large scale prototypes will be fabricated and tested using R&D operating funds. Prior year total has been adjusted to more accurately account for actual R&D costs.

[c] Includes operating costs for development of conceptual design and scope definition for the NuMI facility. Also includes costs for NEPA documentation, to develop an Environmental Assessment, including field tests and measurements at the proposed construction location. Prior year total has been adjusted to more accurately account for actual conceptual design costs.

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

7. Related Annual Funding Requirements

(FY 2003 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs [a]	500	500
Utility costs (estimate based on FY 1997 rate structure) [b]	500	500
Total related annual funding	1,000	1,000
Total operating costs *(operating from FY 2005 through FY 2010)*	5,000	5,000

[a] Including personnel and M&S costs (exclusive of utility costs), for operation, maintenance, and repair of the NuMI facility.

[b] Including incremental power costs for delivering 120 GeV protons to the NuMI facility during Tevatron collider operations, and utility costs for operation of the NuMI facilities, which will begin beyond FY 2004.

Nuclear Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Nuclear Physics					
Medium Energy Nuclear Physics	116,164	124,198	-731[a]	123,467	125,775
Heavy Ion Nuclear Physics............................	159,611	167,805	-989[a]	166,816	173,600
Low Energy Nuclear Physics............................	67,587	71,789	-424[a]	71,365	72,805
Nuclear Theory................	27,293	28,138	-163[a]	27,975	28,860
Subtotal, Nuclear Physics......	370,655	391,930	-2,307[a]	389,623	401,040
Use of Prior Year Balances.........................	0	-826	0	-826	0
Total, Nuclear Physics	370,655[bc]	391,104	-2,307[a]	388,797	401,040

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 manpower that are needed to underpin the Department of Energy's missions for nuclear-related national security, energy, and environmental quality. The program provides world-class, peer-reviewed research results and operates user accelerator facilities in the scientific disciplines encompassed by the Nuclear Physics mission areas under the mandate provided in Public Law 95-91 that established the Department.

Benefits

The Office of Science'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 manpower in fundamental nuclear

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[a] Excludes a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003.

[b] Excludes $8,416,000 which was transferred to the SBIR program and $505,000 which was transferred to the STTR program.

[c] Excludes $2,483,381 rescission in accordance with the Consolidated Appropriations Resolution, FY 2003.

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 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, to advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences, and to 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 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, Low Energy, Heavy Ion and 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, provides for the nation's security, economic growth and opportunities, and improved quality of life. In developing strategies to pursue these exciting research opportunities, the Nuclear Physics program is guided by the 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, NSF, and NASA.
The Medium Energy subprogram will contribute to Program Goal 05.20.00.00 by investigating the quark and gluon substructure inside the nucleon. Although protons and neutrons can be separately observed, their quark constituents cannot be, because they are permanently confined inside the nucleons. Measurements are carried out primarily using electron beams at the Thomas Jefferson National Accelerator Facility (TJNAF), using polarized proton collisions at the Relativistic Heavy Ion Collider (RHIC) and with electron beams at the MIT/Bates Linear Accelerator Center. MIT/Bates operations will continue for three months in FY 2005, ensuring that the BLAST detector research program is completed to provide information complimentary to that obtained at TJNAF on the quark and gluon substructure of the nucleon. 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 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 heated sufficiently, quarks will become de-confined: 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 recreating brief, 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 and the nature of neutrinos. The coming decade in nuclear physics may reveal new 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 its three types as it travels through space. 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). 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 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 Theory subprogram also supports an effort in nuclear data compilation and evaluation that serves a broad community of users as well as the nuclear physics community.

Annual Performance Results and Targets

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 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]	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]		

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
				At Thomas Jefferson National Accelerator Facility perform experiments and record the weighted average of approximately 2.4 billion events in Hall A, 7.2 billion events in Hall B, and 2.1 billion events in Hall C, weighted by the relative event rates, where approximately means within 20% of the expected baseline.	At Thomas Jefferson National Accelerator Facility perform experiments and record the weighted average of approximately 2.9 billion events in Hall A, 9.6 billion events in Hall B, and 2.8 billion events in Hall C, weighted by the relative event rates, where approximately means within 20% of the expected baseline.
		Commissioned polarized protons at RHIC. [Met Goal]	Collected first data with polarized protons with the RHIC STAR, PHENIX and pp2pp detectors. [Met Goal]		
Heavy Ion Nuclear Physics					
Advanced knowledge from experiments at the Relativistic Heavy Ion Collider (RHIC) to see possible evidence of the predicted quark-gluon plasma (a high-temperature, high-density state of nuclear matter that may have existed a millionth of a second after the “Big Bang”). [Met Goal]	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 2×10^{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]	At the Relativistic Heavy Ion Collider, perform experiments with approximately the weighted average of 0.9 billion heavy-ion collision events sampled for the PHENIX detector and 40 million heavy-ion collision events recorded for the STAR detector, weighted by the relative event rates, where approximately means within 30% of the expected baseline.	At the Relativistic Heavy Ion Collider, perform experiments with approximately the weighted average of 1.8 billion heavy-ion collision events sampled for the PHENIX detector and 40 million heavy-ion collision events recorded for the STAR detector, weighted by the relative event rates, where approximately means within 30% of the expected baseline.
	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] Met the cost and schedule milestones for the PHENIX Muon Arm Instrumentation (Major Item of Equipment) within 10% of baseline estimates. [Met Goal]	Upgraded the RHIC cryogenics system by replacing turbine oil skids and removing seal gas compressor, eliminating a single point failure. [Met Goal]		

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
Low Energy Nuclear Physics					
				Perform experiments and record the weighted average of approximately 25 billion events at the Argonne Tandem Linac Accelerator System (ATLAS) facility and 5.3 billion events at the Holifield Radioactive Ion Beam (HRIBF) facility, weighted by the relative event rates, where approximately means within 20% of the expected baseline.	Perform experiments and record the weighted average of approximately 25 billion events at the Argonne Tandem Linac Accelerator System (ATLAS) facility and 5.3 billion events at the Holifield Radioactive Ion Beam (HRIBF) facility, weighted by the relative event rates, where approximately means within 20% of the expected baseline.
	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]		
	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 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 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 Office of Science 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 Aeronautics and Space Administration) and industry to carry out important studies of the effects of particle beams (radiation) in a variety of materials and biological systems.

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 Nuclear Physics (NP) program has incorporated feedback from OMB into the FY 2005 Budget Request and has taken, or will take, the necessary steps to continue to improve performance.

In the PART review, OMB gave the Nuclear Physics (HEP) 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. Although NP is establishing 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, this committee has not yet met. Once the COV issues a report, NP will develop an action plan to respond to the findings and recommendations within 30 days. The assessment found that NP has developed a limited number of adequate performance measures and has already engaged its advisory committee in developing research milestones for the long-term performance goals. However, OMB noted concerns regarding the collection and reporting of performance data. To address these concerns, NP will work to improve performance reporting by grantees and contractors, will include the long term research goals in grant solicitations, and will work with the CFO to improve NP sections of the Department's performance documents. NP's role in providing scientific research facilities is strongly supported by the Administration. Funding is provided in FY 2005 to operate the program's five facilities at 88 percent of maximum capacity. NP will also ensure that a thorough, independent scientific assessment of the proposed Rare Isotope Accelerator is carried out by October 2005.

Funding by General and Program Goal

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
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	116,164	123,467	125,775	+2,308	+1.9%
Heavy Ion Nuclear Physics	159,611	166,816	173,600	+6,784	+4.1%
Low Energy Nuclear Physics	67,587	71,365	72,805	+1,440	+2.0%
Nuclear Theory	27,293	27,975	28,860	+885	+3.2%
Total Program Goal 05.20.00.00 Explore Nuclear Matter in All its Forms	370,655	389,623	401,040	+11,417	+2.9%
Use of Prior Year Balances	0	-826	0	+826	+100.0%
Total, Nuclear Physics	370,655	388,797	401,040	+12,243	+3.1%

Overview

Nuclear science began by studying the structure and properties of atomic nuclei as assemblages of protons and neutrons. Research focused on nuclear reactions, the nature of radioactivity, and the synthesis of new isotopes and new elements heavier than uranium. Great benefit, especially to medicine, emerged from these efforts. But today, nuclear science is much more than this. Today, its reach extends from the quarks and gluons that form the substructure of the once-elementary protons and neutrons, to the most dramatic of cosmic events—supernovae. At its heart, nuclear physics attempts to understand the composition, structure, and properties of atomic nuclei, 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 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.

Advisory and Consultative Activities

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

The ***Nuclear Science Advisory Committee*** (NSAC) provides advice to the Department of Energy and the National Science Foundation on a continuing basis regarding the direction and management of the national basic nuclear sciences research program. In FY 2003, the DOE Nuclear Physics program provided about 90% of the federal support for fundamental nuclear physics research in the nation. The National Science Foundation (NSF) provided most of the remaining support. NSAC regularly conducts reviews of university and national laboratory facilities to assess their scientific productivity, evaluates major components of the Division's research program, and evaluates the scientific case for new facilities. One of the most important functions of NSAC is development of long-range plans that express community-wide priorities for the upcoming decade of nuclear physics research.

Facility directors seek advice from ***Program Advisory Committees*** (PACs) to determine the allocation of scarce scientific resources—the available beam time. The committees are comprised of members mostly external to the host lab 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 manpower 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 the Office of Science's Construction Management Support Division, these reviews enlisted experts from DOE National Laboratories and NSF-supported university nuclear physics facilities to evaluate present performance and costs of operations. In 2003 the Office conducted operations reviews of the Holifield Radioactive Ion Beam Facility (HRIBF) and the Argonne Tandem Linac Accelerator System (ATLAS) facility, using such external experts. Annual reviews of the RHIC and CEBAF 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. In 1998, the Medium Energy subprogram was reviewed. In 2001, the Low Energy subprogram was reviewed. A review of the Theory subprogram was completed in November, 2003. 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

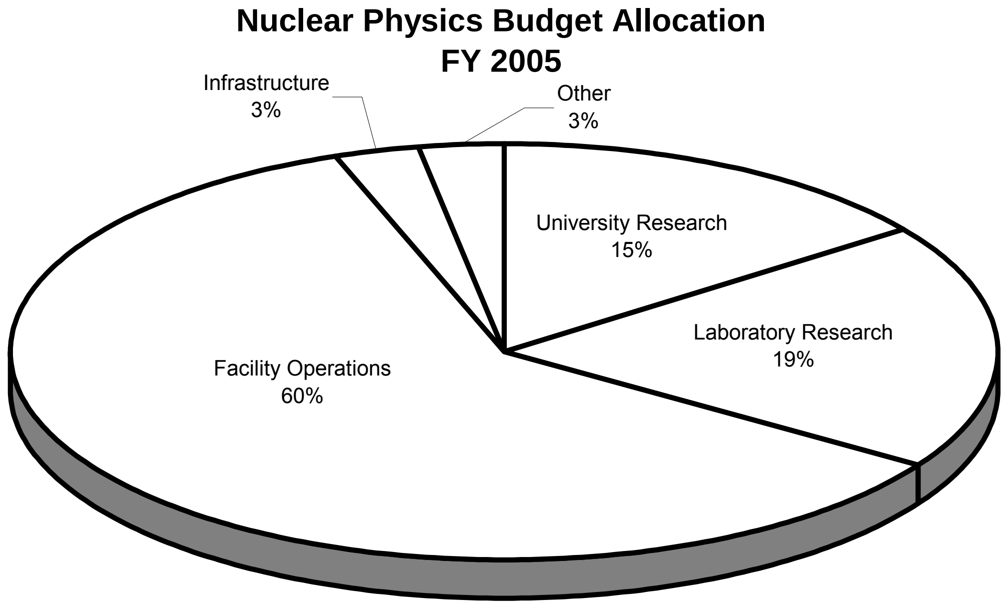
One of the most important activities of NSAC is the development of long-range plans that serve as a framework for the coordinated advancement of the field for the coming decade. These plans are undertaken every 5-6 years to review the scientific opportunities in the field, perform retrospective assessments of the major accomplishments by the field, and set priorities for the future. NSAC 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. Priority within the recent budgets has been given to implementing these recommendations by making tough programmatic decisions. In the FY 2005 budget, funding supports increased utilization of the large major nuclear physics scientific user facilities CEBAF and RHIC. In FY 2004 the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory transitions from a nuclear physics user facility to a facility providing 2,000 hours for testing electronic components for radiation "hardness" to cosmic rays with support from the National Reconnaissance Office and the Air Force, and for a small in-house research program. The support for reduced operations for nuclear physics will allow enhanced support for the remaining Low Energy user facilities and to make investments in instruments and to enhance capabilities. At the end of the first quarter of FY 2005 operations will be terminated at the MIT/Bates Linear Accelerator Center with completion of the research program using the Bates Large Acceptance Spectrometer Toroid (BLAST) detector. Theory and experimental research efforts are supported to collect and analyze data at the operating facilities and to interpret results. The NSAC Long Range Plan identified the proposed Rare Isotope Accelerator (RIA) as the highest priority for major new construction: the FY 2005 budget requests continued support for RIA R&D. Furthermore, the NSAC Long Range Plan recommended an upgrade of TJNAF from 6 to 12 GeV and R&D and conceptual design activities for this upgrade are supported.

Committee of Visitors

A Committee of Visitors was appointed under the guidance of the Nuclear Science Advisory Committee to review the management practices of the Nuclear Physics program. 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.

How We Spend Our Budget

The Nuclear Physics budget has three major components: research, facility operations and experimental support, and construction and laboratory infrastructure support. The FY 2005 budget request is focused on optimizing the scientific productivity within the resources available. Research support, including capital equipment and R&D activities, is almost constant compared to FY 2004. Support for facility operations is increased ~5% in FY 2005 from FY 2004, allowing the achievement of 85% and 92% utilization of the TJNAF and RHIC facilities, respectively. Despite the closure of the MIT/Bates facility, there will be about the same number of beam hours for research compared to FY 2004. Modest R&D and other investments are made.



Research

One-third of the program's funding was provided to scientists at universities and laboratories to conceive and carry out the research. The DOE Nuclear Physics program involves over 1900 researchers and students at over 100 U.S. academic, federal and private sector institutions. The program funds research activities at over 85 academic institutions located in 35 states and at 7 DOE Laboratories in 6 states. Funding for university and national laboratory research (excluding capital equipment and proposed RIA R&D) is increased ~3.5% compared to FY 2004, resulting in about constant manpower. National laboratory research scientists work together with the experimental collaborations to collect and analyze data as well as support and maintain the detectors. The laboratories provide state-of-the-art resources for detector and accelerator R&D for future upgrades and new facilities. The division of support between national laboratories and universities is adjusted to maximize scientific productivity.

- ***University Research***: University researchers play a critical role in the nation's research effort and in the training of graduate students. During FY 2003, the DOE Nuclear Physics program supported approximately two-thirds of the nation's university researchers and graduate students doing fundamental nuclear physics research. Among the 85 academic institutions DOE supports researchers in five university laboratories with local accelerators (Texas A&M Cyclotron Laboratory, Triangle Universities Nuclear Laboratory (TUNL) at Duke University, MIT Laboratory for Nuclear Science, University of Washington, and Yale University). DOE also supports the Institute for Nuclear Theory at the University of Washington. Typically about 80 Ph.D. degrees are granted annually to students for research supported by the program. One-half of those who received nuclear science Ph.D.'s between 1980 and 1994 are pursuing careers outside universities or national labs in such diverse areas as nuclear medicine, medical physics, space exploration, and national security.

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

Significant Program Shifts

In the FY 2005 budget request the scientific scope of the nation’s nuclear physics program is maintained. The FY 2005 budget request terminates operations of the MIT/Bates facility at the end of the first quarter of FY 2005. This follows the transitions of the LBNL 88-Inch Cyclotron in FY 2004 from a user facility to a dedicated in-house facility. This will allow resources to better utilize and increase science productivity of the remaining user facilities (BNL/RHIC, TJNAF/CEBAF, ANL/ATLAS, and ORNL/HRIBF) with operations at these facilities at ~87% of maximal utilization. The research programs at these major user facilities are integrated partnerships between DOE scientific laboratories and the university community, and the planned experimental research activities are considered essential for scientific productivity of the facilities. Funding for university and national laboratory research is maintained approximately constant compared to FY 2004. Funding for capital equipment will address opportunities identified in the recently completed 2002 NSAC Long Range Plan, and R&D activities for the proposed RIA are maintained. Increased funding from FY 2004 is provided for R&D activities associated with the upgrade from 6 to 12 GeV at TJNAF.

Scientific Discovery through Advanced Computing

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

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 - TSI), and grid technology (Particle Physics Data Grid Collaborative Pilot) that support the scientific goals of the Nuclear Physics subprograms. Each of these projects is not only at the cutting-edge of science and technology, but collectively these projects are supplying innovative new ideas to other disciplines and industry. The principal goal of TSI 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. Recently, new three-dimensional hydrodynamics simulations reveal a particular type of supernova shock wave instability that could provide the first explanation of the polarization of the light emitted from a supernova. Simulations of the r-process have also led to a surprising observation: nucleosynthesis can occur in very different environments than previously thought. An example of a technical accomplishment is the development of algorithms to solve algebraic equations for multidimensional radiation transport on terascale computers. Without these algorithms, the simulation of neutrino transport in stars would not be possible. 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 initiative provides results complementary to a similar initiative by the High Energy Physics program.) Two unique computational hardware approaches are being pursued: one using specially designed systems-on-a-chip that leverages IBM proprietary core technology, the other using commodity general-purpose computing systems. Under the SciDAC Program, Applications Program Interface (QCD API) software has been designed to provide a unified programming environment to achieve high efficiency for running lattice gauge calculations on multi-terascale computer architectures targeted for future deployment. The Particle Data Grid project has allowed Nuclear Physics experiments to tackle the task of replicating thousands of files. Members of the Solenoidal Tracker at RHIC (STAR) collaboration and the Scientific Data Management group at Lawrence Berkeley National Laboratory have collaborated on deploying Hierarchical Resource Managers to automate data transport between the RHIC Computing Facility (RCF) storage system at Brookhaven National Laboratory and the storage system at the National Energy Research Scientific Computing Center (NERSC) at LBNL. In tests, rates of up to 8 MB/sec for the wide-area-network stage have been achieved, with rates of 3-4 TB/week reached during the 2003 data taking run for STAR at RHIC.

Scientific Facilities Utilization

The Nuclear Physics request for FY 2005 supports the Department's scientific user facilities. In FY 2003 Nuclear Physics operated six National User Facilities, which provide research time for scientists in universities and other Federal laboratories. In FY 2004 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; and
- The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory.

These facilities provide beams for research for a user community of about 2,290 scientists. The FY 2005 Budget Request will support operations of five facilities (MIT/Bates for only one-quarter year) that will provide ~21,450 hours of beams for research, ~1.5% increase from the anticipated beam hours in FY 2004.

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 2001	FY 2002	FY 2003	FY 2004	FY 2005 Request
Number of Facilities	7	7	6	5	5
Maximum Hours	31,600	31,600	32,275	27,675	24,300
Planned Operating Hours...........	20,285	17,510	23,570	21,145	21,450
Achieved Operating Hours.........	24,575	26,750	28,150	–	–
Unscheduled Downtime – Major user facilities	18%	13%	12%	–	–
Number of Users*......................	3,020	2,440	2,355	2,290	2,325

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

In FY 2003, increased efficiency in operations of the TJNAF facility and the change from 5 to 7-days per week operation for much of the year at the HRIBF and ATLAS facilities resulted in actual operating hours that exceeded what was planned.

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

High Energy Density Physics

The high energy density environment at the core of stars and especially inside the core of collapsing and then exploding supernovae is the cauldron in which we believe all the heavier chemical elements are formed. Such an environment is necessary in order for nuclear reactions to proceed in rapid succession, with radioactive products able to participate in further reactions before they decay. Such conditions are needed for the nucleosynthesis of the elements. Experiments at the Holifield Radioactive Ion Beam

Facility explore this process with radioactive isotope beams in the lighter elements. The proposed Rare Isotope Accelerator (RIA) would provide the world's most powerful facility for such measurements, extending capability for these measurements into the heavier isotopes and to the very limits of nuclear stability.

The beginning of the universe created nuclear matter in its most extreme energy density. A new form of matter, the quark-gluon plasma, composed of deconfined quarks and gluons, is predicted to be this initial state, and experiments at the Relativistic Heavy Ion Collider (RHIC) are searching to find and characterize this new state. 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, whose study is facilitated by measurements with rare-particle probes.

The High Energy Density Physics activities support research and development (R&D) for the proposed RIA and for electron beam cooling at the Relativistic Heavy Ion Collider (RHIC). The R&D for RIA is focused on developing and testing prototype accelerator components to yield design improvements that could reduce project cost and schedule and cost risk to the project. Pre-conceptual design activities are also supported. The R&D activities for electron beam cooling at RHIC also consist of developing and testing prototype components. The electron cooling would produce more focused, or brighter, beams, in the two RHIC rings. These, in turn, could produce an anticipated factor of 10 increase in the luminosity, or collision rate, at the crossing areas. This increase would allow the development of a physics program using rare particle probes.

Construction and Infrastructure

Funding for capital equipment in FY 2005 is reduced by ~2% compared to FY 2004. The Nuclear Physics program, as part of its responsibilities as the landlord for Brookhaven National Laboratory and Thomas Jefferson National Accelerator Facility (TJNAF), provides funding for general plant projects (GPP) to both sites and general purpose equipment (GPE) to BNL only. Funding for GPP is increased by ~8.5% in FY 2005 compared to FY 2004 to address the backlog of needed infrastructure improvements.

Workforce Development

The Nuclear Physics program supports development of the Research and Development (R&D) workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. It also provides talent for a wide variety of technical, medical, security and industrial areas that require the finely-honed thinking and problem-solving abilities and the computing and technical skills developed through an education and experience in a fundamental research field. Scientists trained as Nuclear Physicists can be found in such diverse areas as nuclear medicine, medical physics, space exploration, and national security. The Outstanding Junior Investigator (OJI) program, initiated in FY 2000, through ~5 new awards each year, has been very successful in identifying, recognizing, and supporting promising young faculty. About 865 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2003 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 human capital are given below. In FY 2003 there were about 274 faculty researchers supported at the universities (~1.5 per grant), with an average award of ~$200,000 per faculty researcher. Almost all grants have a duration of three years.

	FY 2001	FY 2002	FY 2003	FY 2004, est.	FY 2005, est.
# University Grants*	180	181	183	185	185
Average size (excl. CE)	$310,000	$306,000	$304,000	$306,000	$314,000
# Lab groups	28	28	28	28	28
# Permanent Ph.D.'s	683	702	727	730	730
# Postdocs	362	364	410	410	410
# Graduate students	408	442	457	460	460
# Ph.D.'s awarded	67	100	79	80	80

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

Medium Energy Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Medium Energy Nuclear Physics					
Research					
University Research	15,183	15,409	15,618	+209	+1.4%
National Laboratory Research	14,741	15,223	16,034	+811	+5.3%
Other Research	418	5,647	5,411	-236	-4.2%
Subtotal, Research	30,342	36,279	37,063	+784	+2.2%
Operations					
TJNAF Operations	72,635	74,693	79,212	+4,519	+6.1%
Bates Operations	13,169	12,495	9,500	-2,995	-24.0%
Other Operations	18	0	0	0	0.0%
Subtotal, Operations	85,822	87,188	88,712	+1,524	+1.7%
Total, Medium Energy Nuclear Physics	116,164	123,467	125,775	+2,308	+1.9%

Description

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

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

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 Chromo-Dynamics. 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 program operates the Thomas Jefferson National Accelerator Facility, a unique, world-class facility, funds research at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory, and supports university researchers to carry out the necessary experiments at these facilities. These research activities contribute to the training of the next generation of scientists and engineers that contribute to the Department’s nuclear and energy missions.

Supporting Information

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

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

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

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

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

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

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

The operation of the national user facility, TJNAF, supported by Medium Energy Nuclear Physics, serves a nationwide community of about 300 Department of Energy and about 300 National Science Foundation supported scientists and students from over 140 American institutions and involves about 300 scientists per year from 19 foreign countries. Many of these scientists are from the European Center for Nuclear Research (CERN) member states. At TJNAF, the National Science Foundation (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.

Accomplishments

The DOE Nuclear Physics program has made important discoveries in the past decade. The assembly of a large set of precision nucleon-nucleon scattering data, 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 recent long-range plan singled out three significant achievements of the Medium Energy program related to the important central question of the structure of the nucleon:

- The combined discovery that the spins of the quarks alone account for only one third of the proton's overall spin and the observed increasing density of gluons inside the proton with increasing beam resolving power has increased the importance of the role of gluons in understanding nucleon structure.
- The discovery of a significant imbalance between antiquarks of different types inside the proton suggests that 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.

These discoveries have been further extended by these recent highlights:

- *Evidence for the existence of a new five-quark state of matter:* Data from TJNAF indicates the existence of a new kind of matter that contains five quarks rather than the two or three quarks that make up all matter presently observed. Identification of this particle along with the observation of additional particles of similar five-quark structure would provide vital information on how quarks and gluons interact to form nuclear matter.
- *Providing a link between the Bjorken and the Gerasimov-Drell-Hearn (GDH) Sum Rules:* These two sum rules are well defined "benchmarks" for the nucleon's spin structure: the GDH sum rule, which applies at long distance scales that are not directly calculable in Quantum Chromo-Dynamics (QCD), and the Bjorken sum rule, which applies in the very small distance scale where perturbative QCD is known to work. New data from TJNAF show how the nucleon's spin structure transitions between these two extremes, providing essential information for developing an understanding of how the nucleon total spin evolves from the underlying quark and gluon structure. Such data are vital to eventually developing a quantitative understanding of the nucleon based on QCD.
- *The first exclusive measurement of Deeply Virtual Compton Scattering (DVCS) from the Proton:* These results from Hall B at TJNAF provide strong support for the interpretation of this class of reactions within the framework of the Generalized Parton Distributions, theoretical functions which provide a means to determine the quark wave functions inside the nucleon.
- *Role of the "sea quarks" in the structure of the nucleon:* The deformation from a spherical shape of the first excited state of the nucleon was measured at Thomas Jefferson National Accelerator Facility. New data revealing the spatial character of the this state are in agreement with the first full lattice QCD calculation of the transition amplitudes, and indicate an oblate shape resulting from the sea of virtual quark-antiquark pairs inside the nucleon.
- *New results from SLAC have determined the value of the weak mixing angle that is expected at lower energies:* A fundamental tenant of the Standard Model of particle physics predicts that the Weinberg or 'weak mixing' angle, a parameter that determines the strength of the weak interaction, should change as particle interactions occur at lower energies. The new SLAC results are consistent with the Standard Model prediction.

Facility and Technical Accomplishments:

- *The BLAST Detector at the MIT/Bates facility begins operations*: The Bates Large Acceptance Spectrometer Toroid (BLAST) experimental program at Bates began taking data in FY 2003 to obtain unique information on proton and neutron structure.
- *The G0 Detector is complete:* At the Thomas Jefferson National Accelerator Facility, the research program using the G0 detector to measure the strangeness content of the proton over a wide range of momentum transfer was initiated in FY 2003.
- *The MiniBooNE detector fabrication is completed and operations begin:* This jointly supported high-energy and nuclear physics experiment at Fermilab began in late FY 2002 to look for the disapperance of muon neutrinos in an attempt to confirm the earlier result of the Los Alamos Liquid Scintillator Neutrino Detector (LSND) experiment's observation of the disappearance of muon anti-neutrinos. With the observation of electron neutrino oscillations by the SNO experiment, this experiment becomes important for determining whether or not 'sterile' or non-interacting neutrinos exist. First results are expected in FY 2005.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Research	**30,342**	**36,279**	**37,063**
▪ **University Research**	**15,183**	**15,409**	**15,618**

These activities comprise a broad program of research, and include support of about 165 scientists and 105 graduate students at 34 universities in 17 states and the District of Columbia. These research efforts utilize not only each of the accelerator facilities supported under the Medium Energy program, but also other U.S. and foreign accelerator laboratories. *Support for university research increases by ~1.5%.*

• **Bates Research**	**2,238**	**2,400**	**2,300**

MIT scientists along with other university researchers are completing the Bates Large Acceptance Spectrometer Toroid (BLAST) program of research started in FY 2003 on the structure of the nucleon and the nature of the nucleon-nucleon force. Support for analysis of data will continue after data taking is completed in FY 2005.

• **Other University Research**	**12,945**	**13,009**	**13,318**

Most of the university research supports the activities associated with our main facilities at MIT/Bates, TJNAF, and RHIC. At TJNAF the experiments are largely focused on the study of nucleon structure and its internal dynamics. Hall A will continue its measurements of the neutron electric form factor and is expected to complete installation of the new high resolution hypernuclear spectrometer which will begin a program to study hypernuclear states (quantum states in which a nucleon is replaced by a baryon containing a strange quark) in light to medium-heavy nuclei. Hall B is expected to carry out its first broad range Deeply Virtual Compton Scattering (DVCS) experiment using the CLAS detector to test the new Generalized Parton Distribution functions calculated for the nucleon's structure. In Hall C, the G0 experiment is expected to complete the first phase of its experimental program started in FY 2003.

A number of university groups are collaborating in experiments using the new BLAST detector and the South Hall Ring at the MIT/Bates Linear Accelerator Center, for which operations are planned to terminate at the end of the first quarter of 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 include the HERMES (HERa MEasurements with Spin) experiment at the DESY laboratory in Hamburg, Germany, the Crystal Ball detector at the Mainz, Germany, electron accelerator, and the precision experiments in weak decay at the Paul Scherrer Institute, Switzerland.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **National Laboratory Research**	**14,741**	**15,223**	**16,034**

Included are: (1) the research supported at the Thomas Jefferson National Accelerator Facility (TJNAF), that houses the world's most powerful high intensity continuous wave electron accelerator and (2) research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories. The National Laboratory groups carry out research at various world facilities as well as at their home institutions**.**

• **TJNAF Research**	**5,085**	**5,184**	**5,405**

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. One of the priorities in FY 2005 will be the G0 experiment that is being supported in cooperation with the National Science Foundation. This detector will determine the electromagnetic contribution of the strange quark to the nucleon for a range of different resolutions. A follow-up experiment, Q-weak, is being developed to make a precision measurement of the weak charge of the proton.

• **Other National Laboratory Research**	**9,656**	**10,039**	**10,629**

Support for research activities at accelerator and non-accelerator facilities at National Laboratories is increased by ~6% to provide constant effort relative to FY 2004. These activities include:

- ► Argonne National Laboratory scientists will pursue research programs at TJNAF and at the DESY Laboratory in Germany. The theme running through this entire effort is the search for a detailed understanding of the internal quark-gluon structure of the nucleon. The ANL program at DESY is expected to be phased out in FY 2005. ANL scientists have also made important advances in a new laser atom-trapping technique Atom Trap Trace Analysis (ATTA) to be used in measurements of rare isotopes for precision studies of nuclear structure.
- ► At Brookhaven National Laboratory, the Medium Energy Research group plays a lead 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 "ice" 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 (NSLS).

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

► 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. This experiment, the Mini Booster Neutrino Experiment (MiniBooNE), uses neutrinos generated from the Fermi National Accelerator Laboratory Booster proton beam; data collection began in FY 2002. Initial results are expected in FY 2005.

Los Alamos scientists also are involved in experiments at Fermilab and at RHIC (RHIC Spin) that will probe the structure of the virtual "sea" of quarks in the nucleon and the gluonic contribution to its spin, respectively. The Los Alamos group has also been instrumental in providing major components of the PHENIX detector at RHIC that are crucial in carrying out the RHIC Spin program of research.

	FY 2003	FY 2004	FY 2005
▪ **Other Research**	**418**	**5,647**	**5,411**

In FY 2003 $4,260,000 was transferred to the SBIR program and $505,000 was transferred to the STTR program. This section includes $3,770,000 for SBIR and $1,049,000 for STTR in FY 2004 and $3,711,000 for SBIR and $1,084,000 for STTR in FY 2005 and other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2003	FY 2004	FY 2005
Operations	**85,822**	**87,188**	**88,712**
▪ **TJNAF Operations**	**72,635**	**74,693**	**79,212**

Included is the funding that supports: (1) operation of the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF), and (2) major manpower, equipment, and staging support for the assembly and dismantling of complex experiments.

	FY 2003	FY 2004	FY 2005
• **TJNAF Accelerator Operations**	**46,620**	**48,542**	**52,284**

Accelerator operations in FY 2005 support a 4,985 hour running schedule, 92% utilization of the facility. At this level of funding the accelerator provides beams of differing energies and currents simultaneously to all three experimental halls.

	(hours of operation with beam)		
	FY 2003	FY 2004	FY 2005
TJNAF	5,400	3,715	4,985

Funding of $1,500,000 is provided for R&D and possible conceptual design activities for the proposed 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. There is an increase in accelerator improvement project (AIP) funds of $100,000 to $1,200,000 and an additional amount of $340,000 is provided for GPP funding above the FY 2004 level in order to address a backlog of needed infrastructure improvements at the laboratory. Recent investments in AIP projects have improved the reliability of CEBAF resulting in a decrease in

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

unscheduled downtime from 17.8% in FY 2002 to 14.7% in FY 2003, a significant improvement. Further improvement is anticipated with an ongoing reliability improvement campaign.

• **TJNAF Experimental Support**	**26,015**	**26,151**	**26,928**

These funds provide for the scientific and technical manpower, materials, and services needed to support three hall operations and to integrate rapid assembly, modification, and disassembly of large and complex experiments for optimization of schedules. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment for specific experiments. In FY 2005 funding for experimental support is increased by ~3%.

Capital equipment funds ($6,100,000) 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, as a follow-up to the G0 experiment, to perform a precision measurement of the weak charge of the proton.

▪ **Bates Operations**	**13,169**	**12,495**	**9,500**

MIT/Bates Linear Accelerator Center is provided funding for operation during the first quarter of FY 2005 to complete the BLAST research program followed by phase-out activities of the facility. These phaseout activities will include final calibration activities and initiation of decontamination and decommissioning (D&D).

	(hours of operation with beam)		
	FY 2003	FY 2004	FY 2005
Bates	3,920	4,000	1,625

Operating funds will provide for 1,625 hours of operation of the BLAST detector in early FY 2005, followed by termination of the Bates research program. Although the BLAST detector was completed on schedule, the experimental program also requires a polarized gas target. Due to technical difficulties a longer than anticipated commissioning of this target resulted in a delay in the beginning of the data collection program until the fourth quarter of FY 2003. As a result, completion of the planned experimental program by the end of FY 2004 will not be possible. The funds provided will allow a successful completion of the program and realize the scientific return on the sizeable investment in both hardware and manpower in fabricating the BLAST detector.

▪ **Other Operations**	**18**	**0**	**0**

No funds are provided for other operations in FY 2005.

Total, Medium Energy Nuclear Physics	**116,164**	**123,467**	**125,775**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Research	
▪ **University Research**	
• Funding supports the continuation of the MIT/Bates research effort focused on analysis of BLAST data. Support for Bates research staff is then phased out.	-100
• The research support at Other Universities increases by ~2.5% relative to FY 2004. Support is focused on the TJNAF and RHIC spin-physics research programs.	+309
Total, University Research	+209
▪ **National Laboratory Research**	
• Funding for capital equipment increases by $329,000 from FY 2004, of which $200,000 will provide funding for developing an experiment to measure the electric dipole moment of Radium-225 using the Atom Trap Trace Analysis (ATTA) technique at ANL. Funding for research support increases by ~3% ($482,000), providing approximately constant effort.	+811
▪ **Other Research**	
• Estimated SBIR/STTR and other obligations decrease.	-236
Total Research	+784
Operations	
▪ **TJNAF Operations**	
• TJNAF Accelerator Operations: Accelerator operating funds are increased by ~7.5% relative to FY 2004, providing a 4,985 hour running schedule, 92% utilization of the accelerator, and support for R&D and possible conceptual design activities for the proposed 12 GeV upgrade. Included is funding for AIP/GPP ($2,000,000) that is increased by $440,000 compared to FY 2004 to address the backlog in accelerator/physical infrastructure.	+3,742
• TJNAF Experimental Support: The increase of 3% ($722,000) for Experimental Support relative to FY 2004 supports the increased running schedule. Overall capital equipment funding ($6,100,000) is increased by $55,000 compared to FY 2004.	+777
Total, TJNAF Operations	+4,519

	FY 2005 vs. FY 2004 ($000)
▪ **Bates Operations**	
• The funding for Bates operations is decreased from FY 2004 with the termination of operations of the Bates facility at the end of the first quarter of FY 2005. Funds are provided for phaseout and decontamination and decommissioning activities and transitioning of staff.	-2,995
Total Operations	+1,524
Total Funding Change, Medium Energy Nuclear Physics	+2,308

Heavy Ion Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Heavy Ion Nuclear Physics					
Research					
University Research	12,173	12,325	12,848	+523	+4.2%
National Laboratory Research	18,054	18,374	16,826	-1,548	-8.4%
Other Research	0	4,242	3,958	-284	-6.7%
Subtotal, Research	30,227	34,941	33,632	-1,309	-3.7%
Operations					
RHIC Operations	118,849	120,047	129,201	+9,154	+7.6%
Other Operations	10,535	11,828	10,767	-1,061	-9.0%
Subtotal, Operations	129,384	131,875	139,968	+8,093	+6.1%
Total, Heavy Ion Nuclear Physics	159,611	166,816	173,600	+6,784	+4.1%

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. At extremely high temperatures, however, such as those that existed in the early universe immediately after the "Big Bang," the quarks and gluons become deconfined and form a quark-gluon plasma. It is the purpose of this research program to recreate 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. At much lower temperatures, nuclear matter passes through another phase transition from a Fermi liquid to a Fermi gas of free roaming nucleons; understanding this phase transition is also a goal of the subprogram.

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 manpower that is 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 three 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. 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 distinguished scientists that review and evaluate experiments regarding their merits and scientific priority. An annual review of the effectiveness of RHIC operations and its research program is conducted by the program office and its recommendations are used to improve RHIC operations.

Accomplishments

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

- Production of small regions of space with energy densities more than twenty times that of atomic nuclei. Matter under these extreme conditions 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 the second RHIC running period in FY 2002 with gold-gold collisions. The third running period, in FY 2003, successfully collided deuterons (d) with gold (Au) nuclei—another landmark technical accomplishment — allowing scientists to report preliminary, but tantalizing results of central importance to the whole RHIC program. Some of the highlights from the Au-Au and d-Au programs are:

- *First measurements of Jet-like behavior:* Measurements of a spray of highly energetic particles emitted back-to-back ("jets") have been measured with Au-Au collisions; separated from a background of thousands of other particles using correlation techniques. Because "jet" phenomena occur at very early times, they are harbingers of the environment in which they are born. In peripheral or glancing collisions, two back-to-back jets are observed, but in the most violent head-on or "central" collisions one jet is "lost" or "quenched." 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. Data from observing deuteron on gold collisions, in which neither heating nor compression of nuclear matter is expected, show that both jets are present.
- *Hadron suppression:* The hadron suppression effect in Au-Au collisions and the disappearance of back-to-back 'jets' are positively correlated.
- *Reconstruction of multiply strange hadrons:* Yields of kaons, phi mesons, and lambda, cascade and omega baryons containing one to three strange quarks have been measured, the amount of strangeness affecting the particle lifetime. Each particle is emitted during a different "window" of time; thus, by comparing rates for the different species, the evolution of the hot matter collision zone can be studied.
- *Kaon and lambda elliptic flow show scaling behavior:* Measurement of elliptic flow (a parameter based on azimuthal anisotropy of particle emission) of neutral kaons and lambda particles show evidence of collective scaling behavior derived from the hypothesis of partonic (quark) coalescence in the early stages of the collisions.
- *Hydrodynamic expansion:* Elliptical flow measurements for different particle species exhibit a hierarchy of strength which monotonically decreases with increasing mass of the particle. This behavior is observed below particle momentum ~ 2 GeV/c, indicating that a high degree of local thermal equilibrium is achieved, a requirement for a "plasma" state to be observed.

Facility and Technical Accomplishments:

- *RHIC obtains first collisions of deuterons with gold nuclei:* In FY 2003, RHIC successfully collided deuterons (d) with gold (Au) nuclei (a landmark achievement producing the world's first colliding accelerated beams of asymmetric nuclei) at full beam energies of 100 GeV per nucleon, with final typical peak and average luminosities (collision rate) reaching 130% and 150% of the d on Au program goals, respectively. This third period of operation (Run 3) supported a very successful experimental research program with several papers already being submitted for publication.
- *RHIC provides polarized protons from two colliding beams:* After the d-Au running, the RHIC was commissioned (involving a very complex sequence of adjustments) to deliver polarized proton beams for the second part of the Run 3 research program in FY 2003. RHIC successfully accelerated polarized protons in the two RHIC rings with about 37% polarization at beam energies of 100 GeV,

representing a 25% improvement over the polarization value attained in the previous year. Both the STAR and PHENIX collaborations expect to collect sufficient data for a first publication on gluon polarization inside the proton.

- *Spin Rotators at RHIC become operational:* A system of complex magnets, called “Helical Spin Rotators” (also referred to as “Siberian Snakes”) were successfully deployed at RHIC in FY 2003 that allow the direction of the polarization of the circulating protons to be rotated from being perpendicular to its direction of motion (transverse polarization) to point along its path of motion (longitudinal polarization). This “tour de force” of magnetic engineering allows RHIC to deliver highly versatile beams of polarized protons with which scientists can probe the spin structure of the nucleon.
- *RHIC detector enhancements remain on cost and schedule:* In FY 2003, the Electromagnetic Calorimeter (EMCAL) of STAR was completed on schedule and within its estimated cost.

The Heavy Ion Nuclear Physics subprogram also provides general purpose equipment (GPE), general plant project (GPP), and other funding as part of Nuclear Physics' stewardship responsibilities for this laboratory. These funds are for general purpose equipment, minor new capital construction, alterations and additions, improvements to land, buildings, and utility systems, and other normal operations that are needed for effective laboratory operations.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Research	**30,227**	**34,941**	**33,632**
▪ **University Research**	**12,173**	**12,325**	**12,848**

Support is provided for the research of about 135 scientists and 85 graduate students at 26 universities in 18 states. Support for university research is increased by ~4% ($523,000) compared with FY 2004.

- 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 core manpower for the operation of the RHIC detectors, data analysis and publication of results.
- Researchers using primarily the NSF supported National Superconducting Cyclotron Laboratory at Michigan State University, at the DOE supported Texas A&M University, and at foreign facilities in France and Italy, investigate nuclear reactions at intermediate energies, with the aim of studying the fragmentation of nuclei and the flow of nuclear matter in violent collisions.
- 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.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **National Laboratory Research**	**18,054**	**18,374**	**16,826**

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 of expected experimental behavior for a proposed relativistic heavy-ion program at the Large Hadron Collider at CERN that will begin data taking in 2008.

• **BNL RHIC Research**	**8,506**	**7,991**	**6,496**

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 2005 funding for capital equipment decreases by $1,760,000, with the completion of the STAR Electromagnetic Calorimeter Enhancement MIE project, while support for manpower increases by ~4.5% ($265,000). The initial survey work with gold ions at the full energy will be substantially complete by FY 2004 and measurements of the yields of rarer signals, such as the expected J/ψ suppression due to its breakup by the quark-gluon plasma, will dominate the experimental program. By the end of FY 2004, the initial RHIC detector enhancement projects will be completed and ready for investigations of the "rarer" signals during the next experimental running period at RHIC. 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, based on Multi-gap Resistive Plate Chamber (MRPC) technology developed at CERN for the ALICE experiment, 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 d-Au run.
- ► The PHENIX spectrometer-matched micro vertex detector, based on barrels and disks of silicon strip and pixel technologies, will provide D- and B-meson reconstruction capability to directly probe the production of charm and bottom quark production at RHIC.

• **Other National Laboratory Research**	**9,548**	**10,383**	**10,330**

Researchers at LANL, LBNL, LLNL, and ORNL provide leadership in the commissioning of the PHENIX muon arms and the STAR electromagnetic calorimeter, as well as playing leadership roles in the research utilizing these detectors. At LBNL, a large scale computational system, PDSF (Parallel Distributed Systems Facility), 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.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

Compared to FY 2004 there is a decrease in capital equipment funding of $844,000 to $275,000. Support for research manpower increases by ~8.5% ($791,000) to correct for erosion in effort in recent years, needed with the increase in utilization of RHIC.

	FY 2003	FY 2004	FY 2005
▪ **Other Research**..	**0**	**4,242**	**3,958**

In FY 2003 $3,285,000 was transferred to the SBIR program. This section includes $3,879,000 for SBIR in FY 2004 and $3,958,000 for SBIR in FY 2005.

	FY 2003	FY 2004	FY 2005
Operations	**129,384**	**131,875**	**139,968**
▪ **RHIC Operations**..	**118,849**	**120,047**	**129,201**

The Relativistic Heavy Ion Collider (RHIC) is a unique world-class scientific research facility that achieved first collisions in 2000. Its colliding beams of relativistic heavy ions allow scientists an unprecedented opportunity to explore and understand the nature of hot, dense matter and to recreate conditions under which nuclear matter dissolves into its primeval form – the quark-gluon plasma. The first two initial survey runs (Run 1 in 2000 and Run 2 in 2001-2002) have already produced 42 refereed journal papers, creating an enormous interest in the scientific community. Run 3 in FY 2003 marked another milestone of technical accomplishment with the realization of the world's first relativistic collisions of 100 GeV per nucleon deuterons (d) and gold nuclei (Au) in the intersection regions of the two RHIC rings. Analysis of the d-Au research program is well underway providing exciting new insights into understanding the properties of exotic nuclear matter. During the later part of Run 3, RHIC successfully operated with 100 GeV polarized protons and successfully demonstrated the functionality of the Spin Rotator Helical Magnet system which manipulates the spin direction of the circulating protons. Initial measurements for the RHIC spin-physics research program 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 critical 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 in 2008.

	FY 2003	FY 2004	FY 2005
• **RHIC Accelerator Operations**	**88,400**	**89,685**	**96,824**

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 2005 funding will support 3,840 hours of operations, a 16% increase in hours from FY 2004, and 85% utilization of the collider. This funding also supports $1,000,000 for R&D activities towards increasing luminosity of the collider. Capital equipment is maintained at $1,200,000 compared to FY 2004 and accelerator improvement (AIP) funding is increased by $200,000 to $3,100,000. These funds allow needed improvements to be made and allow the replacement of legacy systems such as the AGS main magnet power supply, in order to sustain reliability, increase efficiency and maintain safety of RHIC operations, as well as to provide funds for the design efforts for the Electron Beam Ion Source (EBIS) that will provide a more efficient ion source than the present Tandem Van de Graaff.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

RHIC Operations

	(hours of operation with beam)		
	FY 2003	FY 2004	FY 2005
RHIC	3,440	3,300	3,840

- **RHIC Experimental Support** **30,449** **30,362** **32,377**

  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) reached their initial planned potential by FY 2003. 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. In FY 2005, funding for capital equipment is increased by $350,000 to $4,525,000 compared with FY 2004, to provide increased support for upgrades to the RHIC computing facility and minor upgrades to the four detectors.

- **Other Operations** **10,535** **11,828** **10,767**

As steward for Brookhaven National Laboratory (BNL), the Nuclear Physics program provides general plant project (GPP), general purpose equipment (GPE) and other funding for minor new construction, other capital alterations and additions, and for buildings and utility system, for needed laboratory equipment and other expenses. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and for meeting its requirement for safe and reliable facilities operation. In FY 2005 funding for GPP is increased by ~3.5% ($213,000) to $6,357,000 and GPE is increased by $26,000 to $4,410,000, relative to FY 2004. Funding of other operations decreases by $1,300,000 to $0.

	FY 2003	FY 2004	FY 2005
Total, Heavy Ion Nuclear Physics	**159,611**	**166,816**	**173,600**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)

Research

- **University Research**
  - FY 2005 funding for grants for University Research increases by ~4%, providing increased travel funds needed for the increased running of the research program at RHIC. .... +523

	FY 2005 vs. FY 2004 ($000)
▪ **National Laboratory Research**	
• BNL RHIC Research: Research support for manpower is increased by ~4.5% ($265,000) from FY 2004. Funding for capital equipment is decreased by $1,760,000, because of the completion of the STAR Electromagnetic Calorimeter Enhancement project.	- 1,495
• Other National Laboratory Research: Support for research operations is increased by ~8.5% ($791,000) compared to FY 2004, to correct for erosion in effort in recent years. Funding for capital equipment decreases by $844,000 to $275,000, compared to FY 2004.	-53
Total, National Laboratory Research	-1,548
▪ **Other Research**	
• Estimated SBIR and other obligations decrease.	-284
Total, Research	-1,309
Operations	
▪ **RHIC Operations**	
• Collider Complex Operations: A ~8% increase in operating funds compared with FY 2004 brings operations to 85% utilization. This includes a $200,000 increase in accelerator improvement project (AIP) funds to $3,100,000 and $1,000,000 is provided for R&D activities towards increased luminosity of the collider.	+7,139
• Experimental Support: A ~6.5% increase in funding for experimental manpower and materials support compared with FY 2004 provides for running at 85% utilization. An increase of $350,000 in capital equipment funds provides for support of the RHIC Computing Facility and the detectors.	+2,015
Total, RHIC Operations	+9,154
▪ **Other Operations**	
• FY 2005 funding for general plant projects at Brookhaven National Laboratory is increased by ~3.5% ($213,000) to $6,357,000, compared with FY 2004, to address the backlog of needed infrastructure improvements. Funding for general purpose equipment at Brookhaven National Laboratory is increased by $26,000 compared with FY 2004. Other operations decrease by $1,300,000.	-1,061
Total, Operations	+8,093
Total Funding Change, Heavy Ion Nuclear Physics	+6,784

Low Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Low Energy Nuclear Physics					
Research					
University Research	17,070	18,212	18,642	+430	+2.4%
National Laboratory Research	20,297	22,172	24,775	+2,603	+11.7%
Other Research	3,910	7,963	5,738	-2,225	-27.9%
Subtotal Research	41,277	48,347	49,155	+808	+1.7%
Operations	26,310	23,018	23,650	+632	+2.7%
Total, Low Energy Nuclear Physics	67,587	71,365	72,805	+1,440	+2.0%

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 the nuclear astrophysics processes responsible for the production of the chemical elements in the universe, and the explosive dynamics of supernovae.

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

Benefits

The Low Energy subprogram supports the mission of the Nuclear Physics program by fostering fundamental research for the purpose of obtaining 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, 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 the proposed new Rare Isotope Accelerator (RIA) facility which would allow scientists to expand their knowledge of the origin of the elements. The Low Energy subprogram is an important source of trained manpower 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 these pre-conceptual design and R&D activities is provided in FY 2005.

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 2005 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. The 88-Inch Cyclotron (LBNL) transitions in FY 2004 from a user facility to a facility for tests of electronic circuit components for radiation "hardness" to cosmic rays and a small in-house research program. These facilities are utilized by DOE-, NSF-, and foreign-supported researchers. The allocation of beamtime is made with the guidance of Program Advisory Committees, consisting of distinguished scientists, who review and evaluate proposed experiments regarding their merit and scientific priority. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems, and for accelerator instrumentation for effective utilization of all the national accelerator facilities operated by this subprogram. Accelerator improvement project (AIP) funds are provided for additions, modifications, and improvements to the research accelerators and ancillary equipment facilities to maintain and improve the reliability and efficiency of operations, and to provide new accelerator capabilities. University-based research is an important feature of the Low Energy subprogram. Accelerator operations are supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL), University of Washington, and Yale University. Each of these university centers of excellence has a critical mass of nuclear physics faculty involved in research that is conducted both on and off campus 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 exquisite measurements to test the present understanding of the Standard Model. Some experiments use accelerators in conjunction with special apparatus to study fundamental nuclear and nucleon properties, for example the ultra-cold neutron trap at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory. Other experiments in Low Energy nuclear physics do not require the use of accelerators: the Sudbury Neutrino Observatory (SNO) detector is studying the production rate and properties of solar neutrinos, while the Kamioka Large Anti-Neutrino Detector (KamLAND) is studying the properties of anti-neutrinos produced by nuclear power reactors.

Research in the Low Energy subprogram continues to evolve to address forefront scientific questions. The 1990's began with research efforts at the 88-Inch Cyclotron, ATLAS, and other facilities to identify and characterize rapidly rotating superdeformed nuclei that have elongated football shapes. These spectroscopic studies have led to a deeper understanding of nuclear structure at high spin and large deformation. In 1997, the HRIBF facility became operational and is now producing over 100 proton-rich and neutron-rich radioactive beams. Research at these three facilities has explored nuclei at the extremes of nuclear spin, deformation, stability, and excitation energy. Stable beams and the first radioactive beams in the mid-1990's enabled nuclear structure and cross-section experiments to determine the nuclear reaction paths and some rates for the breakout from the stellar carbon-nitrogen-oxygen (CNO) cycle that leads to production of heavier elements. In neutrino physics, following the pioneering work 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 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. Both SNO and KamLAND continue to operate to extend and refine measurements of neutrino oscillation parameters.

Accomplishments

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

- Studies of nuclei at extreme conditions are pointing to alterations of the nuclear shell structure, the ability of heavy nuclei to sustain rapid rotation demonstrating unexpected stability, and evidence for phase transitional behavior between spherical and deformed nuclei.
- Nuclear measurements of very neutron-rich, unstable nuclei, combined with new computational techniques, are leading to a better identification of the r-process site or sites for nucleosynthesis in stars and to quantitative models for the production of heavy elements.
- Measurements of solar neutrinos have indicated that neutrinos change their identity on the way to earth, implying that they have mass, and providing a key to the fundamental structure of the forces of nature.

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

- *Kamioka Large Anti-Neutrino Detector (KamLAND) first results:* This joint Japanese/U.S. detector project, which utilizes neutrinos from distant reactors, was completed in FY 2002. The collaboration reported the first physics result in December 2002 on neutrino oscillations, the ability of neutrinos of one type to change to another type. This first result favors the so-called Large Mixing Angle solution, one of the solutions found possible by solar neutrino experiments. KamLAND will operate for additional years to reduce the measurement uncertainty and extend the result. U.S. participation in KamLAND is supported jointly with the High Energy Physics program.
- *Measurement of masses important in nuclear astrophysics processes:* The Canadian Penning Trap (CPT) located at the ATLAS facility at ANL has been used for accurate measurement of the masses of ^{64}Ge and ^{68}Se, two important nuclei on the rp-process pathway to production of heavy proton-rich nuclei in stars. The CPT has also been utilized to measure the masses of twenty neutron-rich nuclei

in the A = 140 region extending toward the region where the r-process occurs in stellar explosions. The masses of many of these nuclei are found to deviate from those calculated using common nuclear models.

- *Measurement of the E2 transition rate for ^{132}Sn*: Researchers at ORNL have utilized intense, pure beams of ^{132}Sn to perform Coulomb excitation experiments to study the electric quadrupole (E2) transition rate in that nucleus, which has closed shells of both protons and neutrons, and thus has extra binding and is more stable against excitation. Normally, the E2 transition rate in such nuclei is lower than that of neighboring nuclei; unexpectedly, the E2 transition rate for ^{132}Sn is higher than that of its close neighbors. Current nuclear structure models may have to be extended to accommodate this result.

Facility and Technical Accomplishments:

- *On the possibility of stimulated emission from the ^{178}Hf Isomer:* Quantities of long-lived nuclear isomers such as $^{178}Hf^{m}$ could serve as energy storage media. Researchers at ANL and LLNL have investigated the claim that low energy X-rays can stimulate emission from the ^{178}Hf isomer, releasing the energy on demand. The ANL/LLNL results do not support that claim, and the upper limit the team establishes for any release is compatible with known nuclear processes.
- *The Gammasphere spectrometer moved to ATLAS for a second science campaign there:* Gammasphere, the premier gamma-ray spectrometer in the world, has completed its most recent science campaign at LBNL, and has been moved to ANL to begin its second research campaign at ANL. Gammasphere has moved approximately every two years to address compelling research opportunities. The Gammasphere research program at ATLAS will include forefront topics in nuclear structure, nuclear astrophysics, and fundamental interactions.
- *Elementally pure neutron rich beams at the HRIBF:* At the Holifield Radioactive Ion Beam Facility at ORNL, an important parameter is isotopic purity of rare beams for research. Rare isotope beams usually contain mixtures of several isotopes, but a new technique of adding sulfur to the production target utilizes in-target chemistry to produce pure tin (Sn) and germanium (Ge) beams. These pure beams are being used to expand nuclear structure and astrophysics studies to new neutron rich species.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Research	**41,277**	**48,347**	**49,155**
▪ **University Research**	**17,070**	**18,212**	**18,642**

Support is provided for the research of about 120 scientists and 90 graduate students at 29 universities in 21 states. Nuclear Physics university scientists perform research as users at National Laboratory facilities, at on-site facilities and at other specifically fabricated experiments. These activities address a broad range of fundamental issues as diverse as the properties of nuclei, the nature of the weak interaction, the production mechanisms of the chemical elements in stars and supernovae, and the properties of neutrinos. FY 2005 funding for operation of university accelerator facilities, for equipment and for researchers and students is increased ~2.5% compared to FY 2004, maintaining approximately constant effort. Research activities include:

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

- Research programs conducted using the low energy heavy-ion beams and specialized instrumentation at the national laboratory user facilities supported by this subprogram (the ANL-ATLAS and ORNL-HRIBF facilities). The effort at the user facilities involves about two-thirds of the university scientists supported by this subprogram.
- Accelerator operations at four universities: the University of Washington, the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University, Texas A&M University (TAMU) and at Yale University. Each of these small university facilities has a well-defined and unique physics program, providing light and heavy ion beams, specialized instrumentation and opportunities for long-term measurements that complement the capabilities of the National Laboratory user facilities. Equipment funds are provided for new instruments and capabilities, including an energy and intensity upgrade to the High Intensity Gamma-ray Source (HIγS) facility at TUNL.
- Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements, such as measurements of solar neutrino rates and the neutrino mass at the Sudbury Neutrino Observatory (SNO) in Canada. The U.S. effort with the Kamioka Large Anti-Neutrino Detector (KamLAND) in Japan is being supported jointly with the High Energy Physics program.

▪ **National Laboratory Research**	**20,297**	**22,172**	**24,775**

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**...	**14,352**	**13,447**	**14,351**

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 2005 funding is increased by ~6% for manpower compared with FY 2004, to correct for erosion in manpower in recent years. 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 has been built, and is being utilized in an experimental program in nuclear astrophysics.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

- 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 the completion of data analysis from the research program at the 88-Inch Cyclotron and the use of this DOE user facility to study nuclei at high angular momentum and deformation. Development of test modules, electronics, and data analysis algorithms of a high-sensitivity gamma-ray tracking detector, GRETINA, is continuing.

	FY 2003	FY 2004	FY 2005
• **Other National Laboratory Research**	**5,945**	**8,725**	**10,424**

Scientists at BNL, LBNL, LLNL, LANL and ORNL play important roles in a number of high-priority accelerator- and non-accelerator-based experiments directed towards fundamental questions. FY 2005 funding for manpower increases from FY 2004 for low energy accelerator R&D activities and retaining critical manpower at LBNL. Capital equipment investments increase from FY 2004 by $1,819,000 to $5,106,000. These activities include:

- The Sudbury Neutrino Observatory (SNO) experiment in Canada. The SNO detector, jointly built by Canada, England and the U.S., addresses the question of whether the observed reduced rate of solar neutrinos reaching the earth results from unexpected properties of the sun, or whether it results from a fundamental property of neutrinos–namely that neutrinos produced in the sun change their nature (that is, oscillate to a new neutrino type) during the time it takes them to reach the earth. This latter explanation would imply that the neutrinos have mass. In FY 2001 and 2002, the first results from SNO with the heavy water detector were reported, indicating strong evidence for neutrino oscillations. Results from the second phase measurements of neutrino types to which the solar neutrinos have been transformed were reported in FY 2003. In FY 2003, the third phase of SNO began; it will provide additional detail and confirmatory information on neutrino oscillations. Results from this phase are expected to be reported in FY 2005-2006.
- 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. The U.S. participation in KamLAND is supported jointly with the High Energy Physics program.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

- 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 begins in FY 2004. Funds ($1,200,000) are provided in FY 2005 to continue development of a beamline for neutron studies at the Spallation Neutron Source (SNS) (a Major Item of Equipment). Also, development and design of an experiment to search with high precision for the electric dipole moment of the neutron is supported.
- 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, and a smaller version of the proposed GRETA detector for the Rare Isotope Accelerator. The improved position resolution and higher efficiency for high-energy gamma rays compared with presently available gamma-ray detector arrays will allow this new detector system to utilize fragmented nuclear beams to open up a new frontier for understanding exotic nuclei that may exist in stars and supernovae, but live only briefly (fractions of a second). In FY 2005 funding of $2,500,000 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 2005 with funding of $1,200,000.

▪ **Other Research**..	**3,910**	**7,963**	**5,738**
• **RIA R&D Activities**.....................................	**3,910**	**5,965**	**4,000**

Funds are provided for R&D and pre-conceptual design activities directed at the development of an advanced proposed Rare Isotope Accelerator (RIA) facility. A next-generation facility for beams of short-lived, radioactive nuclei for nuclear structure, reaction and astrophysics studies is identified in the NSAC 2002 Long Range Plan as a compelling scientific opportunity and as the highest priority for new construction. The RIA concept emerged from the 1999 NSAC Taskforce study involving international experts as a new paradigm for producing intense beams of very short-lived nuclei. This facility would position the U.S. to play a leadership role in an area of study with the potential for new discoveries about basic properties of nuclei and to significantly advance our understanding of astrophysical phenomena. Funding for FY 2005 is increased by $500,000 compared to the FY 2004 Presidential Request, supporting some needed R&D activities in critical accelerator components and possibly Conceptual Design Report (CDR) activities.

• **SBIR and Other**...	**0**	**1,998**	**1,738**

In FY 2003 $871,000 was transferred to the SBIR program. This section includes $1,092,000 for SBIR in FY 2004 and $1,363,000 for SBIR in FY 2005 and other established obligations. The Lawrence and Fermi Awards, funded under this line, provide annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to science.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Operations	**26,310**	**23,018**	**23,650**
▪ **User Facility Operations**	**26,010**	**22,868**	**23,500**

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 86% of full utilization.

HRIBF has coupled the existing cyclotron and tandem accelerator to develop a focused radioactive-ion beam program. Both proton-rich and neutron-rich beams are provided to spectrometer systems such as CHARMS, designed for nuclear structure studies, and the Daresbury Recoil Separator and the Silicon Detector Array for nuclear astrophysics studies. In FY 2005 accelerator improvement project funding is provided ($1,400,000) to continue fabrication of a platform for development and testing targets and ion sources.

ATLAS provides stable heavy-ion beams and selected radioactive-ion beams for research. Experiments utilize ion traps, the Fragment Mass Analyzer, and advanced detectors to study the structure of nuclei at the limits of stability, and fundamental and decay properties of nuclei. In FY 2005 accelerator improvement project funding is directed towards upgrading the accelerator to increase the radioactive beam capabilities of ATLAS

Operations at the 88-Inch Cyclotron are transitioning in FY 2004 to provide resources to optimize the utilization and science productivity of the remaining user facilities and to be consistent with the recommendations of the NSAC Low Energy Program Review in 2001. In late FY 2003 the National Reconnaissance Office and the Air Force 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. A Memorandum of Understanding has been developed in which these offices will 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. They will decide in late FY 2004 if they wish to continue this arrangement beyond FY 2005. If this funding is not continued, the operations will terminate. Funding of $3,000,000 is provided in FY 2005 for a small in-house program of testing of ion sources for RIA R&D and for a limited scientific program in nuclear science studies using local LBNL and University of California (Berkeley) researchers and the unique capabilities of the LBNL complex.

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 2005 these low energy facilities will carry out about 95 experiments involving over 360 U.S. and foreign researchers. Planned hours of operation with beam are indicated below:

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

	(hours of operation with beam)		
	FY 2003	FY 2004	FY 2005
ATLAS	6,220	6,350	6,650
HRIBF	4,725	3,780	4,350
88-Inch Cyclotron*	4,445	0	0
Total Beam Hours for Low Energy Facilities	15,390	10,130	11,000

* Operations as a user facility is terminated in FY 2004 as the facility transitions to a dedicated facility for the testing of electronic circuit components for use in space (using funding from other agencies) and a small in-house nuclear physics research program.

	FY 2003	FY 2004	FY 2005
▪ **Other Operations**	**300**	**150**	**150**

Funding is provided for maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA.

	FY 2003	FY 2004	FY 2005
Total, Low Energy Nuclear Physics	**67,587**	**71,365**	**72,805**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Research	
▪ **University Research**	
• FY 2005 funding for researchers and students and capital equipment is increased ~2.5% compared to FY 2004	+430
▪ **National Laboratory Research**	
• National User Facilities Research: FY 2005 funding provides an increase of +6.5% for research efforts and activities at the user facilities. This increase will help correct erosion of manpower in recent years.	+904
• Other National Laboratory Research: Research funding decreases by $120,000 in FY 2005 compared with FY 2004. Equipment funds are increased by $1,819,000 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	+1,699
Total, National Laboratory Research	+2,603

	FY 2005 vs. FY 2004 ($000)
▪ **Other Research**	
• RIA R&D funding is decreased from $5,965,000 to $4,000,000.	-1,965
• Estimated SBIR and other obligations decrease	-260
Total, Other Research	-2,225
Total Research	+808
Operations	
▪ In FY 2005 operating funds are increased by ~5% ($832,000) compared to FY 2004 for ATLAS and HRIBF operations to provide an estimated 11,000 hours of beam time. Funding for capital equipment and accelerator improvement projects decreases by $200,000 compared to FY 2004.	+632
Total Funding Change, Low Energy Nuclear Physics	+1,440

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Nuclear Theory					
Theory Research					
University Research	11,644	11,888	12,204	+316	+2.7%
National Laboratory Research	8,516	8,962	9,192	+230	+2.6%
Scientific Computing (SciDAC)[a]	1,980	1,988	2,000	+12	+0.6%
Subtotal Theory Research	22,140	22,838	23,396	+558	+2.4%
Nuclear Data Activities	5,153	5,137	5,464	+327	+6.4%
Total, Nuclear Theory	27,293	27,975	28,860	+885	+3.2%

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-

[a] In FY 2003 funding for the NP portion of the SciDAC program was distributed between University ($1,026,843) and National Laboratory Research ($953,157).

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 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 manpower 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 Department of Energy's missions for nuclear-related national security, energy, and environmental quality.

Supporting Information

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

The program is 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.

Accomplishments

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

- *Studies of hadronic structure on the lattice:* Recent lattice calculations, which solve the equations of Quantum Chromodynamics (QCD) numerically on a granular space-time "lattice", appear to give clear answers to some very old questions about the hadron structure studied experimentally at TJNAF and other laboratories. Researchers report this year the first observation of the Roper resonance on the lattice and conclude that the Roper is a radially excited nucleon with 3 valence quarks and not a Λ-K bound state, thus settling (if confirmed) a thirty year controversy in the literature. They also have found the Λ(1405) has a quark structure and is not therefore a hadron bound state. They confirm on the lattice the experimental pattern of positive and negative parity excited states in N, Δ, and Λ, a result which has profound implications for the interpretation of the quark-quark hyperfine interaction.
- *Ab initio calculations of light nuclei:* Green's Function Monte Carlo (GFMC) methods allow one to reliably calculate the properties of light nuclei (up to ten nucleons) with nucleon-nucleon (NN) interactions which describe NN data very precisely and include three-nucleon (NNN) interactions needed to describe three-body nuclei correctly. With this tool, researchers have attacked a basic question that involves an entire nucleus: Why are there no stable 5- or 8-body nuclei? Lacking these nuclei, the "Big Bang" created nothing heavier than lithium, and therefore the Sun has shone long enough for humans to evolve. The answer is the presence of the tensor force, which is similar to the force felt by two magnets side by side, in the NN interaction. Remove this force and these nuclei become stable in the calculations. Another program of ab initio calculations, under the label of No-Core Shell Model, has calculated properties of nuclei with up to twelve bodies. It does not have quite the accuracy of GFMC, but treats a greater variety of NN and NNN interactions such as those emerging effective field theory interactions closely related to QCD. The applications of these calculations, so far, have been aimed at Standard Model tests. These calculations include neutrino-nucleus scattering needed for experimental studies of neutrino oscillations and superallowed beta decay of light nuclei which provide an excellent laboratory for precise tests of the properties of the electroweak interaction.
- *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 recently 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. This observation can be quantitatively described by a quantum chromodynamic (QCD) calculation. Together this confrontation of theory and experiment can provide key information on the properties of dense matter produced 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. Neutrino transport is now being utilized in one-dimensional (spherical) models of stars. Recent progress has also been made in calculating electron-capture rates crucial to the understanding of stellar collapse. Multi-dimensional stellar models are now able to explore effects such as convection induced by neutrino heating. These new computational tools could also be applied to other fields of research.

In the past five years, the availability of enormous computing power has allowed theorists to make spectacular progress on problems that were previously thought intractable. It is now possible to simulate complex nuclear physics processes at extreme length scales ranging from astrophysical objects, to nuclei, to the quark structure of matter. The development of the Green's Function Monte Carlo Technique 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 2003	FY 2004	FY 2005
Theory Research	**22,140**	**22,838**	**23,396**
▪ **University Research**	**11,644**	**11,888**	**12,204**

The research of about 170 university scientists and 95 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 increased by ~2.5% ($316,000) compared with FY 2004, providing almost constant effort.*

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.

	FY 2003	FY 2004	FY 2005
▪ **National Laboratory Research**	**8,516**	**8,962**	**9,192**

Research programs are supported at six National Laboratories (ANL, BNL, LANL, LBNL, ORNL and TJNAF). Funding is increased by ~2.5% ($230,000) compared with FY 2004 to maintain national laboratory theoretical efforts at the FY 2004 level.

- 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.

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

- The larger size and diversity of the National Laboratory groups make them particularly good sites for the training of nuclear theory postdocs.

	FY 2003	FY 2004	FY 2005
▪ **Scientific Computing**	**1,980**	**1,988**	**2,000**

Scientific Discovery through Advanced Computing (SciDAC) is an Office of Science program to address major scientific challenges that require advances in scientific computing using terascale resources. A SciDAC planning effort managed by the High Energy and Nuclear Physics (HENP) programs identified the most compelling opportunities for advancements and for coordinated efforts in these two scientific fields by the application of terascale computing resources. This effort resulted in the identification of two such challenge areas within the domain of theoretical nuclear physics, and in FY 2001 several major multi-institutional grants in high-priority topical areas were awarded through this program for the first time. One topical area is Lattice QCD. The scientific goal is to solve Quantum Chromodynamics (QCD), the fundamental theory of the strong interaction, on a 'lattice' of space-time points using advanced numerical methods. This is an extremely active area of inquiry world-wide, with major ongoing efforts in Europe and Japan. Of particular relevance to nuclear physics are the activities focused on solving QCD in two domains: the structure of the proton and neutron and their excited states at TJNAF and elsewhere, and the quark-gluon plasma that is anticipated to be produced at RHIC. A second topical area is Theoretical Nuclear Astrophysics, particularly focusing on supernova phenomena. Two types of supernova explosions are being modeled: Type Ia explodes because of nuclear reaction processes; types II, Ib, and Ic, are thought to explode through core collapse, fueled by neutrino energy transport. These problems are intrinsically multidisciplinary, involving nuclear physics, general relativity, neutrino science, hydrodynamics and transport theory, and advanced computing techniques. This is an ideal challenge to push the frontiers of advanced computing.

	FY 2003	FY 2004	FY 2005
Nuclear Data	**5,153**	**5,137**	**5,464**

The Nuclear Data program collects, evaluates, archives, and disseminates information on nuclear properties and reaction processes for the physics community and the nation. The focal point for its national and international activities is the DOE-managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. Funding is increased by ~6.5% ($327,000) to enhance efforts in this critical activity, helping to correct some of the erosion in effort in recent years. New scientists need to take on compilation and evaluation roles in the U.S. Nuclear Data program. 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).

	FY 2003	FY 2004	FY 2005
Total, Nuclear Theory	**27,293**	**27,975**	**28,860**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
University Research	
▪ FY 2005 funding is increased ~2.5% compared to FY 2004 and will be focused on priority research that was identified in the 2002 NSAC Long Range Plan for Nuclear Science and to implement recommendations from the recent NSAC Subcommittee on Nuclear Theory.	+316
National Laboratory Research	
▪ FY 2005 funding is increased ~2.5% compared to FY 2004, with efforts directed toward higher priority research as identified in the 2002 NSAC Long Range Plan and to implement recommendations from the recent NSAC Subcommittee on Nuclear Theory	+230
Scientific Computing	
▪ FY 2005 funding is increased by ~0.5% compared to FY 2004	+12
Nuclear Data	
▪ FY 2005 funding is increased ~6.5% compared to FY 2004 to enhance efforts to effectively disseminate nuclear data needed for basic and applied research	+327
Total Funding Change, Nuclear Theory	+885

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Plant Projects	6,876	6,604	7,157	+553	+8.4%
Accelerator Improvement Projects	6,745	6,400	6,100	-300	-4.7%
Capital Equipment	27,718	27,046	26,492	-554	-2.0%
Total, Capital Operating Expenses	41,339	40,050	39,749	-301	-0.8%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2003	FY 2004	FY 2005 Request	Accept-ance Date
STAR EM Calorimeter	8,600	8,297	303	0	0	FY 2003
STAR EM Calorimeter Enhancement[a]	4,830	0	2,750	2,080	0	FY 2005
GRETINA gamma-ray detector	15,000	0	0	1,000	2,500	FY 2010
Fundamental Neutron Physics Beamline at Spallation Neutron Source[b]	9,200	0	0	1,000	1,200	FY 2010
Total, Major Items of Equipment		8,297	3,053	4,080	3,700	

[a] The TEC has increased by $130,000 and the completion date has slipped by one quarter due to impact from a late start as a result of the FY 2003 continuing resolution.

[b] The TEC and funding profile were refined in the conceptual design effort. Increased funding from $500,000 to $1,000,000 in FY 2004 will reduce schedule and cost risk. The TEC has decreased by $600,000 to $9,200,000.

Biological and Environmental Research

Funding Profile by Subprogram

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Biological and Environmental Research					
Life Sciences	181,803	205,913	-1,222[a]	204,691	204,011
Climate Change Research	122,182	142,959	-845[a]	142,114	142,959
Environmental Remediation	101,375	108,930	-622[a]	108,308	105,522
Medical Applications and Measurement Science	89,000	134,198	+52,143[ab]	186,341	44,098
Subtotal, Biological and Environmental Research	494,360	592,000	+49,454[ab]	641,454	496,590
Construction	0	0	0	0	5,000
Subtotal, Biological and Environmental Research	494,360	592,000	+49,454[ab]	641,454	501,590
Use of Prior Year Balances	0	-1,930	0	-1,930	0
Total, Biological and Environmental Research	494,360[cdef]	590,070	+49,454[ab]	639,524	501,590

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

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[a] Excludes $3,795,588 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H. Rpt. 108-401, dated November 25, 2003, as follows: Life Sciences $-1,221,588; Climate Change Research $-845,000; Environmental Remediation $-622,000; and Medical Applications and Measurement Science $-1,107,000.

[b] Includes $53,250,000 provided by the Consolidated Appropriations Act, 2004.

[c] Excludes $12,139,000 which was transferred to the SBIR program and $728,000 which was transferred to the STTR program.

[d] Excludes $3,424,284 for a rescission in accordance with the Consolidated Appropriation Resolution, FY 2003.

[e] Includes $3,585,770 for the Emergency Wartime Supplemental Appropriations for FY 2003.

[f] Excludes $19,748,000 transferred for Department of Homeland Security activities in FY 2003.

Mission

For over 50 years the Biological and Environmental Research (BER) program has been advancing environmental and biomedical knowledge that promotes national security through improved energy production, development, and use; international scientific leadership that underpins our Nation's technological advances; and research that improves the quality of life for all Americans. BER supports these vital national missions through competitive and peer-reviewed research at national laboratories, universities, and private institutions. In addition, BER develops and delivers the knowledge needed to support the President's National Energy Plan.

Benefits

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

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, to advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences, and to 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 fundamentally alter the future of medical care and human health.

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

Within the Biological and Environmental Research (BER) program, the Life Sciences, Climate Change Research, Environmental Remediation, and Medical Applications and Measurement Science subprograms contribute 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, peer-reviewed research results. Discoveries at these frontiers in science 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 reduce and 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. BER will lead the way in discovering innovative approaches along unconventional paths to energy independence and environmental cleanup.

Building on this work, BER develops novel radiopharmaceuticals to image defective genes that cause disease. In addition, research 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 read large print and devices that restore neurosensory and motor function to the paralyzed (spinal cord recovery, hearing, bladder control, etc.). This effort builds on leading research programs that provide world-class, peer-reviewed research results. The research capitalizes on the National Laboratories' unique resources and expertise in biological, chemical, physical, and computational sciences for technological advances related to human health. The National Laboratories have highly sophisticated instrumentation (neutron and light sources, mass spectroscopy, and high field magnets), lasers and supercomputers that directly impact research on human health. This research is highly complementary to and coordinated with clinical research at the National Institutes of Health (NIH) and to basic research in the NIH intramural and extramural programs.

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 and 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 & models for policy makers to determine safe levels of greenhouse gases for the Earth 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 cleanup 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 and new radiopharmaceuticals for disease diagnosis.
- **Facilities:** Manage facilities operations to the highest standards of overall performance using merit evaluation with independent peer review.

Annual Performance Results and Targets

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
Program Goal 05.21.00.00 (World-Class Scientific Research Capacity)					
Life Sciences					
Increase the rate of DNA sequencing: Sequence the genome of 1microbe. [Met Goal]	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.	Increase the rate of DNA sequencing: Produce at least 20 billion base pairs of high quality DNA microbial and model organism genome sequence.
Climate Change Research					
Improve climate models: Demonstrated that a coupled climate model consisting of combined atmospheric and ocean general circulation models more accurately simulates the present climate compared to that simulated by uncoupled atmospheric general circulation models alone. [Met Goal]	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.	Improve climate models: Develop a coupled climate model with an interactive carbon cycle, a sub model of secondary sulfur aerosols, and an interactive terrestrial biosphere. This capability will enable studies of the interactions between the carbon cycle and climate and between secondary sulfur aerosols and climate. It will also provide a tool to quantify potentially important feedbacks between the climate system and the terrestrial biosphere.

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
Environmental Remediation					
Determine scalability of laboratory results in field environments: Demonstrated that common bacteria can reduce and immobilize contaminants such as uranium, technetium, and chromium in subsurface environments. [Met Goal]	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.	Determine scalability of laboratory results in field environments – Determine actual in-situ rate of metal reduction in subsurface environments and begin to develop a numerical model to describe and predict these rates.
Medical Applications and Measurement Science					
Advance blind patient sight: Developed technology for application of a novel hermetic seal to protect artificial retina device when inserted into the eye of a human patient. [Met Goal]	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.	Advance blind patient sight: Complete testing on a 60 microelectrode array artificial retina and insert prototype device into a blind patient.
All BER Facilities (Efficiency Measure)					
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 such that achieved operation time is on average greater than 90% of the total scheduled annual operation time.	Maintain and operate BER facilities such that achieved operation time is on average greater than 90% of the total scheduled annual operation time.

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 supports fundamental, innovative, peer-reviewed research to create new knowledge in areas important to the BER mission, i.e., Life Sciences, Climate Change Research, Environmental Remediation, and Medical Applications and Measurement Science. 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. A combination of novel, state-of-the-science user facilities coupled with large, well-integrated, interdisciplinary research teams will form the basis of a new approach for studying complex biological systems and for using those systems to solve 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, believed 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. BER Medical Applications and Measurement Science research capitalizes on the National Laboratories' unique resources and expertise in biological, chemical, physical, and computational sciences for technological advances related to human health. The National Laboratories have highly sophisticated instrumentation that directly impact research on human health. Research is directed to fundamental studies in biological and medical imaging (including construction of the artificial retina), biological and chemical sensors, laser medicine, and informatics.

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, which 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 BER program is closely coordinated with the activities of other federal agencies (e.g., National Institutes of Health, 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, and Department of Defense). 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.

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), and reduced environmental impacts of energy production and use.

Validation and Verification

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

Program Assessment Rating Tool (PART) Assessment

The Department implemented a tool to evaluate selected programs. PART was developed by OMB to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The Biological and Environmental Research (BER) program has incorporated feedback from OMB into the FY 2005 Budget Request and has taken, or will take, the necessary steps to continue to improve performance.

In the PART review, OMB gave the Biological and Environmental Research (BER) program 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. Although BER is establishing 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, this committee has not yet met. Once the COV issues a report, BER will develop an action plan to respond to the findings and recommendations within 30 days. The assessment found that BER has developed a limited number of adequate performance measures. However, OMB noted concerns regarding the collection and reporting of performance data. To address these concerns, BER will work with its Advisory Committee to develop research milestones for the long-term performance goals, will work to improve performance reporting by grantees and contractors, and will work with the CFO to improve BER sections of the Department's performance documents. BER's role in providing scientific research facilities is strongly supported by the Administration. Funding is provided in FY 2005 to operate the program's facilities at maximum capacity.

Funding by General and Program Goal

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Goal 5, World-Class Scientific Research Capacity					
Program Goal 05.21.00.00 Harness the Power of Our Living World					
Life Sciences	181,803	204,691	204,011	-680	-0.3%
Climate Change Research	122,182	142,114	142,959	+845	+0.6%
Environmental Remediation	101,375	108,308	105,522	-2,786	-2.6%
Medical Applications and Measurement Science	89,000	186,341	44,098	-142,243	-76.3%
Construction (PED)	0	0	5,000	+5,000	+100.0%
Total, Program Goal 05.21.00.00 Harness the Power of Our Living World	494,360	641,454	501,590	-139,864	-21.8%
Use of Prior Year Balances	0	-1,930	0	+1,930	+100.0%
Total, Biological and Environmental Research	494,360	639,524	501,590	-137,934	-21.6%

Overview

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

The Opportunity

With the 21st Century dawns what 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 climate change and our ability to predict climate over decades to centuries will enable us to develop science-based solutions to reduce and minimize the impacts of climate change and to better plan for our Nation's future energy needs. BER will lead the way in discovering innovative approaches along unconventional paths to energy independence and environmental cleanup.

The Challenges

Understanding and predicting climate – Can we understand the factors that determine Earth's climate well enough so that we can predict climate decades to centuries in the future? Advanced climate models are needed to describe and predict the roles of oceans, the atmosphere, 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 – Microbes have a remarkable capacity to thrive in almost every environment imaginable, even when heavily contaminated. Can we use nature's own solutions to clean up sites contaminated from years of weapons research? These solutions seem ever closer as we study the molecular details of nature's own cleanup strategies.

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

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

The Investment Plan

BER will continue its investments in core technologies and fundamental science needed to address these daunting challenges. We believe that the most important scientific advances in the 21st century will occur at the interfaces between scientific disciplines such as biology, physics, chemistry, engineering, and information science. 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 clean up 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 in private companies, and maintains a strong research infrastructure across the biological and environmental sciences most relevant to the BER program.

Advisory and Consultative Activities

To ensure that resources are allocated to the most scientifically relevant and promising research, BER actively seeks external input using a variety of advisory bodies. BER regularly compares its programs to the scientific priorities recommended by the BERAC and by the standing committees created by the Office of Science and Technology Policy (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, Fossil Energy, and the National Nuclear Security

Administration. BER program coordination across federal agencies also benefits from international and interagency working groups such as those of the International Human Genome Project, the U.S. Global Change Research Program (USGCRP), and the National Institutes of Health Bioengineering Consortium. Finally, BER consults regularly with groups like JASON and The Washington Advisory Group (WAG), involving physicists, mathematicians, engineers, etc., to receive feedback on BER program elements such as the Atmospheric Radiation Measurement (ARM) program, climate change prediction activities, the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), and the Human Genome program.

Facility Operations Reviews

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

Program Reviews

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

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

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

Planning and Priority Setting

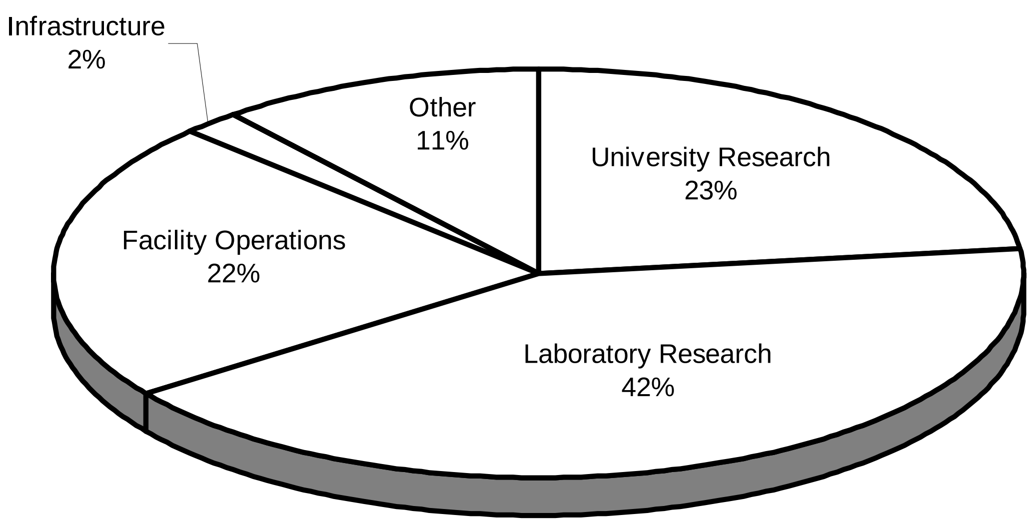
BER prides itself on supporting research and developing new research initiatives that lead the way across many fields of science and that effectively bring together many different disciplines, including biology, chemistry, engineering, computing, and the physical sciences. Peer reviews and user feedback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

BER planning and priority setting are also key BERAC activities and part of BER's interagency coordination. Individual BER program elements, e.g., human genome, low dose radiation research, Genomics: GTL, bioremediation research, and global climate change 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 (23%); basic research at national laboratories (42%); and user facility support (22%). Research at national laboratories also includes support for high throughput DNA sequencing at the Joint Genome Institute, Atmospheric Radiation Measurement Infrastructure, Free-Air CO_2 Enrichment (FACE) experimental facilities, 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 operation and equipment for the Environmental Molecular Sciences Laboratory (EMSL).

Biological and Environmental Research Budget Allocation FY 2005



Research

In FY 2005, the BER program will support fundamental research in climate change, environmental remediation, genomics, proteomics, radiation biology, and medical sciences at 220 public and private research institutions in 44 states and at 16 DOE laboratories in 10 states. This research will be conducted in over 1000 different research projects by over 2,275 researchers and students. In addition to the principal investigator for each research project funded by BER, individual projects typically have between 1 and 20 additional PhD-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.

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

  All research projects supported by the BER program undergo regular peer review and evaluation based on the procedures set down in 10 CFR Part 605 for the extramural grant program (http://www.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 and research infrastructure including the EMSL, ARM, FACE, AmeriFlux sites, Natural and Accelerated Bioremediation Research (NABIR) Field Research Center, the Joint Genome Institute (JGI), and the structural biology user facilities at the synchrotron and neutron sources.

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

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.
- Develop cutting edge technologies, facilities, and resources, including animal models, for the Human Genome Project.

- Provide world leadership in low dose radiation research.
- Provide world-class structural biology user facilities and unique computational and experimental structural biology research emphasizing protein complexes involved in recognition and repair of DNA damage and remediation of metals and radionuclides.
- Provide world leadership in ground-based measurement of clouds and atmospheric properties to resolve key uncertainties in climate change, through the 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.
- Provide world-class scientific user facilities for environmental and climate change research.
- Provide world leadership in radiopharmaceutical development for wide use in the medical and research communities.
- Maintain world leadership in instrumentation development for medical and biological imaging.
- Enable interdisciplinary teams of scientists to use the unique resources in physics, chemistry, material sciences, and biology at the National Laboratories to develop novel medical applications.
- 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

For FY 2005, BER will focus on:

- Project Engineering and Design (PED) of a Genomics: GTL facility for the Production and Characterization of Proteins and Molecular Tags. This facility will incorporate a new generation of sophisticated high-throughput technologies that are required for translating the new biology, making them widely and readily available, and using them effectively to serve the community of national laboratories, academic, and industrial researchers. Research underpinning the development and design of the technologies to be incorporated into this facility is currently being funded as part of the GTL program.
- Changing the Atmospheric Science Program from air quality research on tropospheric ozone and particulates to the direct and indirect effects of aerosols on the atmospheric radiation balance and climate. New field measurement campaigns and modeling studies of the formation, transport, and transformation of aerosols and their radiative properties will be initiated in conjunction with the ARM program. The research will focus on key uncertainties that currently limit our ability to accurately simulate and predict the direct and indirect effect of aerosols on climate.
- Integration of Environmental Remediation research from EMSP, NABIR, EMSL, and SREL to perform "comprehensive" field studies.

Genomics: GTL Research

The FY 2005 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. In FY 2005, PED for a facility for the Production and Characterization of Proteins and Molecular Tags will be initiated. This facility will be a high throughput user facility that will use highly automated processes to mass-produce and characterize proteins directly from microbial DNA sequence data and create affinity reagents or "tags" to identify, capture, and monitor the proteins from living systems.

Climate Change Science Program

In 2003, the Administration launched a new 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 (BER request for CCSP for FY 2005 is $134,169,000). 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 2005, 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) development 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 2005, 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 and 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 EMSL and the structural biology user facilities so that the achieved operation time will be greater than 90%, on average, of total scheduled annual operation.

User Statistics

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
	Achieved				Planned	
EMSL[a]						
Maximum hours	4,365	4,365	4,365	4,365	4,365	4,365
Scheduled hours	3,130	3,130	4,275	4,365	4,365	4,365
Operation Time	95%	95%	95%	95%	95%	95%
Production Genomics Facility						
Maximum hours	3,600	3,600	3,600	3,600	3,600	3,600
Scheduled hours	3,600	3,600	3,600	3,600	3,600	3,600
Operation Time	>99%	>99%	>99%	>98%	>98%	>98%
Center for Comparative Genomics ("Mouse House")						
Maximum hours	0	0	0	0	8,760	8,760
Scheduled hours	0	0	0	0	8,760	8,760
Operation Time	N/A	N/A	N/A	N/A	>99%	>99%
Atmospheric Radiation Measurement (ARM)						
Maximum hours	6,290	6,290	6,290	6,290	6,290	6,290
Scheduled hours [b]	6,290	6,290	6,290	6,290	6,290	6,290
Operation Time	>98%	>98%	>98%	>98%	>98%	>98%
Free Air Carbon Dioxide Enrichment (FACE)						
Maximum hours	15,865	15,865	15,865	15,865	15,865	15,865
Scheduled hours	15,865	15,865	15,865	15,865	15,865	15,865
Operation Time	93%	93%	94%	>94%	>95%	>95%

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

Construction and Infrastructure

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

Funding for capital equipment is decreased in FY 2005 after a one-time increase in FY 2004 for instrument modifications at EMSL. For all other BER activities the capital equipment is held approximately at the FY 2004 level.

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

[b] Allows for weather related downtime based on climatology (e.g., lightning strikes, hail, extreme winds, and cold events).

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

Workforce Development

Workforce development is an integral and essential element of the BER mission to help ensure a science-trained workforce, including researchers, engineers, science educators, and technicians. The research programs and projects at the National Laboratories, universities, and research institutes actively integrate undergraduate and graduate students and post-doctoral investigators into their work. This "hands-on" approach is essential for the development of the next generation of scientists, engineers, and science educators. Specific fellowship programs are also sponsored by BER to target emerging areas of need. Over 1,500 graduate students and post-doctoral investigators will be supported at universities and at National Laboratories in FY 2005. BER will continue its support for graduate students and post-doctoral investigators in FY 2005. The number of graduate students and post-doctoral investigators will remain approximately at the FY 2004 level.

Graduate students and postdoctoral investigators use Office of Science user facilities. For example, they use the structural biology experimental stations on the beam lines at the synchrotron light sources and the instruments at the EMSL. Using these unique research tools enables the graduate students and post-doctoral investigators to participate in and conduct leading edge research. Approximately half of all of the facility users are graduate students and post-doctoral investigators; some 600 graduate students and post-doctoral investigators will conduct their research at the EMSL in FY 2005. The graduate students and post-doctoral investigators are supported by resources from a wide variety of sponsors, including BER, other Departmental research programs, other federal agencies, and U.S. and international private institutions. Graduate students and post-doctoral investigators at the synchrotron light sources are included in the BES user facility statistics and are thus not included here.

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

University-based scientists are the principal users of BER user facilities for structural biology at the synchrotron and neutron sources. They are also users of the EMSL, and the NABIR program's Field Research Center. 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.

DOE-BER Human Capital

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
# University Grants	532	579	628	630[a]	630[a]	630[a]
Size / Duration	$302,000/yr	$287,000/yr	$309,000/yr	$300,000/yr[a]	$300,000/yr[a]	$300,000/yr[a]
	3 years	3 years	3 years	3 years	3 years	3 years
# Lab Projects.............	379	397	392	395[a]	400[a]	400[a]
# Permanent PhDs[b]	1310	1370	1427	1491[a]	1489[a]	1490[a]
# Postdocs[c]	251	274	357	373[a]	372[a]	375[a]
# Graduate Students[c]..	438	443	491	481[a]	488[a]	490[a]
# PhDs awarded[d]........	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]

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

[b] Estimated. Information is not readily available on the total number of permanent PhD 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 PhD-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.

[c] Estimated for national laboratory projects.

[d] Information is not available on the number of PhDs awarded as a result of BER funded research at universities or national laboratories. Such data will be collected for FY 2005.

Life Sciences

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Life Sciences					
Structural Biology	26,689	27,036	21,871	-5,165	-19.1%
Molecular and Cellular Biology	71,384	97,794	101,954	+4,160	+4.2%
Human Genome	73,217	64,230	64,572	+342	+0.5%
Health Effects	10,513	10,175	10,237	+62	+0.6%
SBIR/STTR	0	5,456	5,377	-79	-1.4%
Total, Life Sciences	181,803	204,691	204,011	-680	-0.3%

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 structural biology, 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 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 that it identified as part of the International Human Genome Project using model organisms such as the mouse, *Fugu* (the puffer fish), and *Ciona* (the sea squirt).

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 comprehensive review of the Life Sciences subprogram by BERAC will be in FY 2004.

Accomplishments:

- *Sequencing Leap-Frogs to another Milestone.* The genome of the West African clawed frog, *Xenopus tropicalis*, was sequenced as part of an international collaboration led by the DOE Joint Genome Institute (JGI), with participation by the U.S. Environmental Protection Agency (EPA) and the National Institutes of Health (NIH). This 1.7 billion base pair genome is the first amphibian sequenced. The frog is scientifically important for a number of reasons. It marks an evolutionary milestone coinciding with the appearance of four-legged animals. It serves an "environmental sentinel" for environmental contamination and clean-up since its development is exquisitely sensitive to chemical contaminants. It is also a model organism for studying embryonic development, growth, and maturation and will help scientists decipher gene regulatory and morphogenetic events in early vertebrate development leading to greater understanding of human biology.
- *A New Window on the Microbial World - Studying the Other 99%.* Microbes play a major role in the health of our planet; but fewer than 1% of the Earth's microbes can be cultured in the laboratory. These unculturable bacteria and archaea live in every imaginable environment on Earth, thriving under remarkably harsh conditions and possessing metabolic capabilities that enable them to detoxify contaminants and use unique sources of energy. They live in our oceans and terrestrial environments, playing critical roles in the maintenance and regulation of water and atmospheric composition. In several pioneering projects, JGI scientists and their collaborators have opened a new window on microbial diversity, using DNA sequencing of environmental samples to reveal the genomic underpinnings and biochemical capabilities of the resident microbes. These new analyses are illuminating the diversity of unculturable microbial life on Earth, revealing a wide range of

biochemical capabilities that suggest new approaches for environmental cleanup, energy production, and carbon sequestration.

- *Victory Declared - Human Genome Sequence Finished.* In April 2003, the International Human Genome Consortium announced the formal completion of the sequencing of the human genome. This announcement, two years ahead of original projections, represents the achievement of the quality and completeness milestones for the human DNA sequence – a sequence accuracy of less than one error in ten thousand bases and the closure of all sequence gaps within the limits of current technology. For its role in this international project, the JGI produced nearly 12% of the finished human genome sequence, human chromosomes 5, 16, and 19, which include the most gene-rich human chromosome (number 19) and one of the most internally duplicated chromosomes (number16). Computational and biological analyses of these three chromosomes to date have revealed nearly 4,000 genes impacting human health. Deciphering our genomic "text" will be a major focus of future biology, relying in part on extensive comparisons with other related genome sequences such as the frog, Fugu fish, and sea squirt all sequenced by the JGI.
- *Revealing the genomes of "Sudden Oak Death" and other plant pathogens.* Genome sequencing of pathogens provides direct insight into the working of these agents that informs the diagnosis, treatment, and ultimately prevention of disease in both plants and animals. In collaboration with the U.S. Department of Agriculture, the JGI determined and analyzed the genome sequences of two members of the genus *Phytophthora*, including the organism causing "Sudden Oak Death" in California, as well as two species of the fungal genus *Phakopsora*, the cause of soybean blight and a potential agricultural bioterror agent. By sequencing pairs of related organisms simultaneously, similarities and differences between the genomes can be used to identify genes that determine the host specificity of a pathogen and its ability to evade the host immune response.
- *Primate Genomes Help Understanding of Human Gene Function.* While comparisons between DNA sequences of the human and of the rat and mouse can illuminate characteristics shared by mammals; not surprisingly many human-specific molecular traits cannot be understood by studying these evolutionarily distant DNA sequences. DOE scientists developed a new approach that uses DNA sequence information from close primate relatives to decipher functional elements in the human genome. Human and primate DNA sequences are quite similar. New methods to identify these differences across a range of primates provide a novel tool for identifying the presence and functionality of genes that are unique to the human genome.
- *First Tree Genome is Sequenced.* The genome of the black cottonwood tree (*Populus balsamifera ssp. trichocarpa*), a member of the poplar family, is the first tree genome to be sequenced. Scientists working on tree genetics, productivity, and forest product utilization are enthusiastic about the sequencing of this tree species because it represents an important first step in understanding the genome of a common, commercially important tree species with potential impacts including improved carbon sequestration and biomass for energy. This effort was led by a consortium of scientists from the JGI, Oak Ridge National Laboratory, the University of Washington, the British Columbia Genome Sequence Center, the Swedish University of Agricultural Sciences, Oregon State University, Pennsylvania State University, the National Center for Genome Research, and other institutions. The sequencing, assembly, and initial analysis were carried out at DOE's high throughput DNA sequencing facility, the Production Genomics Facility.
- *Beginning to Decipher Poplar's Genome.* Molecular markers derived from the Poplar DNA sequence have been used to create the most complete genetic map ever assembled for a forest tree

species. Research was begun to identify regions of the Poplar genome responsible for above- and below-ground carbon allocation/chemistry in the Poplar that could lead to innovative plantation strategies for bioenergy and carbon sequestration. This included an extensive carbon inventory conducted for stems, branches, leaves, coarse roots, and fine roots, as well as chemical composition of selected tissues from more than 1000 progeny of a unique hybrid poplar family growing in the Pacific Northwest and use of the newly created Poplar genetic map. Preliminary model analyses indicate that increasing the allocation of carbon to Poplar's roots and altering Poplar's tissue chemistry to favor longer-lived pools of soil organic matter, i.e., lignin, would together enhance global carbon sequestration in terrestrial ecosystems by 0.56 Gigatons of carbon per year (approximately 8.6% of annual global carbon emissions), assuming that 222 million hectacres of land was available globally for the establishment of fast-growing poplar forest plantations (an area the size of Texas and Alaska combined).

- *First DNA sequence of a green algae*. The genome of a unicellular green algae has been determined by the JGI - the first algae to be sequenced. *Chlamydomonas reinhardtii* - known as the "green yeast" for its ease of study and manipulation - is a model organism for the study of various fundamental biological processes, including photosynthetic carbon fixation, important for carbon sequestration in the ocean, and flagellar structure and function. Unicellular green algae are found nearly everywhere - in soil, fresh water, oceans, and even in snow on mountaintops. DOE is interested in *Chlamydomonas* because of its widespread global distribution and its ability to carry out photosynthesis, the most powerful biological technology for carbon dioxide capture from the atmosphere. An international consortium of scientists is participating in the analysis and interpretation of the genome of this model alga.
- *First DNA sequence of a diatom*. The genome of a marine diatom, *Thalassiosira pseudonana*, has been determined by the JGI and analyzed in collaboration with an international consortium of marine biologists. Diatoms, a type of marine phytoplankton, are important model organisms for carbon sequestration and are found in all of Earth's oceans. They display an incredible and intriguing variety of shapes and are major players in the Earth's carbon cycle. They are responsible for much of the ocean's ability to move carbon dioxide captured in the near surface regions by photosynthesis to the deep ocean. The shapes, growth rates, and carbon fixation processes of diatoms are all under genetic control and could be exploited to enhance their carbon processing capabilities as one strategy towards mitigation of global warming. Additionally, the silicate shells of many diatoms are engineering and material science marvels and could provide important insights for nanoscience research.
- *Sea Squirt Genome Gives New Clues to Origins of Chordates and Vertebrates.* Humans are members of the chordate phylum, an ancient group of animals that first appears in the fossil record over 540 million years ago. Our most distant living relatives in this group are the sea squirts, humble filter-feeding marine creatures whose tadpole larvae represent plausible modern approximations to the ancestral chordates. To understand the origins of chordates and vertebrates, the JGI previously sequenced the genome of the most studied sea squirt, *Ciona intestinalis*. Ciona has approximately 16,000 protein-coding genes, similar to the number in other invertebrates, but only half that found in vertebrates. Vertebrate gene families are typically found in simplified forms in Ciona, suggesting that these primitive organisms have the basic ancestral complement of genes involved in cell signaling and development. The Ciona genome also has a number of lineage-specific biochemical pathways such as a group of genes for cellulose metabolism related to those found in bacteria and fungi. This international project includes scientists from the US, Japan, Italy,

France, Canada, and Australia, and provides a foundation for genome-scale analysis of gene regulatory networks.

- *Another Record-Breaking Year of Microbial DNA Sequencing.* The JGI has again surpassed expectations in microbial DNA sequencing in FY 2003 by determining high quality draft sequences of 41 microbes important to DOE needs in energy, environmental cleanup, and counter-terrorism. Twelve of these organisms are pathogens or their close genetic relatives that were sequenced as part of a coordinated interagency effort to quickly characterize as many potential threat agents as possible.
- *Rapid Detection of DNA Sequence Variants.* The mouse continues to be a valuable research tool for helping scientists understand the function of the human genome. DOE's long history of leading mouse genetics research continues to provide scientists with new tools that take advantage of current capabilities in genomics. A strength of mouse genetics research has always been the ability to isolate mouse mutants that provide insights on the homologous human genes. A new method for rapid detection of mutants has been developed that combines gradient capillary electrophoresis (TGCE) for mutation and single-nucleotide polymorphism (SNP) detection, DNA sequencing to identify the exact location in the DNA sequence of the identified variants, and multiplexed single-base extension to survey the mutations and SNPs at the known sites of the mutation within the DNA sequence. This combined approach offers scientists a fast and cost-effective method for high-throughput mutation/SNP detection. This new method was enabled by the DOE investments in DNA sequencing technology that contributed to the successful completion of the Human Genome Project.
- *Protein X-ray Crystallography Upgraded.* The National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL) serves a large community of structural biologists in the northeastern United States. However, its X-ray beams are not as bright as those at the newest light sources, limiting its usefulness for determining the structures of larger, more complicated proteins and protein complexes. A beam line has now been assembled at the NSLS using new technology in which the X-rays are produced by a mini-gap undulator device, resulting in beam brightness close to the best at the other American light sources. This beam line was developed by BNL in collaboration with the Albert Einstein College of Medicine.
- *Robots Enhance Protein Crystallography Throughput.* Obtaining protein structures using X-ray crystallography involves screening a hundred or more crystals of the protein one at a time to find the one that gives the best data. A new robotic crystal handling system at the Stanford Synchrotron Radiation Laboratory (SSRL) was installed early in FY 2003. This system enabled a user group to test 130 crystals of a protein complex in less than eight hours. The previous experiment by this group with manual handling of the samples required 24 hours to screen 100 crystals of a similar complex, with several of the samples being damaged or lost. All of the Department of Energy synchrotron light sources are implementing automated systems for this process, which will enable a substantial increase in the number of users that can be accommodated.
- *A Step Closer to Automated Protein Structure Prediction.* Being able to predict the three dimensional structure of a protein from its amino acid sequence is one of the grand challenges in structural biology. A new threading-based protein structure prediction system, PROSPECT, is the latest addition to the structural biologist's tool kit. PROSPECT consists of a dozen tools for identification of protein domains and signal peptide, protein triage to determine the protein type (membrane or globular), protein fold recognition, generation of atomic structural models, prediction

result validation, etc. Different processing and prediction branches are determined automatically by a prediction pipeline manager based on identified characteristics of the protein. The pipeline has been implemented to run in a heterogeneous computational environment as a client/server system with a web interface. PROSPECT placed fifth in a field of 150 in the Fifth Critical Assessment of Techniques for Protein Structure Prediction Experiment (CASP5) in the fold recognition category.

- *Responses to Low Dose Rates of Radiation Not All the Same.* Sensitive genetic assays (microarrays) have been used to identify genes whose expression is induced by radiation delivered at low dose rates. Two classes of genes exhibiting different responses to low dose rates of radiation were identified in cultured human myeloid cells. One group of genes induced in a dose rate-dependent fashion included a preponderance of genes with known roles in the regulation of apoptosis, a form of terminal differentiation. A second group of genes induced in a dose rate-independent manner included a preponderance of genes involved in cell cycle regulation. If these results hold true *in vivo*, there may be important implications for carcinogenesis and risk assessment. For example, cells damaged by exposure to very low doses and dose rates of radiation may escape apoptosis, but undergo normal cell cycle arrest. This increases the likelihood that some critically damaged cells may misrepair their damage and continue proliferating. Under this scenario, low doses of radiation delivered at low dose rates could pose a greater carcinogenic risk than radiation delivered at a higher dose rate.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Structural Biology	**26,689**	**27,036**	**21,871**
▪ **Basic Research**	**11,389**	**11,736**	**6,571**

Understanding the workings of the multi-protein molecular machines that enable microbes to cleanup metals and radionuclides or to sequester carbon dioxide will help us to design biotechnology solutions for environmental cleanup and for reducing atmospheric levels of carbon dioxide. Multi-protein complexes, or molecular machines, carry out most of the biochemical functions within cells. Understanding how molecular machines form and work requires that we observe dynamic changes in protein structure, modification, translocation, and subcellular concentration. Research is supported to understand the structures of microbial molecular machines, the regulatory networks that they are part of, and the structures and regulation of their component proteins.

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

Structural biology research is reduced and the funds are redirected to the PED construction project for the Genomics: GTL Facility for Production and Characterization of Proteins and Molecular Tags. The research being reduced is more than offset by large National Institutes of Health increases in investments in the Protein Structure Initiative to determine the structures of a large number of individual proteins and multiprotein complexes.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **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, 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. BER also supports access to unique high performance mass spectrometry and nuclear magnetic resonance spectrometry user facilities at the EMSL that are used for both proteomic and structural biology research. DOE investment in structural biology facilities 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 (over $30,000,000 per year from FY 2001 to FY 2005) in pilot projects for NIH's Protein Structure Initiative to develop high throughput methods for determining protein structure. Six of the nine pilot projects funded by NIH include partners from DOE Laboratories and nearly all make substantial use of DOE user facilities. 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	**71,384**	**97,794**	**101,954**
▪ **Microbial Genomics**	**9,906**	**9,932**	**9,838**

Microbial genomics research underpins DOE research programs - Fundamental microbiology research will continue to underpin DOE's need to exploit the capabilities of microbes to address mission needs from clean up of the environment to sequestration of atmospheric carbon dioxide to new sources of bio-fuels. Microbial genomics research strengthens the foundation that underpins other BER and DOE programs, including Genomics: GTL, bioremediation research, and carbon sequestration. The underlying scientific justification remains a central principle of the BER genome programs – knowing the complete DNA sequence of a microbe provides important keys to its biological capabilities and is the first step in developing strategies to more efficiently use, or reengineer it to address DOE needs. The complete sequence is also an extraordinarily powerful engine for developing new and testable hypotheses about microbial functions thus advancing fundamental science.

Microbial genomics research includes:

Development of bioinformatics tools for analyzing microbial DNA sequence information. More than a third of the several hundred publicly available genomic sequences of archaea and bacteria are a result of DOE funding. Novel computational tools are being developed to increase the value of microbial genomic information, such as identifying distant relationships of genes, understanding microbial evolution, predicting gene function, identifying and modeling gene expression networks, and extracting longer stretches of useable DNA sequence from raw sequence data.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

Microbial Systems and Functional Analysis. Even simple microbes are constituted from thousands of genome-derived proteins that often do no act alone but are parts of protein complexes that carry out functions not mediated by the individual gene products themselves. Research is being conducted to improve and develop high-throughput approaches to the functional characterization (e.g., transporters, environmental sensors, redox enzymes, cytoskeletal components, DNA repair systems, metal reductases, biodegradative enzymes, etc.) of the multi-protein complexes within microbes whose DNA sequences are known and that play a role in bioremediation, carbon sequestration, or energy production.

Consortia and Hard-to-Culture Microbes. Most of our knowledge of microbes is derived from individual species that either cause diseases or can be grown in laboratory conditions. However, most microbes in the environment do neither. In fact, many microbes are part of interdependent consortia in which one species supplies a nutrient necessary for the growth of another. Virtually nothing is known of the organization, membership, or functioning of these microbial consortia. Research is conducted to develop technologies and approaches that will enable genomic analyses of microbial consortia as well as analyses of the genomic information content and diversity of those species that have proven refractory to laboratory culture but are plentiful in environments challenged with metal and radionuclide wastes, or involved in carbon sequestration.

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

■ **Carbon Sequestration Research**	**6,028**	**7,063**	**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 2005 the program continues to leverage the genomic DNA sequence of the poplar tree, completed in FY 2003, by developing high throughput experimental and computational methods for understanding the poplar genome and proteome, especially related to carbon utilization. Research will also focus on microbes that live in the poplar rhizosphere (root zone) with the intent of understanding the role 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. In FY 2005, the program also completes the DNA sequencing and preliminary annotation (DNA sequence analysis) of another plant, such as switch grass. This new information will enable scientists to develop new strategies for carbon sequestration and for generating energy from biomass.

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

■ **Genomics: GTL**	**35,321**	**63,460**	**67,493**

Genomics: GTL is a microbe-based program at the forefront of the biological revolution - a systems approach to biology at the interface of the biological, physical, and computational sciences. It will take advantage of solutions that nature has already devised to solve many of 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 past 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, in the end, 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 "factories" much like DNA sequencing was moved from the research laboratory to sequencing factories 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.

Anticipated outcomes of Genomics: GTL include, within 10 years, advances in systems biology, computation, and technology to address challenges in:

- *Clean Energy* — that will contribute to increased biology-based energy sources. In the long-term, they could contribute to energy security through a major new bioenergy industry;
- *Reduced Carbon Dioxide in the Atmosphere* — that will help us understand Earth's carbon cycle and design ways to enhance carbon dioxide (CO_2) capture. In the long-term, these advances could help us stabilize atmospheric carbon dioxide to counter global warming; and
- *Cleanup of the Environment* — that will lead to cost-effective ways for environmental cleanup. In the long-term, new technology could save billions in waste cleanup/disposal.

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 2005, 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 GTL research and technology.

In FY 2005, research will also continue on 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.

In FY 2005, the program will also initiate the engineering and design of a Facility for the Production and Characterization of Proteins and Molecular Tags. This facility will be a high-throughput user facility that will use highly automated processes to mass-produce and characterize proteins directly from microbial DNA sequence data and create affinity reagents or "tags" to identify, capture, and monitor the proteins from living systems. This facility will greatly accelerate the rate of scientific discovery in the GTL program.

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

	FY 2003	FY 2004	FY 2005
▪ **Human Frontiers Science**	**500**	**0**	**0**

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

	FY 2003	FY 2004	FY 2005
▪ **Low Dose Radiation Research**	**19,629**	**17,339**	**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.

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 2005, BER will continue to increase its emphasis on the development and use of experimental systems that enable scientists to make a transition from the use of highly quantifiable but less relevant *in vitro* systems for studying low doses of radiation to *in vivo* systems that are more relevant to human risk from exposure to low doses of radiation but in which it has been very difficult to quantify results. 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 also increase 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* – are 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 LET (linear energy transfer) radiation delivered at low total doses or dose-rates. This bystander effect potentially "amplifies" the biological effects (and the effective radiation dose) of a low dose exposure by effectively increasing the number of cells that experience adverse effects to a number greater than the number of cells directly exposed to radiation. Scientists will be challenged to determine if bystander effects to low doses of ionizing radiation occur *in vivo*.
- *Genomic instability* – is the loss of genetic stability, a key event in the development of cancer, induced by radiation and expressed as genetic damage that occurs many cell divisions after the insult is administered. Current evidence indicates that DNA repair and processing of radiation

damage can lead to instability in the progeny of irradiated cells and that susceptibility to instability is under genetic control, but there is virtually no information on the underlying mechanisms. Its role in radiation-induced cancer remains to be determined experimentally. It is also important to determine if genomic instability occurs at low total doses (<10 rads) or low dose rates. Scientists will be challenged to determine the extent to which low doses of radiation induce genomic instability *in vivo*.

- *Adaptive response* – is the ability of a low dose of radiation to induce cellular changes that reduce the level of subsequent radiation-induced or spontaneous damage. If low doses of radiation regularly and predictably induce a protective response in cells to subsequent low doses of radiation or to spontaneous damage, this could have a substantial impact on estimates of adverse health risk from low dose radiation. The generality and the extent of this apparent adaptive response needs to be further 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 experimenters 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 peer-reviewed processes. University scientists, competing for funds in response to requests for applications, conduct a substantial fraction of the research in this program.

	FY 2003	FY 2004	FY 2005
Human Genome	**73,217**	**64,230**	**64,572**
▪ **Joint Genome Institute**	**53,405**	**51,480**	**51,480**

In April 2003, the scientific community celebrated the completion of the high quality DNA sequence of the human genome and announced the official end of the International Human Genome Project (HGP). Although research to understand the genes identified in the HGP continues, the Joint Genome Institute's (JGI) high-throughput DNA sequencing factory, the Production Genomics Facility, has transitioned away from human sequencing to help meet the growing demand for DNA sequencing in the broader scientific community. The JGI is devoting 60% of its sequencing capacity to peer 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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

sequencing submitted by individual scientists and other federal agencies. Forty percent of the JGI's DNA sequencing capacity are 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 directly by the Genomics: GTL program and are not included 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, ORNL) and a significant partnership with Stanford University. The JGI's DNA sequencing factory is located in Walnut Creek, California.

	FY 2003	FY 2004	FY 2005
▪ **Tools for DNA Sequencing and Sequence Analysis**	**17,823**	**11,045**	**11,245**

BER continues to develop the tools and resources needed by the scientific, medical, and private sector communities to fully exploit the information contained in complete DNA sequences, including the first human 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 2003	FY 2004	FY 2005
▪ **Ethical, Legal, and Societal Issues (ELSI)**	**1,989**	**1,705**	**1,847**

The completion of the International Human Genome Project does not end the need to understand the ethical, legal, and societal issues associated with genomics research and information. The DOE ELSI program continues to support research focused on issues of: (1) the use and collection of genetic information in the workplace especially as it relates to genetic privacy; (2) the storage of genetic information and tissue samples especially as it relates to privacy and intellectual property; (3) genetics and ELSI education; and (4) the ELSI implications of advances in the scientific understanding of complex or multigenic characteristics and conditions.

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

A table follows displaying both DOE and NIH Human Genome Project funding through the project's completion in FY 2003.

U.S. Human Genome Project Funding

	(dollars in millions)			
	Prior Years	FY 2003	FY 2004	FY 2005
DOE Funding (FY 87-03)	954.6	73.2	0.0	0.0
NIH Funding (FY 88-03)	2,674.6	467.0	0.0	0.0
Total U.S. Funding	3,629.2	540.2	0.0	0.0

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Health Effects	**10,513**	**10,175**	**10,237**
▪ **Functional Genomics Research**	**10,513**	**10,175**	**10,237**

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, that provides a complete parts list for the human genome, and the development of information (a high-tech owner's manual) that is useful in understanding normal human development and disease processes. The mouse continues to be a major focus of our efforts and is an integral part of our functional genomics research program. This effort is greatly enhanced by the completion of the Center for Comparative and Functional Genomics at Oak Ridge National Laboratory that will serve as a national focal point for high throughput genetic studies using mice. BER creates and genetically characterizes new mutant strains of mice that serve as important models of human genetic diseases and for understanding gene function 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. Research to develop new high-throughput strategies for using model organisms such as the mouse, *Fugu*, and *Ciona* to understand the function of human genes continues.

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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
SBIR/STTR	**0**	**5,456**	**5,377**

In FY 2003 $4,375,000 and $256,000 were transferred to the SBIR and STTR programs, respectively. FY 2004 and FY 2005 amounts are the estimated requirements for continuation of these programs.

Total, Life Sciences	**181,803**	**204,691**	**204,011**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Structural Biology	
▪ Structural Biology basic research is reduced by $5,000,000 and the funds are redirected to the PED construction project for the Genomics: GTL Facility for Production and Characterization of Proteins and Molecular Tags.	-5,165
Molecular and Cellular Biology	
▪ Microbial genomics research maintained at near FY 2004 level	-94
▪ Carbon sequestration research maintained at near FY 2004 level	+64
▪ Increase for "Genomics: GTL" supports additional research to develop high-throughput methods for the production of microbial proteins and molecular tags that will be implemented in the first GTL facility.	+4,033
▪ Low dose radiation research maintained at near FY 2004 level.	+157
Total Molecular and Cellular Biology	+4,160
Human Genome	
▪ Tools for DNA sequencing and sequence analysis maintained at near FY 2004 level	+200
▪ Ethical, Legal and Societal Issues (ELSI) support slightly increased due to rescission in FY 2004.	+142
Total Human Genome	+342
Health Effects	
▪ Functional genomics research maintained at near FY 2004 level.	+62
SBIR/STTR	
▪ Decrease in SBIR/STTR due to decrease in research funding for the Genomics: GTL program.	-79
Total Funding Change, Life Sciences	-680

Climate Change Research

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Climate Change Research					
Climate and Hydrology	68,956	74,107	74,559	+452	+0.6%
Atmospheric Chemistry and Carbon Cycle	34,546	37,477	37,707	+230	+0.6%
Ecological Processes	11,678	18,612	18,726	+114	+0.6%
Human Interaction	7,002	8,022	8,071	+49	+0.6%
SBIR/STTR	0	3,896	3,896	0	0.0%
Total, Climate Change Research	122,182	142,114	142,959	+845	+0.6%

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. The BER Climate Change Research subprogram (excluding the carbon sequestration element) represents DOE's contribution to 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). It also contributes to the Administration's Climate Change Research Initiative (CCRI) initiated in FY 2003.

The CCRI is a set of cross-agency programs in areas of climate change research of high priority and where substantial progress is anticipated over the next three to five years. The specific focus areas of the research are climate forcing (atmospheric concentrations of greenhouse gases and aerosols); climate feedbacks and sensitivity; climate modeling, including enabling research; regional impacts of climate change, including environment-society interactions; and climate observations. FY 2005 funding allows DOE to participate in one of the specific research areas: climate forcing, which includes modeling carbon sources and sinks, especially those in North America. In FY 2005 BER will continue to support research to quantify the magnitude and location of the North American carbon sink, a high priority need in the interagency Carbon Cycle Science Plan and expand its CCRI research to include climate modeling, ARM, and Integrated Assessment activities (FY 2005 request is $25,335,000).

The National Institute for Global Environmental Change (NIGEC) is integrated throughout the subprogram (FY 2005 request is $8,495,000). NIGEC regional centers are located at Harvard University (Northeast Region); the University of California, Davis (Western Region); the University of Nebraska, Lincoln (Great Plains Region); Indiana University, Bloomington (Midwest Region); Tulane University, New Orleans (South central Region); and the University of Alabama, Tuscaloosa (Southeastern Region). The national office of NIGEC center is located at the University of California, Davis.

A major emphasis of the Climate Change Research subprogram is on understanding the radiation balance from the surface of the Earth to the top of the atmosphere and how changes in this balance due to increases in the concentration of greenhouse gases in the atmosphere may alter 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 is focused on acquiring the data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter emitted to the atmosphere. In FY 2005, the program will shift to 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. This research includes DOE's contribution to the CCRI.

The BER carbon sequestration element funds basic research that seeks to exploit the biosphere's natural processes to enhance the sequestration of atmospheric carbon dioxide in terrestrial and marine ecosystems. It also seeks the understanding needed to assess the potential environmental implications of purposeful enhancement and/or disposal of carbon in the terrestrial biosphere and at the surface or 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.

The Ecological Processes research is focused on experimental and modeling studies to understand and be able to 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.

The Human Interactions research is focused on improving methods and models that can be used to assess the economic and societal costs and benefits of both human-induced climate change and possible response options or strategies for mitigating or adapting to climate change. It also includes support to archive and analyze climate change data and make it available for use by the broader climate change research community.

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

Accomplishments:

- *New analysis demonstrates better agreement between model simulations and satellite observations of tropospheric warming.* Scientists from BER's Climate Change Prediction Program found a strong agreement between observed three dimensional tropospheric temperature changes and simulations of the 20th Century climate that included anthropogenic forcing. There has been considerable debate over the last few years about the lack of agreement between the upper tropospheric temperatures recorded by satellite measurements, which show little or no warming, and climate model results, which show warming. Recently, the satellite data have been reanalyzed and the temperature trend in the observations is consistent with that produced by the models. Although this result (published in *Science*) does not end the debate, it does set a new standard for the quantitative comparison of model results to observational data.
- *First-of-a-kind measurements help provide better understanding of aerosol effects on climate.* Using new ARM measurements from the ARM Southern Great Plains site, scientists provided new insights into the effect of pollution on clouds, and, in turn, the heating and cooling of the earth's atmosphere. This question, known as the aerosol indirect effect, has been studied by scientists for thirty years. One of the fundamental theories is that by increasing the number of particles in the atmosphere upon which cloud droplets can form, clouds will have more, but smaller, droplets. Since smaller droplets are more reflective, clouds affected by pollution may cool the earth more than clouds unaffected by pollution. Researchers recently presented the first simultaneous measurements of cloud droplet size and aerosol amount to provide a direct link between the properties of the measured aerosol particles and their effect on the cloud droplets. Seven cases were studied in which the aerosol amount changed significantly over a day. The aerosol indirect effect was calculated by

quantifying how much the cloud droplet size changed in response to the changing aerosol amount. The new measurement strategy provides important data for the development of new cloud model parameterizations within climate models.

- *Effects of emissions from urban areas show that air quality management strategies will require tailoring different strategies for different cities.* Research findings from the air quality studies in the southeast Texas/Houston area and Atlanta show that the primary cause of exceedence of ozone standards in these two urban areas is due to different factors that will have to be considered in developing strategies for reducing tropospheric ozone levels to meet air quality standards in a particular region. In the Houston area, for example, elevated ozone is primarily a result of emissions of non-methane hydrocarbons (the fuel that drives ozone formation) from petrochemical facilities, whereas in Atlanta, it is due to both naturally occurring terpenes emitted by vegetation and elevated nitrogen oxide (the catalyst that controls ozone formation) from fossil fuel combustion. The results indicate that controlling ozone levels in Houston will require a different strategy from that in Atlanta because in the case of Atlanta, the primary source of hydrocarbon emissions are natural and can not be easily controlled, whereas hydrocarbon emissions in the Houston region are primarily from human sources that can be reduced. The results of the study have been incorporated into a new east Texas air quality management strategy.

- *First discovery that carbon allocation in plants is genetically controlled.* Carbon allocation and partitioning among woody plant tissues affects various growth processes, and influences pathways and mechanisms of carbon sequestration by terrestrial ecosystems. Research supported by BER showed that the amount of carbon partitioned to stems, roots, branches, leaves and fine roots is genetically controlled. While genetic factors or environmental variation can theoretically affect carbon partitioning, it has now been determined that for *Populus* trees, a small number of genes control cell wall chemistry and carbon partitioning to substances that have long residence times. More detailed studies of biochemistry have found that plant lignin content is also controlled genetically, and since lignin is relatively resistant to microbial degradation, plant tissues enriched in this substance lead to enhanced carbon sequestration in soil organic matter. These studies point toward plant properties and biophysical mechanisms that may be selected for enhanced carbon sequestration. Studies of genetic variability and understanding the functional relationships will further accelerate research on the application of genome sequence data for manipulating plant carbon partitioning when the *Populus* genome sequence maps are provided by JGI. The research contributes unique information to forest geneticists to use in accelerating development and testing of new *Populus* varieties for enhancing intrinsic productivity and carbon sequestration in terrestrial ecosystems.

- *Deep sea experiments using autonomous undersea vehicles (AUV) assess direct injection as a strategy for ocean carbon sequestration.* Using sophisticated AUV's, experiments supported by BER's ocean carbon sequestration program were conducted in marine sediments at a depth of 3600m to determine the potential impact on deep sea organisms of the direct injection of liquid carbon dioxide (CO_2). The research, which was co-funded by BER and the Office of Fossil Energy, showed for the first time the potential effects of a plume of CO_2 on deep sea animals. Mortality and metabolic effects (such as acidosis and decline in respiratory rate) were a direct function of the distance from the CO_2 plume with immotile animals, but varied among different deep sea fish species. Results from these and other experiments will be essential in assessing the potential environmental consequences of deep ocean injection of CO_2 as a potential purposeful strategy for sequestering carbon that would have been otherwise emitted to the atmosphere from facilities that burn fossil fuels.

- *First-ever 10-year-long soil warming experiment produces surprises.* BER's Ecological Processes program, some of which is funded through NIGEC, completed the first ever decade-long soil warming experiment. The study documented changes in soil carbon and nitrogen cycling caused by long-term warming in a Massachusetts hardwood forest. Soil warming accelerated soil organic matter decay and carbon dioxide release from the soil to the atmosphere, but that response was small and short-lived (being mostly dissipated by the eighth year of the experiment) because of the limited size of the soil carbon pool in that forest. Soil warming also increased the availability of soil nitrogen to plants in the experimental area. This effect of warming has the potential to stimulate tree growth because many of the forests in the mid latitudes are nitrogen-limited. The increase in nitrogen availability has the potential to stimulate enough carbon storage in trees to compensate for carbon losses from the soil in such forests, at least for a time. These results challenge assumptions made in some coupled climate-carbon cycle models that lead to projections of large and long-term releases of soil carbon to the atmosphere in response to warming of forest ecosystems.
- *Unique field experiments document potential impacts of climatic change*. BER's Ecological Processes research program tested effects of increased variability in rainfall, a prediction of climate models, on the structure and functioning of native grasslands in Kansas. During a 4-year period, rainstorm frequency was reduced and rainfall amount during each storm was increased, without a change in total annual rainfall, in experimental plots. The rainfall manipulations increased temporal variability in soil moisture and plant species diversity. Carbon cycling processes (such as carbon dioxide release from the soil and carbon dioxide assimilation by the dominant prairie grasses) was slowed by increased rainfall variability. The results show that projected increases in rainfall variability might rapidly alter key carbon cycling processes and plant community composition in Midwestern grasslands.

Detailed Justification

(dollars in thousands)

	FY 2003	FY 2004	FY 2005
Climate and Hydrology	**68,956**	**74,107**	**74,559**
▪ **Climate Modeling**	**26,025**	**26,973**	**27,138**

Model-based climate prediction provides the most scientifically valid way of predicting the impact of human activities on climate for decades to centuries in the future. BER will continue to develop, improve, evaluate, and apply the best coupled atmosphere-ocean general circulation models (GCMs) that simulate climate variability and climate change over these time scales. The goal is to achieve statistically accurate forecasts of future climate over regions as small as river basins using ensembles of model simulations. The ensembles will accurately incorporate the dynamic and thermodynamic feedback processes that influence climate, including clouds, aerosols, and greenhouse gas forcing. Current predictions are limited by 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

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

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 2005 BER will continue the partnership with the Advanced Scientific Computing Research program. This includes applying the computing resources for climate simulation and continuing climate model development and application through the use of collaboratory technologies. Additionally, BER will emphasize data assimilation methods so as to quickly make use of the high-quality observational data streams provided by ARM, satellite, and other USGCRP climate data programs to evaluate model performance.

For CCRI the research will provide ensemble projections of multi-century climate change using the Community Climate System Model through the Climate Change and Assessment Working Group. Additionally, the program will provide the infrastructure for major model evaluation and model improvement research through the coordination of model intercomparisons and the maintenance of model test beds for parameterization testing. In FY 2005 climate model experiments ($15,347,000) will provide scenarios, such as CO_2 stabilization scenarios.

In FY 2005 BER's SciDAC program ($7,776,000) will focus on improving the models used for climate simulation and prediction. A major effort will be dedicated to providing a robust and extensible software engineering framework for the Community Climate System Model, a code used by hundreds of researchers on many different high-end computing platforms. Additional research will provide the prototype climate model of the future that will explore approaches to climate simulation and prediction for the next ten years.

In FY 2005, NIGEC will continue to support research needed to understand how changes in terrestrial ecosystems brought about by climatic changes may, in turn, affect climatic changes through various feedback processes (FY 2005 request is $1,933,000).

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

High performance computing resources are provided for development and implementation of advanced climate models.

	FY 2003	FY 2004	FY 2005
▪ **Atmospheric Radiation Measurement (ARM) Research**	**11,238**	**12,960**	**13,247**

In FY 2005, 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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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 initiated in FY 2003 will be continued to enable the testing and improvement of submodels by rapidly incorporating data from the ARM sites into the models to enable diagnostic tests and intercomparisons of model simulations with real world data.

	FY 2003	FY 2004	FY 2005
▪ **Atmospheric Radiation Measurement (ARM) Infrastructure**..	**28,965**	**31,441**	**31,441**

In FY 2005, the ARM infrastructure program will continue to develop, support, and maintain the three ARM sites and associated instrumentation. BER will continue to operate over two hundred instruments (e.g., multifilter shadowband radiometers for aerosol measurements; Raman Lidar for aerosol and cloud measurements; radar wind profiler systems; radar cloud measurement systems; sky imaging systems; arrays of pyranometers, pyrgeometers, and pyrheliometers for atmospheric and solar radiation measurements; and standard meteorological measurement systems for characterization of the atmosphere) at the Southern Great Plains site and will continue operations at the Tropical Western Pacific station and at the North Slope site in Alaska. The ARM program will continue to provide data to the scientific community through the ARM Archive.

The ARM data streams will continue to be enhanced periodically by additional measurements at the ARM sites during intensive field campaigns referred to as Intensive Operation Periods (IOPs). Ranging from two weeks to two months, the campaigns bring together teams of scientists testing cutting edge remote sensing instruments and coordinate measurements with airborne and satellite observations. The ARM sites have become major testbeds of research in atmospheric processes serving as scientific user facilities for hundreds of scientists from universities and government laboratories. For example, both DOD and NASA have used the ARM sites to “ground truth” their satellite instruments.

The UAV program will conduct a major field campaign in conjunction with the ARM program to measure the effect of cirrus clouds on the absorption and scattering of downwelling radiation over the Western Tropical Pacific ARM-CART site.

The CCRI ARM program will deploy a mobile climate observatory to provide new atmospheric measurements needed to fill data gaps and will develop the corresponding data products needed for evaluating and modeling the effects of atmospheric processes and properties on the radiation balance and for developing and evaluating the models. In FY 2005 a mobile Cloud and Radiation Testbed (CART) ($4,100,000), consisting of a variety of meteorological and atmospheric sensors, will be deployed in a selected data-poor region (e.g., tropics) or a region that represents a location of opportunity for measuring the effects of atmospheric conditions on the radiation balance that are currently poorly understood (e.g., direct and indirect effects of aerosols). The mobile climate

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

observatory will be instrumented for cloud and radiation measurements. The primary siting criterion is to provide those measurements needed to address specific modeling needs that presently cannot be addressed by the permanent ARM sites. Activities will be coordinated with other U.S. agencies and international partners, such as Australia, Japan, China, and European countries. Data products will be developed through collaborations with model developers. In FY 2005 the criteria for data products for evaluating precipitation processes will be established.

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

▪ **Atmospheric Radiation Measurement (ARM)/Unmanned Aerial Vehicles (UAV)**	**2,728**	**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.

Atmospheric Chemistry and Carbon Cycle	**34,546**	**37,477**	**37,707**
▪ **Atmospheric Science**..	**11,546**	**12,475**	**12,551**

The CCSP strategic plan has raised the priority of research dealing with the climate effects of atmospheric aerosols. As a result BER is restructuring the Atmospheric Science program to focus entirely on the aerosol-climate connection.

In FY 2005 the Atmospheric Chemistry Program will, in effect, become the Tropospheric Aerosol Program (TAP) to quantify the impacts of energy-related aerosols on climate. It will be closely coupled with other components of DOE's climate change research, especially the ARM program. TAP will also be broadly coordinated with the air quality and global change research communities, including collaborations with the EPA, NASA, and NOAA and with the DOE Office of Fossil Energy's Airborne Fine Particulate Matter (PM) Research program. Regional patterns of aerosol distribution will be related to sources and sinks and the information will feed the models that simulate the impacts of aerosols on climate.

The Atmospheric Science program will acquire 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 atmospheric processes. 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.

In FY 2005, NIGEC will support research to quantify the effects of natural processes on atmospheric composition, focusing on the exchange of carbon dioxide between the atmosphere and the terrestrial biosphere (FY 2005 request is $2,187,000).

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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

▪ **Terrestrial Carbon Processes and Ocean Sciences**	**15,776**	**16,410**	**16,613**

In FY 2005, BER will continue supporting the AmeriFlux program, a network of approximately 25 research sites that measure the net exchange of CO_2, energy, and water between the atmosphere and major terrestrial ecosystems in North America. These measurements are linked to field measurement campaigns across North America that will test how well point measurements represent larger areas and allow the estimation of carbon sources and sinks on a regional basis. This research supports the interagency Carbon Cycle Science Plan. The fluxes of other greenhouse gases, e.g., methane and nitrous oxide, will also be measured at 5 to 10 AmeriFlux sites.

BER will also continue research to refine and test terrestrial carbon cycle models (based on mechanistic representations and carbon accounting). The models will be used to estimate 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).

In FY 2005 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 2005 the research will deliver an intercomparison of AmeriFlux-based estimates of the net annual exchange of CO_2 between terrestrial ecosystems and the atmosphere for a region of the U.S. with independent estimates using atmospheric sampling and inverse modeling.

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

▪ **Carbon Sequestration Research**	**7,224**	**8,592**	**8,543**

In FY 2005, BER will continue support for one carbon sequestration research consortium, led by ORNL, PNNL, and ANL, and involving six collaboratory universities, that focuses on terrestrial

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

sequestration, consortium for research on enhancing Carbon Sequestration in Terrestrial Ecosystems (CSiTE) ($3,000,000). The consortium develops information to enhance the natural sequestration of carbon in terrestrial soils and vegetation. BER will also continue the support of research at universities and DOE laboratories on ocean carbon sequestration ($2,000,000). The focus of the research on terrestrial and ocean sequestration will continue to be on cellular and biogeochemical processes that control the rate and magnitude of carbon sequestration in terrestrial and oceanic systems, including the identification of pathways and processes that could be modified to enhance the net flow of carbon from the atmosphere to terrestrial plants and soils, and to the ocean surface and, ultimately, to the deep ocean. Also, BER will support the research needed to assess the environmental implications of enhancing carbon sequestration and storage in the ocean and in terrestrial systems. BER research on carbon sequestration in terrestrial ecosystems will improve the scientific understanding of mechanisms of sequestration and how to alter them to enhance sequestration. The CSiTE activity will conduct research that specifically examines those plant and soil processes that capture and retain carbon in chemical and physical forms that are resistant to decay. The data will inform new models for estimating carbon sequestration in terrestrial ecosystems. New technologies will be developed by the BER-supported ocean carbon sequestration research to facilitate the export of carbon to the deep ocean and for re-mineralization of organic carbon at depth. Such technologies are vital to assessing accurately the potential of enhancing ocean carbon sequestration. Initial *in situ* experiments will be designed to determine the feasibility and potential environmental impacts of deep ocean injection of CO_2. Associated research will include determination of chemical reactions at depth, stability of products, and effects of those products on marine organisms.

In FY 2005, university scientists will continue the analyses of research results on the effects of iron fertilization on plankton communities in the Southern Ocean. The ocean surrounding Antarctica is the largest high-nutrient, low-chlorophyll region in the world. The joint DOE-NSF Southern Ocean Iron Enrichment Experiment (SOFeX) will help scientists understand the potential to enhance ocean carbon sequestration through iron enrichment.

Ecological Processes...	**11,678**	**18,612**	**18,726**

In FY 2005, 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 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.

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

BER will continue four Free-Air Carbon Dioxide Enrichment (FACE) experiments. They are located 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 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 2005, NIGEC will support experimental studies to understand how climate change and increasing CO_2 levels in the atmosphere affect structure and functioning of terrestrial ecosystems (FY 2005 request is $2,625,000).

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

Human Interactions	**7,002**	**8,022**	**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. This representation will include both options to enhance natural carbon storage in the terrestrial biosphere, as well as engineering options, such as the capture of carbon dioxide and storage in geologic formations.

The research will include integrating a new land and ocean carbon sub-model in a large integrated assessment model. The submodel includes a detailed representation of direct human influence (mainly agriculture and forestry) on the terrestrial biosphere. In addition to providing a more accurate representation of the global carbon cycle, the improvement will ensure consistent accounting of carbon-sink projects and the carbon uptake that occurs as a result of other land-use change and the effects of climate change and carbon fertilization. A second integrated assessment model will be used to simulate the effect of (1) climate on crop yields and (2) the amount of crop and pasture land necessary to provide (a) a sufficient diet in developing countries under climate change and (b) the

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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 2005 the Integrated Assessment program will produce at least four scenarios to provide alternatives to the scenarios that were published by the Intergovernmental Panel on Climate Change (IPCC) since the published IPCC scenarios have received significant criticism. These scenarios will include forecasts of such items as economic productivity, population, and energy use by global region. They will serve as input to the Integrated Assessment Models and will be used as input to decision support analysis in the CCRI ($2,972,000).

In FY 2005, NIGEC will support research to develop and test ecological models and coupled models of climatic ecologic-economic systems that would be required to conduct integrated assessments of the effects of climate change on regionally important natural resources in the U.S. (FY 2005 request is $1,750,000).

The Information and Integration element stores, evaluates, and quality-assures a broad range of global environmental change data, and disseminates those data to the broad research community. BER will continue the Quality Systems Science Center for the tri-lateral (Mexico, United States, and Canada) NARSTO (formally known as the North American Strategy for Tropospheric Ozone), a public partnership for atmospheric research in support of air quality management. The Center serves a diverse set of users, including academic and laboratory scientists and policy makers across North America.

The Global Change Education program supports DOE-related research in global environmental change for both undergraduate and graduate students, through the DOE Summer Undergraduate Research Experience (SURE), the DOE Graduate Research Environmental Fellowships (GREF), and collaboration with the NSF Significant Opportunities in Atmospheric Research and Science (SOARS) program.

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

SBIR/STTR...	**0**	**3,896**	**3,896**

In FY 2003 $3,108,000 and $186,000 were transferred to the SBIR and STTR programs, respectively. FY 2004 and FY 2005 amounts are the estimated requirements for continuation of these programs.

Total, Climate Change Research	**122,182**	**142,114**	**142,959**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Climate and Hydrology	
▪ Climate Modeling funding restored to FY 2004 level prior to rescission.	+165
▪ Atmospheric Radiation Measurement (ARM) research funding restored to FY 2004 level prior to rescission.	+287
Total, Climate and Hydrology	+452
Atmospheric Chemistry and Carbon Cycle	
▪ Atmospheric Science funding restored to FY 2004 level prior to rescission.	+76
▪ Terrestrial Carbon Processes and Ocean Sciences restored to near FY 2004 level prior to rescission.	+203
▪ Carbon Sequestration maintained at near FY 2004 level.	-49
Total, Atmospheric Chemistry and Carbon Cycle	+230
Ecological Processes	
▪ Ecological Processes funding restored to FY 2004 level prior to rescission.	+114
Human Interactions	
▪ Human interactions funding restored to FY 2004 level prior to rescission.	+49
Total Funding Change, Climate Change Research	+845

Environmental Remediation

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Environmental Remediation					
Bioremediation Research	29,063	27,359	30,640	+3,281	+12.0%
Clean Up Research	33,094	39,013	35,027	-3,986	-10.2%
Facility Operations	39,218	39,158	37,138	-2,020	-5.2%
SBIR/STTR	0	2,778	2,717	-61	-2.2%
Total, Environmental Remediation	101,375	108,308	105,522	-2,786	-2.6%

Description

The mission of the Environmental Remediation subprogram is to deliver the scientific knowledge, technology, and enabling the 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 biological and chemical methods for remediation; to 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 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) and the Savannah River Ecology Laboratory (SREL). These activities provide complementary knowledge and capabilities, which will be integrated to optimize the research.

Bioremediation activities are centered on the Natural and Accelerated Bioremediation Research (NABIR) program, a basic research program focused on determining how and where bioremediation may be applicable as a reliable, efficient, and cost-effective technique for cleaning up or containing metals and radionuclides in contaminated subsurface environments. In the NABIR program, research advances will continue to be made from molecular to field scales in the Biogeochemical Dynamics element; on genes and proteins used in bioremediation and in overcoming physicochemical impediments to bacterial activity through the Biomolecular Science and Engineering element; in non-destructive, real-time measurement techniques in the Assessment element; on species interaction and response of microbial ecology to contamination in the Community Dynamics and Microbial Ecology element; and in understanding microbial processes for altering the chemical state of metallic and radionuclide contaminants through the Biotransformation element. In analogy with the Ethical, Legal, and Social Implications component of the Human Genome program, the Bioremediation and its Societal Implications and Concerns component of NABIR is exploring societal issues surrounding bioremediation research and promoting open and interactive communication with stakeholders to help ensure understanding and acceptance of bioremediation as a potential solution to remediating contaminants. All NABIR elements and EMSL activities have a substantial involvement of academic scientists.

The Clean Up Research and Environmental Management Science Programs (EMSP) focus on a variety of solutions for the DOE weapons complex cleanup effort. Three primary elements include: contaminant fate and transport in the subsurface, nuclear waste chemistry and advanced treatment options, and novel characterization and sensor tools. This program works closely with related programs in the Basic Energy Sciences program and with related programs of other agencies. The SREL is managed through a cooperative agreement with the University of Georgia and performs ecological research aimed at understanding bioavailability of contaminants and ensuring that environmental cleanup operations do not disturb the biodiversity at the restored environment.

Within Facility Operations, support of the EMSL national user facility operations is focused on providing advanced molecular tools to the scientific community in such areas as environmental remediation sciences, biology and genomics, and atmospheric science. In FY 2005, 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.

Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. The next scheduled comprehensive review of the Environmental Remediation Sciences subprogram by BERAC will be in FY 2004.

Accomplishments:

- *Diverse microorganisms reduce metal and radionuclide contaminants and are common in subsurface environments.* Studies funded by the NABIR Program have found that a wide diversity of naturally occurring microorganisms have the capability of reducing metals and radionuclides to an insoluble state. These microorganisms include many different genera from within the family Geobacteraceae as well as unrelated microbes from genera such as *Clostridium* and *Anaeromyxobacter.* Metal reducing microbes were found at six DOE sites as well as at industrial and pristine sites. This finding is important because it means that it will not be necessary to genetically engineer microorganisms for this important function. Rather, we can take advantage of the natural catalytic power of *in situ* microorganisms to remediate metals and radionuclides.
- *Field studies confirm the potential of natural communities of microorganisms to reduce and immobilize uranium and technetium.* "Push-pull" tests are a means to interrogate subsurface microbial communities to assess their ability to perform different metabolic activities. A series of tests (>60) performed at the NABIR Field Research Center at the Oak Ridge Reservation confirmed that naturally occurring subsurface microorganisms can reduce technetium (Tc) and uranium (U) *in situ*. When these microbial communities were fed carbon sources such as ethanol, a sharp reduction occurred in the concentrations of soluble Tc and U at moderate pH's and low nitrate. However, the

presence of high nitrate or low pH inhibited the removal of Tc and U *in situ*. These findings are of critical importance to the development of new *in situ* bioremediation and monitored natural attenuation strategies and technologies.

- *Solve foaming problems in treatment of radioactive wastes*. Foaming during treatment of high level wastes is a major cause of delays and processing problems. Commercial antifoaming agents are not effective because of the complex physicochemical behavior of these wastes. An Environmental Management Science Program (EMSP) project "Foaming and Antifoaming in Waste Pretreatment and Immobilization Processes," studied the detailed mechanisms of foaming in processes for treating high and low level radioactive wastes, and developed plans for preventing this foaming. The project is based at the Illinois Institute of Technology (IIT) in Chicago, with collaborators at the DOE Hanford and Savannah River sites, where the largest quantities of high level radioactive wastes await treatment. Using this knowledge, they designed a combination of antifoam agents that have been deployed successfully to bring the foaming problem under control.
- *Test x-ray analyzer for measuring radioactive elements in waste streams.* Scientists carrying out an EMSP project at Los Alamos National Laboratory entitled "Radiochemical Analysis by High Sensitivity Dual-Optic Micro X-ray Fluorescence," are providing a new and reliable means for measuring small amounts of radioactive species in radioactive wastes. Measurement of the particles emitted when a radioactive atom decays requires preliminary treatment of test samples when the emissions are non-penetrating alpha or low-energy beta particles, as for example with the major fission product technetium-99. The new technique makes use of the characteristic X-rays given off by this element when excited by an X-ray beam, enabling measurements without removal of samples from the waste stream being treated. The new instrumentation has been developed in collaboration with X-ray Optical Systems, Inc.
- *Experimental and computational research by EMSL scientists and users eliminates need for multi-million dollar corrective action at Hanford*. Understanding the extent and potential for migration of radioactive contaminants in the subsurface beneath the high level waste tanks at the Hanford Site are difficult challenges for DOE. Key to understanding the potential for migration is the solubility of contaminants such as cesium, as well as the potential for cesium interactions with mineral surfaces. Using spectroscopic techniques, computational modeling, and other techniques, a group of scientists from the EMSL collaborated with a number of users to demonstrate that cesium leaking from tanks in the S-SX tank farm would interact with mineral surfaces, and would not migrate in ground water. These results provided the scientific basis for an agreement made between DOE-RL and the regulators to avoid such costly cleanup effort at the S-SX Hanford tank farm.
- *EMSL instrumentation used to determine the structure of breast cancer tumor suppressor protein interactions.* The availability of high-end (750 MHz and 800 MHz) NMR spectrometers within the EMSL makes possible studies of the molecular structures of proteins and enzymes. Using these high end NMR's, EMSL users from the University of Washington were able to determine the structure and interactions of proteins and protein complexes involved in breast cancer. These researchers were able to determine structural changes that predispose the protein complexes to lead to breast cancer tumors.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Bioremediation Research	**29,063**	**27,359**	**30,640**
▪ **NABIR and Bioremediation Research**	**23,145**	**21,589**	**24,097**

In FY 2005, NABIR will continue to increase the understanding of the intrinsic bioremediation (natural attenuation) of DOE-relevant metal and radionuclide contaminants, as well as of manipulated, accelerated bioremediation using chemical amendments. Laboratory and field experiments will be conducted to explore the fundamental mechanisms underlying chemical processes and complexation/transformation of contaminants. The NABIR Field Research Center (FRC) is operated by the Oak Ridge National Laboratory. Field site characterization of this FRC and distribution of research samples to investigators will continue. In FY 2005, science elements in the NABIR program continue fundamental research on the following subjects: (1) Biotransformation (microbiology to elucidate the mechanisms of biotransformation of metals and radionuclides); (2) Community Dynamics and Microbial Ecology (structure and activity of subsurface microbial communities); (3) Biomolecular Science and Engineering (molecular and structural biology to enhance the understanding of bioremediation and identify novel remedial genes); (4) Biogeochemical Dynamics (dynamic relationships among *in situ* geochemical, geological, hydrological, and microbial processes); and (5) Assessment (measuring and validating the biological and geochemical processes of bioremediation). University scientists continue to form the core of the NABIR science team that networks with the broader academic community as well as with scientists at the National Laboratories and at other agencies.

The NABIR FRC is located near the Y-12 area at the Oak Ridge Reservation and is the site of field-scale, hypothesis-driven research on the bioremediation of metals and radionuclides. Researchers are characterizing and modeling the subsurface water flow, contaminant transport, and biogeochemical processes at the FRC. These experiments will be completed and prepared for peer-reviewed publication in FY 2003. In FY 2005, field experiments will continue. They will combine both microbiological and chemical treatment of uranium and the common co-contaminant, nitrate.

Additional funds will support new field experiments and will support development of a second FRC, with different geophysical characteristics than the current FRC, as recommended by BERAC.

The NABIR program will continue to take advantage of recently completed genome sequences of important metal and radionuclide-reducing microorganisms to study the regulation and expression of genes that are important to bioremediation.

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

▪ **General Plant Projects (GPP)**	**4,749**	**4,811**	**5,584**

The General Plant Projects (GPP) funding is continued for minor new construction, other capital alterations and additions, and for buildings and utility systems such as replacing piping in 30- to 40-year old buildings, modifying and replacing roofs, and HVAC upgrades and replacements. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting the requirements for safe and reliable facilities operation. This subprogram

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		

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 2003	FY 2004	FY 2005
▪ **General Purpose Equipment (GPE)**	**1,169**	**959**	**959**

The General Purpose Equipment (GPE) funding will continue to provide general purpose equipment for PNNL and ORISE such as information system computers and networks, and instrumentation that supports multi-purpose research.

	FY 2003	FY 2004	FY 2005
Clean Up Research	**33,094**	**39,013**	**35,027**
▪ **Clean Up Research**	**1,823**	**2,362**	**0**

The activities in clean up research that were directly related to Environmental Management clean up operations have concluded and will be incorporated into the EMSP program.

	FY 2003	FY 2004	FY 2005
▪ **Environmental Management Science Program**	**24,471**	**29,052**	**27,251**

The goal of the Environmental Management Science Program (EMSP), transferred in FY 2003 from Environmental Management to the BER program, is to support basic research that improves the science base underpinning the clean up of DOE sites. Traditional clean up strategies may not work or be cost effective for many of the challenges that could prevent the successful closure of DOE sites. The EMSP, through its support of basic research aims to develop and validate technical solutions to complex problems, providing innovative new technologies to overcome major obstacles that lead to future risk reduction and cost and time savings. It is the intent or the expectation of the EMSP that the basic research projects funded are directed toward specific issues and uncertainties at the DOE cleanup sites. EMSP research will focus on contaminant fate and transport in the subsurface, nuclear waste chemistry and advanced treatment options, and novel characterization and sensor tools. In addition, studies on bioremediation of organic contaminants are conducted in EMSP, complementing the NABIR program, which focuses on metals and radionuclides.

EMSP projects will continue to be funded through a competitive peer review process. The most scientifically meritorious research proposals and applications will be funded based on availability of funds and programmatic relevance to ensure a complete and balanced research portfolio that addresses DOE needs. Research will be funded at universities, national laboratories, and at private research institutes and industries. This research will be conducted in collaboration with the Office of Environmental Management. Funding is reduced to increase research at and development of Field Research Centers through the NABIR program.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **Savannah River Ecology Laboratory**............	**6,800**	**7,599**	**7,776**

This activity supports, through a cooperative agreement with the University of Georgia, a long-term (40+ years) ecological research activity aimed at reducing the cost of clean up and remediation while ensuring biodiversity at the restored environment. Peer-reviewed research will be supported to assess the ecological risks of environmental contaminants and remediation activities. Characterizing and understanding the impacts of environmental contamination on intact, living ecosystems is a complex and long-term process since the research is dependent on natural cycles of growth, reproduction, and normal environmental variation. .

In FY 2005, new ecological research will be focused around the Environmental Remediation Science Division Field Research Centers so that it can be integrated with the flow and transport and characterization studies. This will continue a broad educational component at the site including opportunities for K-12, undergraduate, and graduate students, and post doctoral fellows

Facility Operations: William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)..	**39,218**	**39,158**	**37,138**
▪ **Operating Expenses**	**38,579**	**35,169**	**35,149**

The EMSL is a scientific user facility located at the Pacific Northwest National Laboratory focused on conducting interdisciplinary, collaborative research in molecular-level environmental science. Operating funds are essential and will continue to allow the EMSL to operate as a user facility, and are used for maintenance of buildings and instruments, utilities, staff support for users, environment, safety and health compliance activities, and communications. With over 55 leading-edge instruments and a supercomputer system, the EMSL annually supports approximately 1400 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.

▪ **Capital Equipment**..	**639**	**3,989**	**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. Funding is reduced due to completion, in FY 2004, of capital purchases associated with the EMSL computer upgrade and installation of the 900 MHz NMR.

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		
SBIR/STTR..	**0**	**2,778**	**2,717**

In FY 2003 $2,385,000 and $149,000 were transferred to the SBIR and STTR programs, respectively. FY 2004 and FY 2005 amounts are the estimated requirements for continuation of these programs.

	FY 2003	FY 2004	FY 2005
Total, Environmental Remediation	**101,375**	**108,308**	**105,522**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Bioremediation Research	
▪ NABIR and Bioremediation increase will be used for additional integrated Field Research Centers, which are needed to address the complexity, scaling issues, and coupled interactions between microbes and environmental entities.	+2,508
▪ GPP funding increased to reduce maintenance backlog at PNNL	+773
Total, Bioremediation Research...	+3,281
Clean Up Research	
▪ Clean Up Research activities are concluded and program objectives incorporated into EMSP.	-2,362
▪ Environmental Management Science Program funding is redirected to enhance NABIR and bioremediation research at the Field Research Centers.........................	-1,801
▪ Savannah River Ecology Laboratory is maintained at near FY 2004 level.	+177
Total, Clean Up Research	-3,986
Facility Operations	
▪ EMSL operating expenses are maintained at near FY 2004 level.	-20
▪ EMSL capital equipment reduced with completion of congressionally-directed instrument modifications.	-2,000
Total Facility Operations..	-2,020
SBIR/STTR	
▪ SBIR/STTR decreases with reduction in research..	-61
Total Funding Change, Environmental Remediation..	-2,786

Medical Applications and Measurement Science

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Medical Applications and Measurement Science					
Medical Applications........................	86,704	175,206	36,942	-138,264	-78.9%
Measurement Science	2,296	5,917	5,952	+35	+0.6%
SBIR/STTR....................................	0	5,218	1,204	-4,014	-76.9%
Total, Medical Applications and Measurement Science...........................	89,000	186,341	44,098	-142,243	-76.3%

Description

The mission of the Medical Applications and Measurement Science subprogram is to deliver the scientific knowledge and discoveries that will lead to innovative diagnostic and treatment technologies for human health, supporting Department of Energy's Medical Science mission.

Benefits

The basic research supported by this program builds on unique DOE capabilities in physics, chemistry, engineering, biology, and computational science. The developed technologies will improve the diagnosis and treatment of psycho-neurological diseases and cancer and lead to improvement in the function of patients with neurological disabilities, such as blindness and paralysis. The research will lead to new metabolic labels and imaging detectors for medical diagnosis; tailor-made radiopharmaceutical agents and beam delivery systems for treatment of inoperable cancers; and the ability to predict structure and behavior of cells and tissues to better engineer targeted drugs, biosensors, and medical implants. The basic research technologies growing out of this program offer applications for study, detection, diagnosis and early intervention of biochemical, bacterial, and viral health risks of biological, and/or gross environmental insults.

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 applications of radiotracers in diagnosis and treatment driven by the latest concepts and developments in genomic sciences, structural and molecular biology, computational biology, and instrumentation. Using non-invasive technologies and highly specific radiopharmaceuticals, BER is ushering in a new era of brain mapping detection of stem cell turnover and trafficking, and highly specific disease diagnostics. New tools will enable the real-time imaging of gene expression in a developing organism.

Research capitalizes on the National Laboratories' unique resources and expertise in biological, chemical, physical, and computational sciences for technological advances related to human health. The National Laboratories have highly sophisticated instrumentation (neutron and light sources, mass spectroscopy, high field magnets), lasers, and supercomputers that directly impact research on human health. Research is directed to fundamental studies in biological and medical imaging, biological and chemical sensors, laser medicine, and informatics. 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. This research is highly complementary to and coordinated with clinical research at the National Institutes of Health (NIH) and to basic research in the NIH intramural and extramural programs.

Coordination is provided through joint participation of senior NIH research staff and management as BERAC Committee and Subcommittee members. NIH technical staff participates in merit review panels to reduce the possibility of undesirable duplications in research funding. DOE and NIH organize and sponsor workshops in common areas of interest, for example: A joint workshop Optical Imaging of Soft Tissue will be held early in 2004. Members of the Medical Sciences Division staff are formal members of the National Cancer Advisory Board and the BioEngineering Consortium (BECON) of NIH Institutes. Furthermore, a DOE National Laboratory scientist provides technical liaison between the Medical Applications and Measurement Science subprogram and the recently established National Institute of Bioimaging and Bioengineering (NIBIB).

DOE supports cutting edge, high-risk, proof-of-concept research that develops research tools with broad applications in clinical medicine and in biological research. NIH supports cutting edge, disease-specific research that uses those tools, along with many others, to determine fundamental mechanisms of human disease for better diagnosis and treatment. For example, NIH supports clinical imaging research but not the research to develop radiotracers or imaging instruments, whereas DOE is the only government agency that supports research to develop imaging instruments and the radiotracers needed to carry out imaging procedures.

The different focus, roles, and strengths of the DOE and NIH medical sciences research programs are clear:

- DOE medical sciences research is built on a base of chemistry, physics, engineering, computation, and biology. NIH medical sciences research is built on a complementary base of biology and medicine. DOE research leverages the unique combination of multidisciplinary competencies available at the DOE national laboratories.
- DOE develops research tools for medicine by supporting high-risk research often based on theoretical predictions of success rather than preliminary studies that demonstrate a promise of success. As in other fields of science, high risk research often leads to spectacular advances, e.g., the human genome project and genetics. NIH develops disease-specific applications for these research tools by supporting research that is generally based on substantive preliminary studies that demonstrate a promise of success.
- These differences increase opportunities for success in medical sciences research.

Measurement Science research emphasizes development of novel biomedical sensors, including cantilever sensors, with a broad range of biomedical applications including neural prostheses, such as the artificial retina, and detection of carcinogen damage to DNA.

The Medical Applications and Measurement Science subprogram continues a substantial involvement of academic scientists along with the scientists in 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 BERAC will be in FY 2006.

Accomplishments:

- *New radiotracer developed to diagnose Parkinson's disease.* BER investigators at the University of Pennsylvania have developed a new technetium labeled pharmaceutical (TRODAT-1) that specifically localizes in the regions of the brain that are affected by Parkinson's disease. Technetium brain scans of Parkinson's patients show a dramatic decrease in the uptake of the radiopharmaceutical as compared to normal individuals. The radiotracer is in clinical testing to diagnose and monitor treatment of patients with Parkinson's disease.

- *New technologies for diagnosing early Alzheimer's disease.* BER investigators at the University of Pennsylvania, Pittsburgh, and the University of California, Irvine, developed three unique radiopharmaceutical agents that can pinpoint the brain plaque that is the cause of the mental deterioration in Alzheimer's disease. The radiotracers can be detected by Single Photon Emission Tomography (SPECT) and PET clinical imaging. Brain imaging to detect early lesions in Alzheimer's disease has become critically important with the advent of new drugs that can delay the onset of symptoms if the disease is diagnosed in the early stages.

- *New cancer treatment using radiopharmaceuticals.* BER investigators at Duke University have coupled astatine-211 to an antibody to deliver the radionuclide to cancer cells. This technology which utilizes specific radioisotope targeting of tumors with minimal effects on normal cells is presently being tested in a clinical trial at Duke.

- *NIH cancer treatment study initiated at DOE supported reactor at MIT.* The NIH has entered its first patients in a clinical trial to test the efficacy of boron neutron capture therapy in the treatment of malignant melanoma. The neutron beam development and clinical protocols were developed by research supported by BER. The MIT medical nuclear reactor is the best neutron source in the world for clinical studies and is being supported by BER for these NIH funded studies.

- *Sensitive chip to detect carcinogen effects.* BER investigators at Ames National Laboratory have developed a sensitive chip to detect the adducts which form when a carcinogen attaches to DNA. Adducts are the first step in the development of a cancerous cell. Fluorescent antibodies on the chip specifically bind to the adducts and may give investigators an early warning sign that the affected cell may transform into a cancer cell.

- *Using plant proteins to restore human vision.* BER-supported investigators at ORNL, in collaboration with investigators from the Doheny Eye Institute of the University of Southern California, have constructed a hybrid photosynthetic-mammalian system using the spinach photosystem I protein. The investigators successfully inserted the photosystem I protein into a human nerve cell, resulting in the cell becoming light sensitive. This technology has the potential to restore light sensitivity to defective photoreceptive cells in the eye.

- *Artificial retina research project established at USC.* BER has established a research project at the Doheny Eye Institute of USC for the preclinical testing of artificial retina prototypes developed in the DOE artificial retina project. The Doheny Eye Institute successfully inserted the third artificial retina into the eye of a blind patient with retinitis pigmentosa and that patient is undergoing clinical testing.

- *Progress in helping the blind to see.* The collaborative project between five National Laboratories (Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, Argonne National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratory) and the Doheny Eye Institute, University of California at Santa Cruz, North Carolina State, and Second Sight Corporation to develop an artificial retina achieved a number of notable technical successes. A new material, rubberized silicon, was micro machined and performed well in pre-clinical testing and will be used to support the multielectrode array. A novel technology using finely powdered diamond crystals was developed to hermetically seal the device to protect it in the eye for the lifetime of the patient.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Medical Applications	**86,704**	**175,206**	**36,942**
■ **Novel cell-directed cancer therapies**	**4,366**	**4,833**	**3,162**

In FY 2005, BER continues to support fundamental research on the therapeutic use of ionizing radiation that may be achieved with radionuclide therapy and novel methods of tumor targeting. Recent therapeutic successes employing antibodies or ligands linked to radionuclides has grown out of fundamental combinatorial radiochemistry supported by BER. The specific goals include the development of novel therapeutic agents and delivery techniques to target and treat cancer at the cellular level. Research will address such complex challenges as chemical ligand synthesis, tumor-targeting, and dosimetry.

Overall program objectives include: (1) techniques to ensure highly selective tumor-targeting by the proposed therapeutic agents; (2) efficient screening techniques for selecting candidate therapeutic agents for *in vivo* testing; (3) research suggesting a reasonable likelihood of success for *in vivo* targeting of primary tumors and their metastases in pre-clinical animal trials; (4) reliable approaches for dosimetry calculations to normal tissues and to tumor sites based on 3-dimensional modeling; (5) measurement techniques for accurately assessing the success of tumor-targeting *in vivo*; and (6) measurement techniques for assessing therapy effects *in vivo* at the molecular, cellular and metabolic levels.

FY 2004 was intended to be the final year of BER support for BNCT-related medical research reactors. BER's current role in BNCT is to complete the orderly transfer of the clinical BNCT programs to the National Cancer Institute (NCI). This primarily involves facility support for the two research reactors that were upgraded for BNCT applications with DOE funds. The MIT medical reactor is used to conduct the NCI-funded clinical trials, whereas the Washington State University reactor is designed for pre-clinical studies in animals. FY 2005 now provides the final year of BER support for these two reactors. BER will transfer this activity to NIH/NCI. BER also supports the BNCT dosimetry and support programs at INEEL and the core programs at Cornell University and INEEL to determine boron concentrations in biologic specimens.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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

▪ **Radiopharmaceutical Design and Synthesis**...	**22,844**	**24,266**	**24,407**

In FY 2005, BER will continue to support research on radiopharmaceutical design and synthesis using concepts from genomics as well as computational biology and structural biology. BER will continue research into radiolabeling of monoclonal antibodies for cancer diagnosis and new radiotracers for the study of brain and heart function. Molecules directing or affected by homeostatic controls always interact with each other and, thus, are targets for specific molecular substrates. The substrate molecules can be tailored to fulfill a specific need and labeled with appropriate radioisotopes to become measurable in real time in the body on their way to, and during interaction with their targets, allowing the analysis of molecular functions in the homeostatic control in health and disease. The function of radiopharmaceuticals at various sites in the body is imaged by nuclear medical instruments, such as, gamma ray cameras and positron emission tomographs (PET). This type of imaging refines diagnostic differentiation between health and disease at the molecular/metabolic levels leading to more effective therapy. If labeled with high-energy-emitting radioisotopes, the substrate molecules, carrying the radiation dose may be powerful tools for targeted molecular therapy especially of cancer. The program will continue to support development of new radiotracer and radiopharmaceutical molecules for PET imaging applications in normal and abnormal brain function cancer and to monitor stem cell trafficking in animals.

BER will also develop nuclear medicine driven technologies to image mRNA transcripts in real time in tissue culture and whole animals. Currently the expression of endogenous genes in animals (including humans) cannot be imaged, at least not directly. However, given the astounding pace of biotechnology development, such imaging is an attainable goal. This research includes an emphasis on nucleic acid biochemistry, radioactive ligand synthesis and macromolecular interactions. It addresses the functional consequences of gene expression by targeting and perturbing the activity of a particular gene in living cells or animals. It also develops new biological applications using optical and radionuclide imaging devices for imaging specific gene expression in real time in both animals and humans. Methods such as combinatorial chemistry techniques will be used to develop antisense radiopharmaceuticals that hybridize DNA probes to RNA transcripts in highly specific ways to block their activity or function. Molecular signal amplification methods that work *in vivo* at the mRNA level will be developed. Drug-targeting technology will be developed to such an extent that the various biological barriers can be safely surmounted *in vivo*. The research will evaluate the clinical potential of real-time imaging of genes at work in cells, tissues, and whole organisms, including humans. This information will have applications ranging from understanding the development of a disease to the efficacy of treatments for the disease. This new technology will strongly impact developmental biology, genome research, and medical sciences.

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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **Imaging Sciences Instrumentation and Research**	**11,409**	**9,309**	**9,373**

In FY 2005, BER will emphasize support in fundamental research to facilitate the development of imaging systems relevant to solving critical problems related to human health in the Nation. This program capitalizes on the unique resources at the National Laboratories in the fields of computational modeling, detector development, multimodal spectroscopy, high-field magnet development, and microelectronics. Imaging instrumentation and technology being developed includes: (1) the development of a high-density microelectronic array (the artificial retina) that can be packaged into a tiny device to be implanted in to the back of the eye, which will be used for the treatment of the major causes of blindness in the United States, retinitis pigmentosa and age-related macular degeneration; (2) PET and MRI instruments that will be used to study brain function in the awake individual, which will obviate the necessity of anesthetizing animals (inducing coma) to acquire brain images and may also have great potential for use with infants; (3) a range of image detector systems that will be more sensitive and cost effective than current instrumentation used in the diagnosis of human disease; and (4) novel biosensor devices that can detect specific molecules or biological processes important in human biology and disease and convert this information into a measurable signal. These devices can be adapted to rapidly diagnose microorganisms in the field.

BER's imaging technology program works closely with other Federal Agencies, especially the NIH, to help coordinate and focus the research efforts at the National Laboratories. Federal Agency partners include BECON and NIBIB at the National Institutes of Health.

The research activities in this subprogram are principally carried out at National Laboratories.

▪ **Congressional Direction**	**48,085**	**136,798**	**0**

Congressional direction was provided in FY 2003 for University of South Alabama Cancer Center; Institute for Biomedical Science and Biotechnology, University of Arizona; Vocational Education Programs at the Los Angeles Trade Technical College; Fuel Cell Advanced Materials and Demonstration Project at Humboldt State University; National Center for Neurogenetic Research and Computational Genomics at the University of Southern California; Magnetic Resonance Microscope at the Children's Hospital of Los Angeles; PET/CT Scanner at Christiana Care Health System; University of Southern Florida Center for Biological Defense; Barry University Minority Science Center; Natural Energy Laboratory in Hawaii; Riverside Hospital Regional Cancer Center; Bioengineering Research Program at the University of Illinois, Chicago; CT Scanner at Edward Hospital; Purdue University Technology Incubator in Northwest Indiana; University of Notre Dame College of Engineering Multidisciplinary Research Facility; Indiana Genomics Initiative at Indiana University; University of Northern Iowa Existing Business Enhancement Program; Stanley Scott Cancer Center; University of Louisiana-LaFayette National Wetlands Research Center; University of Southern Maine School of Applied Sciences, Engineering, and Technology; Morgan State University Center for Environmental Toxicology; Pioneer Valley Life Sciences Initiative between the University of Massachusetts and the Baystate Medical Center; Hampshire College National Center for Science Education; University of Massachusetts at Boston Multidisciplinary Research Facility and Library; Boston University Photonics Center; Michigan Western Michigan University Nanoscience Research and Computational Institute; Nanotechnology Applications at Western

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

Michigan University in Partnership with Altair; North Mississippi Health Services Positron Emission Tomography Cancer Center; University of Missouri-Columbia Nuclear Medicine and Cancer Research Program; Nevada Cancer Institute; Linear Accelerator at the University Medical Center of Southern Nevada; Nevada Space Grant Consortium at the Desert Research Institute; Drew University Hall of Science; Public Health Research Institute Rapid Detection for Bioterrorism Program in New Jersey; Operations and Capital Investments at the Mental Illness and Neuroscience Discovery Institute (MIND); Environmental Systems Center at Syracuse University; Audubon Biomedical Science and Technology Park at Columbia University ; Center for Sustainable Energy at the Bronx Community College; New York University Genomics Project; Wittenberg University Science Center, Infrastructure and Equipment; Legume Genome Initiative at the University of Oklahoma; Green Chemistry Project at Carnegie Mellow University; Medical University of South Carolina; Center for Environmental Radiation Studies at Texas Tech University; Inland Northwest Natural Resources Research Center at Gonzaga University; and International Water Institute.

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 technologyupgrade 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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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.

Measurement Science	**2,296**	**5,917**	**5,952**

In FY 2005 BER will continue research and development of biomedical sensors, including micromechanical and microelectronic sensors and devices, with a broad range of biomedical applications including neural prostheses, such as the artificial retina, and detection of carcinogen damage to DNA. Fundamental research in the biomedical application of microelectronics, particularly with reference to neural prostheses, including the artificial retina, will continue. This research will include biocompatible chip design, dual band telemetry (for receiving and sending signals), and development of human interface software and design of multiplex electronics that can be directly applied to devices interfacing with the nervous system.

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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
SBIR/STTR	**0**	**5,218**	**1,204**

In FY 2003 $2,271,000 and $137,000 were transferred to the SBIR and STTR programs, respectively. FY 2004 and FY 2005 amounts are the estimated requirements for continuation of these programs.

Total, Medical Applications and Measurement Science	**89,000**	**186,341**	**44,098**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Medical Applications & Measurement Science	
▪ FY 2004 was intended to be the final year of BER support for medical reactor operations. To facilitate an orderly transition of these reactors to NIH/NCI, novel cell-directed cancer therapies research decreases to provide one final year of support for medical reactor operations in FY 2005.	-1,671
▪ Radiopharmaceutical Design and Synthesis funding restored to FY 2004 level prior to rescission.	+141
▪ Imaging Sciences Instrumentation and Research funding restored to FY 2004 level prior to rescission.	+64
▪ Congressionally-directed projects completed.	-136,798
▪ Measurement Science funding restored to FY 2004 level prior to rescission.	+35
▪ SBIR/STTR decreases as research program decreases	-4,014
Total Funding Change, Medical Applications and Measurement Science	-142,243

Construction

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Construction (PED)...............................	0	0	5,000	+5,000	+100.0%

Description

Construction is needed to support the research under the Biological and Environmental Research (BER) program. Cutting-edge basic research requires that state-of-the-art facilities be built or existing facilities modified to meet unique BER requirements.

Benefits

The first Genomics: GTL facility, the Facility for the Production and Characterization of Proteins and Molecular Tags, will surmount a principal roadblock to whole-system analysis by implementing high-throughput production and characterization of microbial proteins. It also will generate protein-tagging reagents for identifying, tracking, quantifying, controlling, capturing, and imaging individual proteins and molecular machines in living systems. Over the next 10 years, our goal is to produce 250,000 proteins in milligram quantities; around 1 million molecular tags for those proteins; and multiple biophysical characterizations of each, beginning with an organism's genomic sequence.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Construction	**0**	**0**	**5,000**

- Initiate Project Engineering and Design (PED) for the Genomics: GTL Facility for the Production and Characterization of Proteins and Molecular Tags. 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 2005 vs. FY 2004 ($000)
Construction	
▪ Funding is initiated for the Project Engineering and Design for the Genomics: GTL Facility for the Production and Characterization of Proteins and Molecular Tags.	+5,000
Total Funding Change, Construction	**+5,000**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Plant Projects	4,749	4,811	5,584	+773	+16.1%
Capital Equipment	24,257	21,788	19,625	-2,163	-9.9%
Total Capital Operating Expenses	29,006	26,599	25,209	-1,390	-5.2%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp.	FY 2003	FY 2004	FY 2005	Unappro-priated Balance
PED, 05-SC-004 Production and Characterization of Proteins and Molecular Tags	5,000	0	0	0	5,000	0
Total, Construction		0	0	0	5,000	0

05-SC-004, Project Engineering Design (PED), Facility for the Production and Characterization of Proteins and Molecular Tags

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)
	A-E Work Initiated	Completed A-E Work	Physical Construction Start	Physical Construction Complete	
FY 2005 Budget Request *(Current Estimate)*......................	1Q 2005	2Q 2006	N/A	N/A	5,000[a]

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2005	5,000	5,000	3,000
2006	0	0	2,000

3. Project Description, Justification and Scope

This PED request provides for Title I and Title II Architect-Engineering (A-E) services for the first Genomics: GTL facility - the Facility for Production and Characterization of Proteins and Molecular Tags. The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design, working drawings and specifications, and provide construction schedules including procurements. The design effort will ensure that construction can physically start or long-lead procurement items can be procured in the fiscal year in which Title III construction activities are funded.

Genomics: GTL User Facilities

Genomic information is providing the starting point for understanding the instructions for the manufacture of all of life’s molecular machines and the systems needed to control and operate them. Understanding, not “simply” decoding, the operation, function, and coordination of genome information will be the next transforming phase in biology. From experience gained in sequencing genomes and conducting large scale biology projects, we have learned that the combined capabilities and imagination of biological, physical, and computational scientists will be needed to organize creative new venues for discovery.

[a] The full Total Estimated Cost (design and construction) ranges between $170,000,000 and $200,000,000. This estimate was based on preliminary data and should not be construed as a project baseline.

The central goal of the Genomics: GTL program is to understand the microbes and communities of microbes, and their molecular machines at the molecular level to address DOE and national needs. The DOE Office of Science has the ability and institutional traditions to bring the biological, physical, and computing sciences together at the scale and complexity required for Genomics: GTL success.

The Facility for the Production and Characterization of Proteins and Molecular Tags will implement high-throughput production of and characterization of microbial proteins.

This resource will help build a bridge between large and small laboratories by making the most sophisticated and comprehensive technologies, materials, and information equally available to all scientists. Using combinations of new equipment and technologies, automation, data management, and data analysis tools, this user facility will provide the Genomics: GTL program and the scientific community with an unprecedented resource for systems biology.

SC has determined that the site selection strategy for this facility will be based upon a competition within the DOE laboratory system. This facility will be a high throughput production facility that will produce or isolate hundreds of proteins or molecular tags. It will likely require a close working relationship with other facilities and resources such as synchrotron light sources and neutron sources that will provide some of the many resources that will be needed to characterize the products of this facility. This facility will also be highly dependent on the development and use of robotics for many aspects of the protein and molecular tag production lines. Finally, high performance computational resources will be required to plan, monitor, and characterize both the production, characterization, and inventory aspects of this facility. All of these features are necessary to ensure that this facility provide high quality, reproducible products to the scientific community and users of this facility. The National Laboratory setting will be essential for this facility, for the National Laboratories provide both the necessary experience in developing and operating large multi-disciplinary high-throughput facilities, and the close proximity to the associated specialized technological resources cited above.

Key performance criteria under consideration for selecting a contract and for inclusion in the resultant contract include maximizing the involvement of the full scientific community in the design, construction, and use of this facility and ensuring broad public notice to universities and other potential users of the need for input in the design, construction, and use of this facility. A tentative schedule for the Facility for the Production and Characterization of Proteins and Molecular Tags includes a solicitation for site selection in February 2004, followed by an information workshop approximately one month after the solicitation, and review and site selection in the summer of 2004. The Project Engineering and Design datasheet will then be updated to identify the project site.

FY 2005 Proposed Design Projects

05-01: Facility for the Production and Characterization of Proteins and Molecular Tags

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2005	2Q 2006	N/A	N/A	5,000 [a]	N/A[a]

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2005	5,000	5,000	3,000
2006	0	0	2,000

The Facility for the Production and Characterization of Proteins and Molecular Tags, will surmount a principal roadblock to whole-system analysis by implementing high-throughput production and characterization of microbial proteins. It also will generate protein-tagging reagents for identifying, tracking, quantifying, controlling, capturing, and imaging individual proteins and molecular machines in living systems. Over the next 10 years, our goal is to produce 250,000 proteins in milligram quantities; around 1 million molecular tags for those proteins; and multiple biophysical characterizations of each, beginning with an organism's genomic sequence.

Research is being conducted in the Genomics: GTL program to develop the core technologies that will underpin the high throughput capabilities of this facility including the development of technologies for the high-throughput synthesis of proteins and their biophysical characterization and for the production of molecular tags to identify individual proteins and to characterize multi-protein complexes in microbial cells.

It is recognized that no satisfactory general approach currently exists for the production of proteins in the laboratory from DNA sequences and that not all proteins will likely yield to the same techniques. It is expected that a variety of both cell-free and cell-based systems will be required, as well as multiple characterization methods. Production and characterization technologies should be scalable, economic, and sufficiently robust to work in a production environment. Another early need is the development of improved techniques for predicting from sequence what production and purification approaches are most likely to succeed with each protein. Thus, informatics is an integral component. Algorithms based on data from successful and failed protein expressions are expected to substantially inform and improve future protein production efficiency. Informatics coupled with biophysical characterizations are expected to provide functional insights that may also explain why such a large number of biologically important, full-length proteins either can not be expressed in soluble form, or have structures that cannot

[a] The full Total Estimated Cost (design and construction) ranges between $170,000,000 and $200,000,000. This estimate was based on preliminary data and should not be construed as a project baseline.

be determined once expressed. These proteins may include substantial disordered regions that adopt structures only after interaction with appropriate protein binding partners. Reliable predictive algorithms based on expression and characterization databases are therefore needed to predict disorder and binding partners.

Research is being and will be supported to:

- Optimize cloning and clone validation techniques to support the protein production process.
- Optimize cell-free and cellular expression methods.
- Optimize protein purification protocols.
- Improve strategies for increasing the fraction of proteins that can be synthesized by automated methods. This may include sequence-based predictions of methods most likely to succeed and insights for optimization of expression protocols.
- Optimize high-throughput, economical approaches for characterizing synthesized protein to assess product quality and to predict protein function such that each protein produced will be characterized biophysically under several conditions.

Research is also being supported to advance the technology needed to mass-produce molecular tags for proteins and protein complexes as tools to be used for determining function. As a top priority, technologies are being developed for mass-producing specific protein recognition tags capable of functioning as capture reagents in affinity extraction and purification protocols and as labeling reagents for intracellular and *'in situ'* localization and mapping studies. As for protein production strategies, these technologies must also be scalable to permit large numbers of useable molecular tags to be produced and characterized per year at affordable costs. None of the many approaches under development to address this problem have yet demonstrated sufficient scalability. It is assumed that purified protein 'targets' will be provided to the researchers in micro-gram to milligram quantities so that tags can be optimized and characterized. Tags that interfere with function as well as those that do not interfere with protein function are both needed to help better define the biological roles of proteins.

Research is being and will be supported to:

- Develop scalable methods for producing 'epitope-directed' affinity reagents of high specificity and affinity for proteins capable of functioning either as affinity extraction and capture reagents or as intra-cellular labeling reagents. High success ratios (fraction of protein epitopes yielding useful reagents) are essential.
- Improve protein-directed affinity tag design to improve tag utility, e.g., to facilitate subsequent purification and or/imaging, to facilitate release of the tagged protein, to image with and without disrupting activity, etc.
- Improve methods for developing tags directed specifically to protein complexes as distinct from their component proteins. Labeling complexes with and without disrupting interactions amongst protein components will provide important functional insights.

- Improve strategies for predicting, from sequence data, what potential protein epitopes are likely to be successful targets for tagging with and without interfering with function, and for predicting what tag development methods are likely to work for a particular protein/epitope.
- Develop imaging and labeling methods for multiplex mapping of proteins within cells. Simultaneously monitoring multiple labeled proteins will provide more comprehensive views of multi-protein complexes and their activities.
- Optimize informatics tools both for managing tag production processes and for managing the data resulting from their use

The Facility for the Production and Characterization of Proteins and Molecular Tags will be a user facility that integrates the necessary basic research, technology and automation to enable (1) the production and characterization of all proteins expressed by a genome and (2) the generation of affinity reagents to each protein. The goal of the facility will be to make possible rapid experimental characterization of the function of gene products on the scale of whole genomes.

Protein production will utilize multiple bacterial expression systems; cell free expression; and chemical synthesis methods. Protocols for automated expression, purification and characterization of proteins will be optimized for multiple classes of soluble proteins; membrane proteins; periplasmic proteins; and very small or very large proteins. Cloning, expression, purification, quality assurance (QA) and characterization will be carried out by automated systems directly linked to the Laboratory Information Management System (LIMS). Clones, proteins and affinity tags will be shipped to collaborators at other DOE laboratories, universities and corporate partners for further functional characterization.

Comprehensive protein characterization will include a QA suite to demonstrate that the proper proteins have been produced and to determine the physical state of the proteins. This suite will include mass spectrometry and DNA sequencing for protein identification; dynamic light scattering to assess solubility and ultra violet spectrometry.

Bioinformatics will be used to make an initial assignment of protein function where possible. Further characterization will be designed to elaborate on this assignment and identify additional biophysical and biochemical clues as to protein function. Biophysical characterization techniques to be used include circular dichroism to assess secondary structure; small angle x-ray scattering to determine quaternary structure; x-ray absorption fine structure to determine metal content and the environment of metal ions; wide-angle x-ray scattering to determine the quaternary structure as well as assignment of a structural fold. Biochemical characterizations will include mass spectrometry to identify co-factors and bound ligands; binding assays to the most common small molecule ligands; and high-throughput enzymatic assays for the most common biochemical activities.

The facility will be run by an advanced Laboratory Information Management System (LIMS) that will be capable of predicting the optimum method for production and purification of any protein based on its amino acid sequence and past experimental outcomes. The LIMS will collect experimental data from automated systems as well as manual input from handheld computers in a completely wireless environment. The results of expression, purification, quality assurance and characterization experiments will be automatically fed into a database of protein properties accessible through web-based servers. Results of experiments that are both successes and failures will be available to guide future work.

At least 50% of all proteins are anticipated to pose significant problems for any current production method. Consequently a significant component of the protein production and characterization facility will be research into new methods of protein production and into automation of existing methods of expression, purification and characterization. Proteins that cannot at present be readily produced include most membrane proteins, high molecular weight proteins, toxic and unstable proteins, proteins with unknown co-factors and proteins that are integral parts of complexes. Consequently a significant research effort will be needed to (i) address the 50% of all proteins that currently cannot be produced in milligram quantities in soluble, native conformations (ii) automate all portions of the multiple synthetic routes needed (iii) automate the purification and characterization of all proteins (iv) devise informatic methods to predict optimal strategies for each protein to be produced (v) develop novel libraries of affinity tags, advanced methods of library production and methods for screening these libraries.

The primary production facility will include approximately 125,000 to 175,000 sq. ft. consisting of laboratory space for production, as well as research, office and administrative space. A protein characterization network including researchers from multiple national laboratories and universities will utilize the proteins and affinity tags produced in the facility and feed the results of characterization experiments into the central facility database.

4. Details of Cost Estimate [a]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	3,600	N/A
Design Management costs (13.9% of TEC)	700	N/A
Project Management costs (13.9% of TEC)	700	N/A
Total Design Costs (100% of TEC)	5,000	N/A
Total, Line Item Costs (TEC)	5,000	N/A

5. Method of Performance

Site selection will be made based on a complete scientific, technical, and project management review of offers received. Conceptual design of the facility and technical equipment will be completed by the fourth quarter of FY 2005 to establish an appropriate cost range and conceptual scope. PED will be utilized to perform preliminary and final design of the building; and engineering, design, and development of the technical equipment. Design services will be obtained through competitive and/or negotiated contracts. Site staff may be utilized in areas involving security, production, proliferation, etc.

[a] These costs reflect only those associated with design phase activities only.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2003	FY 2004	FY 2005	Outyears	Total
Facility Cost						
PED	0	0	0	3,000	2,000	5,000
Other Project Costs						
Conceptual Design Costs	0	0	850	150	0	1,000
NEPA Documentation	0	0	150	50	0	200
Total, Other Project Costs	0	0	1,000	200	0	1,200
Total Project Cost (TPC)	0	0	1,000	3,200	2,000	6,200

Basic Energy Sciences

Funding Profile by Subprogram

	(dollars in thousands)				
	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Basic Energy Sciences					
Research					
Materials Sciences and Engineering	533,552	575,711	-3,355[a]	572,356	603,228
Chemical Sciences, Geosciences, and Energy Biosciences	211,898	220,914	-1,332[a]	219,582	228,422
Subtotal, Research	745,450	796,625	-4,687	791,938	831,650
Construction	256,491	219,950	-1,297[a]	218,653	231,880
Subtotal, Basic Energy Sciences.	1,001,941	1,016,575	-5,984[a]	1,010,591	1,063,530
Use of Prior Year Balances	0	-2,291	0	-2,291	0
Total, Basic Energy Sciences	1,001,941[bcde]	1,014,284	-5,984[a]	1,008,300	1,063,530

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.

[a] Excludes a rescission of $5,984,276 in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H. Rpt. 108-401 dated November 25, 2003.

[b] Excludes $437,000 transferred to Security Operations in FY 2004 for waste management activities at the New Brunswick Laboratory.

[c] Excludes $16,584,000 which was transferred to the SBIR program and $995,000 which was transferred to the STTR program.

[d] Excludes $6,654,740 for a rescission in accordance with the Consolidated Appropriations Resolution, FY 2003.

[e] Includes $2,806,481 for the Emergency Wartime Supplemental Appropriations for FY 2003.

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 and combat terrorism. As part of its mission, the BES program plans, constructs, and operates major scientific user facilities to serve researchers at universities, national laboratories, and industrial laboratories.

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

A key strategic emphasis of these subprograms is to lead the nanoscale science revolution, delivering 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 the development of advanced tools and instruments for x-ray, neutron, and electron diffraction, scattering, and imaging and for other advanced probes of matter for exploration and discovery in materials sciences and engineering; chemistry; earth, environmental, and geosciences; and plant and biosciences. 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 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 contributes to this goal by managing the Combustion Research Facility at Sandia National Laboratories in Livermore, California, an internationally recognized facility for the study of combustion science and technology.

Annual Performance Results and Targets

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
Program Goal 5.22.00.00 Advance the Basic Science for Energy Indpendence					
Materials Sciences and Engineering					
N/A	N/A	N/A	N/A	Improve Spatial Resolution: Demonstrate first measurement of spatial resolutions for imaging in the hard x-ray region of <115 nm and in the soft x-ray region of <19 nm, and spatial information limit for an electron microscope of 0.08 nm.	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 temporal resolution: Demonstrate first measurement of x-ray pulses that are <200 femtoseconds in duration and have an intensity of >5,000 photons per pulse.	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).
Chemical Sciences, Geosciences, and Energy Biosciences					
N/A	N/A	N/A	N/A	As a part of the Scientific Discovery through Advanced Computing (SciDAC) program, perform a three-dimensional combustion reacting flow simulation involving more than 44 reacting species and 500,000 grid points.	As a part of the SciDAC program, perform a three-dimensional combustion reacting flow simulation involving more than 44 reacting species and 7 billion grid points.

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
Materials Sciences and Engineering					
Scientific user facilities were maintained and operated to achieve an average at least 90 percent of the total scheduled operating time. [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90 percent of the total scheduled operating time. [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90 percent of the total scheduled operating time. [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90 percent of the total scheduled operating time. [Met Goal]	Maintain and operate the scientific user facilities to achieve an average at least 90 percent of the total scheduled operating time.	Maintain and operate the scientific user facilities to achieve an average at least 90 percent of the total scheduled operating time.
Construction					
Cost and timetables were maintained within 10 percent 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 percent 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 percent 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 percent of the baselines given in the construction project data sheets for all construction projects ongoing during the year. [Met Goal]	Meet the cost and timetables within 10 percent of the baselines given in the construction project data sheets for all ongoing construction projects.	Meet the cost and timetables within 10 percent 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, U.S. Department of Agriculture, Department of Interior, and National Institute 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 held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART) Assessment

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

In the PART review, OMB gave the Basic Energy Sciences (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. However, OMB noted concerns regarding the collection and reporting of performance data. To address these concerns, BES will work with its Advisory Committee to develop research milestones for the long-term performance goals, will include the long term research goals in grant solicitations, will work to improve performance reporting by grantees and contractors, and will work with the CFO to improve BES sections of the Department's performance documents. BES role in providing scientific research facilities is strongly supported by the Administration. OMB noted concerns regarding underutilization and poor performance reporting at some BES facilities. Funding is provided in FY 2005 to operate the program's main major scientific user facilities at maximum capacity. BES will continue to improve performance reporting and centralize management and planning of operations at its user facilities.

Funding by General and Program Goal

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Basic Energy Sciences					
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	533,552	572,356	603,228	+30,872	+5.4%
Chemical Sciences, Geosciences and Energy Biosciences	211,898	219,582	228,422	+8,840	+4.0%
Construction	256,491	218,653	231,880	+13,227	+6.0%
Total, Program Goal 5.22.00.00 Advance the Basic Science for Energy Independence	1,001,941	1,010,591	1,063,530	+52,939	+5.2%
Use of Prior Year Balances	0	-2,291	0	+2,291	+100.0%
Total, Basic Energy Sciences	1,001,941	1,008,300	1,063,530	+55,230	+5.5%

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 2003, the program funded research in more than 143 academic institutions located in 47 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; and on a 20-year roadmap for BES facilities. 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 at: http://www.sc.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 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 (1) the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document proposal actions and (2) the quality of the resulting portfolio, specifically the breadth and depth of portfolio elements and the national and international standing of the elements. The first reviews assessed the chemistry activities (FY 2002) and the materials sciences and engineering activities (FY 2003). In FY 2004, the activities associated with the management of the scientific user facilities will be assessed. The cycle will begin again in FY 2005, so that all elements of the BES program will be reviewed once every three years.

Planning and Priority Setting

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

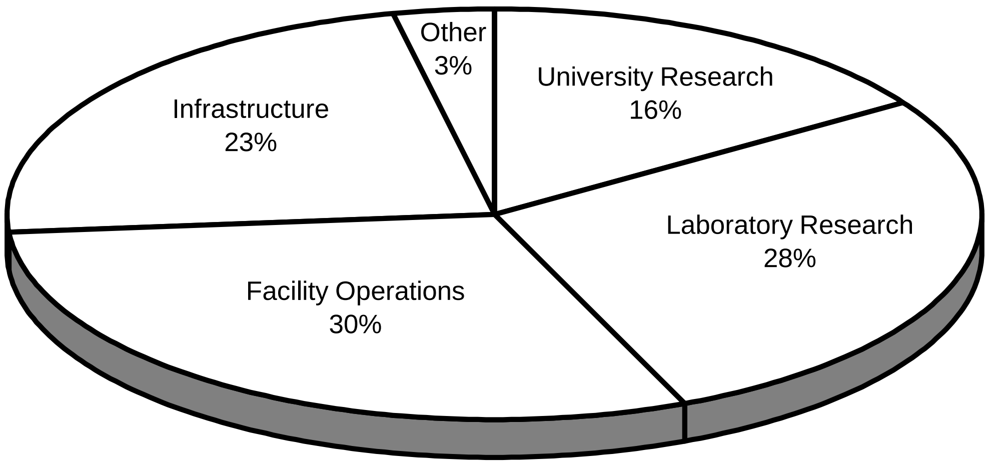
Inputs to our prioritization include overall scientific opportunity, projected investment opportunity, DOE mission need, and Administration and Departmental priorities. During the past few years, these considerations have led to: increased investments in science at the nanoscale to take advantage of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

The FY 2005 budget request continues priorities established in the past few years. Construction of the Spallation Neutron Sources continues in accord with the established baseline. A significant investment in the area of nanoscale science includes construction funding for four 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 is providing $36,000,000 in FY 2003 and FY 2004 for the construction of the building. BES funding will provide clean rooms, instrumentation, and ultimately operations support for the Center. Project Engineering Design funding is also provided for the Linac Coherent Light Source, a 4th generation light source that will provide orders of magnitude higher intensities of x-ray light than do current synchrotron radiation light sources. 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.

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, construction, and long-lead procurement remain significant budget components in FY 2005, including the Spallation Neutron Source, Nanoscale Science Research Centers, and the Linac Coherent Light Source.

Basic Energy Sciences Budget Allocation
FY 2005



Research

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

National Laboratory Research: Research sited at DOE laboratories often takes advantage of the premier scientific user facilities for x-ray, neutron, and electron beam scattering at the laboratories as well as other specialized facilities, such as hot cells, which are not typically found at universities. Mission critical research is also sited at DOE laboratories when it 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.

Significant Program Shifts

In FY 2005, Project Engineering Design (PED) and construction will proceed on four Nanoscale Science Research Centers (NSRCs) and funding will be continued for a Major Item of Equipment for the fifth NSRC. NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. They are designed to enable the nanoscale revolution by collocating multiple research disciplines, 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.

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."

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

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

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

Nanoscale Science Research Funding

	TEC	TPC	FY 2003	FY 2004	FY 2005
Research					
Materials Sciences and Engineering..			65,018	74,355	66,995
Chemical Sciences, Geosciences, and Biosciences......................			26,726	28,190	28,360
Capital Equipment					
Major Item of Equipment -- ANL, Center for Nanoscale Materials......			0	10,000	12,000
Nanoscale Science Research Centers					
PED – All sites..			11,850	2,982	2,012
Construction					
BNL, Center for Functional Nanomaterials.........................	79,700	81,000	0	0	18,465
LBNL, Molecular Foundry..........	83,700	85,000	0	34,794	32,085
ORNL, Center for Nanophase Materials Sciences..................	63,882	64,882	23,701	19,882	17,811
SNL/A and LANL, Center for Integrated Nanotechnologies.....	73,800	75,800	4,444	29,674	30,897
Total BES Nanoscale Science Funding...			131,739	199,877	208,625

In FY 2005, $29,183,000 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.er.doe.gov/production/bes/hydrogen.pdf. The 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 ten or more 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. The only hope of narrowing the gap significantly is 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. The areas targeted for increased funding, include: low-cost and efficient solar energy production of hydrogen, nanoscale catalyst design, biological, biomimetic, and bio-inspired materials and processes, complex hydride materials for hydrogen storage, nanostructured and other novel hydrogen storage materials, theory, modeling, and simulation of materials and molecular processes, low-cost, highly active, durable cathodes for low-temperature fuel cells, membranes and separations processes for hydrogen production and fuel cells, and analytical and measurement technologies. The new work is by its nature multidisciplinary and touches virtually all of the BES research activities. The work will be coordinated by a team of program managers and will have annual contractors' meetings to promote cohesion and rapid information exchange. This activity will be a part of the President's Hydrogen Initiative and will be coordinated with the DOE technology programs and with other Federal agencies through the Office of Science and Technology Policy's Hydrogen R&D Task Force.

President's Hydrogen Initiative

	FY 2003	FY 2004	FY 2005
Materials Sciences and Engineering Research	3,025	3,063	14,761
Chemical Sciences, Geosciences, and Biosciences	4,615	4,674	14,422
Total Hydrogen Initiative	7,640	7,737	29,183

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: characterizing chemically reacting flows as exemplified by combustion and 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 molecular where the physical descriptions are discrete in nature to 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. In the past year, 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 level of operations will be equal to that in FY 2004. 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 2001 Actual*	FY 2002 Actual*	FY 2003 Actual*	FY 2004 Estimate	FY 2005 Estimate
All Facilities					
Maximum Hours	36,800	36,800	36,800	36,800	36,800
Scheduled Hours	27,563	31,215	31,400	31,350	35,450
Unscheduled Downtime	4%	4%	9%	<10%	<10%
Number of Users	6,982	7,603	8,218	8,280	8,530
Advanced Light Source					
Maximum Hours	5,700	5,700	5,700	5,700	5,700
Scheduled Hours	5,468	5,236	5,530	5,700	5,700
Unscheduled Downtime	4%	7%	5%	<10%	<10%
Number of Users	1,163	1,385	1,662	1,500	1,600
Advanced Photon Source					
Maximum Hours	5,700	5,700	5,700	5,700	5,700
Scheduled Hours	5,000	4,856	4,912	5,700	5,700
Unscheduled Downtime	4%	3%	3%	<10%	<10%
Number of Users	1,989	2,299	2,767	2,400	2,500
National Synchrotron Light Source					
Maximum Hours	5,700	5,700	5,700	5,700	5,700
Scheduled Hours	5,556	5,818	5,570	5,700	5,700
Unscheduled Downtime	0%	3%	6%	<10%	<10%
Number of Users	2,523	2,413	2,206	2,500	2,500
Stanford Synchrotron Radiation Laboratory					
Maximum Hours	5,300	5,300	5,300	5,300	5,300
Scheduled Hours	4,781	4,706	2,841	2,000	5,000
Unscheduled Downtime	5%	5%	3%	<10%	<10%
Number of Users	907	1,023	867	1,000	1,000

* Scheduled hours for FY 2001, FY 2002, and FY 2003 show actual number of hours delivered to users.

	FY 2001 Actual*	FY 2002 Actual*	FY 2003 Actual*	FY 2004 Estimate	FY 2005 Estimate
High Flux Isotope Reactor					
Maximum Hours	6,100	6,100	6,100	6,100	6,100
Scheduled Hours	8	4,111	5,256	5,000	6,100
Unscheduled Downtime	0%	3%	20%	<10%	<10%
Number of Users....................................	38	76	218	400	400
Intense Pulsed Neutron Source					
Maximum Hours	4,700	4,700	4,700	4,700	4,700
Scheduled Hours	3,868	4,308	4,274	4,250	4,250
Unscheduled Downtime	0%	0%	7%	<10%	<10%
Number of Users	240	243	229	280	280
Manuel Lujan, Jr. Neutron Scattering Center					
Maximum Hours	3,600	3,600	3,600	3,600	3,600
Scheduled Hours	2,882	2,180	3,017	3,000	3,000
Unscheduled Downtime	18%	12%	21%	<10%	<10%
Number of Users	122	164	269	200	250

Cost and Schedule Variance

	FY 2001 Actual	FY 2002 Actual	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate
Spallation Neutron Source					
Cost Variance...................................	+0.4%	-0.3%	+0.5%		
Schedule Variance	-6.7%	-1.8%	-1.4%		
Major (Levels 0 and 1) Milestones Completed or Committed to	None	Linac Design Completed	Front End Beam Available to Linac Target Design Complete Linac Tunnel Beneficial Occupancy Ring Tunnel Beneficial Occupancy	None	Instrument Systems Design Complete Linac Beam Available to Ring

* Scheduled hours for FY 2001, FY 2002, and FY 2003 show actual number of hours delivered to users.

	FY 2001 Actual	FY 2002 Actual	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate
Linac Coherent Light Source (SLAC)					
Cost Variance	N/A	N/A	N/A		
Schedule Variance	N/A	N/A	N/A		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approved Critical Decision 0 – Mission Need	None	Approved Critical Decision 1 – Preliminary Baseline Range Approved Critical Decision 2a – Long-Lead Procurement Budget	Approve Critical Decision 2b – Performance Baseline	
Center for Nanophase Materials Sciences (ORNL)					
Cost Variance	N/A	N/A	0%		
Schedule Variance	N/A	N/A	0%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approved Critical Decision 0 – Mission Need	Approved Critical Decision 1 – Preliminary Baseline Range Approved Critical Decision 2 – Performance Baseline	Approved Critical Decision 3 – Start of Construction	Approve Critical Decision 4a – Initial Start of Operations	
Center for Integrated Nanotechnologies (SNL/LANL)					
Cost Variance	N/A	N/A	-0.4%		
Schedule Variance	N/A	N/A	-2.9%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approved Critical Decision 0 – Mission Need	Approved Critical Decision 1 – Preliminary Baseline Range	Approved Critical Decision 2 – Performance Baseline	Approve Critical Decision 3a – Start Utility Construction Approve Critical Decision 3b – Start of Full Construction	None

	FY 2001 Actual	FY 2002 Actual	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate
The Molecular Foundry (LBNL)					
Cost Variance	N/A	N/A	+1.0%		
Schedule Variance	N/A	N/A	+1.4%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approved Critical Decision 0 – Mission Need	Approved Critical Decision 1 – Preliminary Baseline Range	Approved Critical Decision 2 – Performance Baseline	Approve Critical Decision 3 – Start Construction	None
Center for Nanoscale Materials (ANL)					
Cost Variance	N/A	N/A	N/A		
Schedule Variance	N/A	N/A	N/A		
Major (Levels 0 and 1) Milestones Completed or Committed to			Approved Critical Decision 0 – Mission Need Approved Critical Decision 1 – Preliminary Baseline Range	Approve Critical Decision 2 – Performance Baseline Approve Critical Decision 3 – Start Construction	None
Center for Functional Nanomaterials (BNL)					
Cost Variance	N/A	N/A	N/A		
Schedule Variance	N/A	N/A	N/A		
Major (Levels 0 and 1) Milestones Completed or Committed to		Approved Critical Decision 0 – Mission Need	Approved Critical Decision 1 – Preliminary Baseline Range	Approve Critical Decision 2 – Performance Baseline	Approve Critical Decision 3 – Start Construction
SSRL SPEAR3 Upgrade					
Cost Variance	+0.3%	+2.0%	0%		
Schedule Variance	-7.8%	-1.6%	0%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approved Preliminary Safety Assessment Document	Completed RF System Production Completed Magnet Production	Approved Final Safety Assessment Document Completed Vacuum System Production	Complete Accelerator Readiness Review Start Commission-ing	None

	FY 2001 Actual	FY 2002 Actual	FY 2003 Actual	FY 2004 Estimate	FY 2005 Estimate
			Completed Raft Assemblies	Approve Critical Decision 4 – Start Operations	
			Completed Major Installation		

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 2005 budget authority is requested to continue R&D, procurement, and installation of equipment for instrument systems. The extraction dump, high-energy beam transport, and accumulator ring will be commissioned; and installation and testing for the ring-target beam transport system will be performed. Preparation for the ring-target beam transport system accelerator readiness review will begin. Installation and testing will be completed and preparation for the accelerator readiness review will start for target systems. Conventional facilities construction will be completed. Procurement, installation, and testing will continue for integrated control systems.

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

Linac Coherent Light Source (LCLS) Project

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

1.5 - 15 Å range. The characteristics of the light from the LCLS will open new realms of scientific applications in the chemical, material, and biological sciences including fundamental studies of the interaction of intense x-ray pulses with simple atomic systems, structural studies on single nanoscale particles and biomolecules, ultrafast dynamics in chemistry and solid-state physics, studies of nanoscale structure and dynamics in condensed matter, and use of the LCLS to create plasmas.

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

The preliminary Total Estimated Cost (TEC) is in the range of $220,000,000 to $260,000,000. FY 2005 Project Engineering Design (PED) funding of $20,075,000 is requested for Title I and Title II design work and $4,000,000 is requested for research and development. Additional information on the LCLS Project is provided in the LCLS PED data sheet, project number 03-SC-002.

In addition, FY 2005 Long-lead Procurement (LLP) funding of $30,000,000 is requested for selected components of the gun laser, the electron injector, and the linac system. Additional information on the LLP is provided in the LCLS construction datasheet, project number 05-R-320.

Nanoscale Science Research Centers (NSRCs)

Funds are requested for Project Engineering Design (PED) and construction of NSRCs located at Oak Ridge National Laboratory, 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-312, 03-R-313, 04-R-313, and 05-R-321; in the Project Engineering Design (PED) data sheet, project number 02-SC-002; and in the Materials Sciences and Engineering subprogram.

Stanford Synchrotron Radiation Laboratory (SSRL) Upgrade

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade was undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The upgrade increased injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decreased beam emittance by a factor of 7 to increase beam brightness; increased operating current from 100 mA to 200 mA to increase beam intensity; and maintained long beam life time (>25 hr). The increased photon flux will greatly improve performance in a variety of applications including powder and thin film diffraction, topographic studies, surface microcontamination studies, x-ray tomographic analysis, x-ray absorption studies, and protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring were replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC was $29,000,000; DOE and NIH equally funded the upgrade with a total Federal cost of $58,000,000. NIH provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and $1,000,000 in FY 2001.

BES provides funding for general plant projects (GPP) and general plant equipment (GPE) for Argonne National Laboratory, Ames Laboratory, and Oak Ridge National Laboratory.

Workforce Development

The BES program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. In addition, the BES scientific user facilities provide outstanding hands-on research experience to many young scientists. Thousands of students and post-doctoral investigators are among the 8,000 researchers who conduct experiments at BES-supported facilities each year. The work that these young investigators perform at BES facilities is supported by a wide variety of sponsors including BES, other Departmental research programs, other federal agencies, and private institutions. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research and also provides talent for a wide variety of technical and industrial areas that require the problem solving abilities, computing skills, and technical skills developed through an education and experience in fundamental research.

	FY 2001	FY 2002	FY 2003	FY 2004 Enacted	FY 2005 Request
# University Grants	1,094	1,071	1,100	1,200	1,270
Average Size ($ thousands/yr)	134	140	145	145	150
# Permanent Ph.D.s	3,780	3,650	3,800	3,970	4,050
# Postdocs	1,090	1,050	1,100	1,150	1,200
# Grad Students	1,780	1,700	1,750	1,800	1,900

Materials Sciences and Engineering

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Materials Sciences and Engineering					
Materials Sciences and Engineering Research	252,539	263,929	275,543	+11,614	+4.4%
Facilities Operations	281,013	294,517	312,854	+18,337	+6.2%
SBIR/STTR	0	13,910	14,831	+921	+6.6%
Total, Materials Sciences and Engineering	533,552	572,356	603,228	+30,872	+5.4%

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.

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

Selected FY 2003 Research Accomplishments

- *Towards an Exciton Condensate – A New Form of Matter*. A Bose-Einstein condensate, a form of matter heretofore observed only in atoms chilled to less than a millionth of a degree above absolute zero, may now have been observed at temperatures in excess of one Kelvin in excitons, the bound pairs of electrons and holes that enable semiconductors to function as electronic devices. Researchers have observed excitons in a macroscopically ordered electronic state, indicating the formation of a condensate. The observations were made by shining laser light on specially designed nano-sized structures called quantum wells, which were grown at the interface between two semiconductors – gallium arsenide and aluminum gallium arsenide. These quantum wells allow electrons and electron holes (spaces in the crystal that are positively charged) to move freely through the two dimensions parallel to the quantum well plane, but not through the perpendicular dimension. Under photoluminescence, the macroscopically ordered exciton state appeared against a black background as a bright ring that had been fragmented into a chain of circular spots extending out to one millimeter in circumference. Just as the Nobel prize-winning creation of Bose-Einstein condensate atoms offered scientists a new look into the hidden world of quantum mechanics, so, too, will the creation of Bose-Einstein condensate excitons provide scientists with new possibilities for observing and manipulating quantum mechanical properties. The observation also holds potential for ultrafast digital logic elements and quantum computing devices.
- *Magnetic Nanocomposites*: *The Next Little Thing*. Magnetic materials are indispensable to a modern industrial society; however, it is no longer possible to squeeze significantly better performance out of today's most advanced magnets. A new approach is to create a composite material of two magnetic materials combined on the nanoscale to create a material with better performance than either taken separately. The boundary between the two magnetic materials is exceedingly important. Studies of bilayers of magnetically-hard and magnetically-soft magnetic materials have revealed that diffusion between the two materials alters the interface between them, resulting in improved magnetic properties. Theoretical modeling confirms that interfacial modification can enhance interlayer magnetic coupling. The results reveal the potential of careful interfacial control for improving magnets through manipulation of the material at the nanoscale.
- *Tuning the Properties of Materials at the Nanoscale*. As the size of silicon electronic devices shrinks toward the nanometer scale, the properties of the nanometer-thick silicon thin film in the devices depart from those of the bulk form of silicon. Nanostressors will be able to tune the properties of such thin films. For example, germanium islands grown on silicon act as nanostressors to shape the silicon film. The induced bending of the silicon film modifies the local electronic and optical properties of silicon. This ability to "tune" the properties of solid thin films is expected to become more prominent as semiconductor devices shrink to ever smaller scales.
- *New Nanoscale Structures Form where Grain Boundaries Meet Surfaces*. A newly discovered nanoscale "defect" may be connected to unusual behavior of metal catalysts and thin films, which are critical to the chemical and electronic industries. A distinct channel with a V-shaped cross section has been observed along the intersection of a grain boundary with an external surface. Atomic-resolution observations of gold surfaces in combination with atomic-scale simulations show that this channel has a different crystal structure than the remainder of the material. One implication is that when the grains become sufficiently small, these channel regions may dominate the surface and

result in very different reactivity and catalytic activity than expected based on the bulk structure. These channel defects may also pin grain boundaries, slowing or preventing their motion and affecting the processing of thin films for microelectronics. Furthermore, the channels can be thought of as naturally occurring nanoscale wires along the surface of a material, whose arrangement could be controlled by appropriate processing.

- *Imaging Single, Individual Molecules*. By using a tightly focused beam of electrons less than a nanometer in diameter and by reconstructing images from the electron scattering data, the exact atomic positions in an individual carbon nanotube have been determined. Images of high resolution and high contrast can be obtained as has been shown by solving the structure of a single, double-walled carbon nanotube – a very complicated problem involving one tube nested in another. The technique has the potential to allow imaging of atomic arrangements in individual non-periodic structures such as biological macromolecules.
- *Nanofluids Improve Heat Transfer*. Suspensions of nanoscale metal particles or carbon nanotubes in fluids exhibit unusual enhancements in thermal conductivity. Picosecond measurements using laser techniques have been used to make the first quantitative measurements of heat transfer at the solid/fluid interface. Very large improvements for thermal conductivity are expected based on simple theory for carbon-nanotubes, but are not observed. The picosecond data shows that the thermal coupling between the nanotube and the surrounding matrix is weak, greatly impeding heat transfer in the carbon-nanotube composite. The results also indicate that the thermal conductance at the particle/fluid interface is highly sensitive to both structure and chemistry.
- *Silicon: From Information Age to an Efficient Light Emitter?* Silicon is the bedrock on which the information age is built, but it is a notoriously poor light emitter. The holy grail of silicon technology is to make silicon an efficient light emitter so that digital information can be converted to light for the ultimate transmission speed across optical fiber networks. New calculations have shown that a novel impurity superlattice structure of thin-layer oxide could do precisely that by altering silicon electronic charge characteristics to couple directly to light. This breakthrough opens the door so that the light-emitting efficiency of silicon could be drastically enhanced. This discovery will dramatically impact the microelectronics industry by significantly reducing the cost and complexity associated with the integration of optoelectronics into silicon-chip products.
- *Synchrotron Light Sources Help Reveal Secrets of Welding.* Welding is a critical metal joining technology used worldwide in the energy, automotive, aerospace, construction, and chemicals industries. Rapid cooling during welding induces numerous phase changes in the metal. Theories have been developed to describe this, but they have never been verified experimentally. Time-resolved x-ray diffraction using synchrotron radiation has now been used for the first time to monitor in-situ phase evolution of a multi-component steel weld during melting and subsequent solidification. The results show that equilibrium theories applied to rapid cooling conditions are not valid for steel welds containing fast diffusing (carbon) and slow diffusing (aluminum) atoms. This new ability to observe the competition of multi-component phases at the microstructural level will make it possible to design stronger and tougher welds, chemically tailored for optimum performance.
- *Ultrathin, Laminar Films for Instantaneous Computer Boot-up.* A new technique has been developed to deposit metal atoms onto thin oxide layers. This technique will help next-generation computers boot up instantly by making entire memories immediately available for use. The method anchors ultrathin metallic cobalt layers on sapphire by using a surface chemical reaction that overcomes an island formation problem that has long plagued researchers. The new, inexpensive trick to prevent

island formation is as simple as exposing thin oxide films to water vapor before depositing the metal layer. The thin metal layer achieves crystallinity after the deposition of only a few atomic layers. This process should be applicable to a wide range of metals on metal oxides.

- *Novel Synthesis of Shape-Controlled Nanostructures.* Fabricating shape-controlled nanostructures such as nanowires and nanodots plays a central role in nanoscale science and technology. A novel electrodeposition process has been developed to self-assemble an array of nanostructures on flat surfaces. The new technique is based on the application of an electric field to ions on graphite substrates immersed in an aqueous solution. A large variety of voltage-controlled nanostructures have been grown such as cubes, pyramids, pentagons, hexagons, nanowires and snowflakes in superconductors and ferromagnets as well as in emerging application systems such as catalytic silver and hydrogen-sensing palladium. These unique nanostructures provide a new theater to explore shape effects on quantum confinement and present new opportunities for nanoelectronic applications.
- *Biomolecular Route to Photovoltaic and Semiconductor Nanocrystals.* Biology exhibits a remarkable ability to control the nanostructures of materials, such as the exquisitely shaped microscopic shells of diatoms and radiolarians, with a precision that far exceeds the capability of present human engineering. Now, the biomolecular mechanism that directs the nanofabrication of silica in living organisms has been harnessed to direct the synthesis of photovoltaic and semiconductor nanocrystals of such materials as titanium dioxide, gallium oxide, and zinc oxide -- materials that biology has never used in structures before. Proteins from a marine sponge – and their counterparts produced from cloned, recombinant DNA – were used to catalyze and structurally direct the growth of the inorganic semiconductors at low temperature and under mild conditions, in marked contrast to the need for elevated temperatures and caustic chemicals presently required by conventional manufacturing methods. The nanocrystallites of gallium oxide formed in this process show a preferential alignment directed by the underlying proteins, revealing a template-like structure-directing activity of the biomolecules. Furthermore, the proteins working at low temperature produce and stabilize crystal forms of gallium oxide and titanium dioxide normally seen only at very high temperatures. Such biomolecular routes may lead to new, environmentally benign routes to semiconductor and photovoltaic materials with improved control over both nanostructure and performance, as well as improved interfaces between optoelectronic devices and living systems.
- *The Impact of a Single Atom.* Never before has it been possible to identify single atoms within bulk materials and determine the influence of a single atom on its surroundings. Isolated atoms can significantly modify the physical properties of many of the technologically most relevant and scientifically interesting materials. While it has long been known that in semiconductors, for example, the presence of a single dopant atom among 1019 host elements drastically modifies the macroscopic properties, the possibility of identifying, localizing, and even measuring the electronic properties of single atoms becomes of fundamental importance in the nanotechnology era. We now have that capability. The aberration-corrected scanning transmission electron microscope allows not only the imaging of individual atoms inside a crystal, but their chemical identification. This remarkable improvement in sensitivity reaches the quantum limit of information, the ability to probe the electronic environment of a single atom.
- *Molecular Cages under Pressure.* The isolation, removal, and entombment of radioactive waste are challenging scientific problems. Structural data from high-pressure x-ray powder diffraction has demonstrated that cage-like zeolites can potentially separate toxic waste from the environment. Using reversible superhydration -- the selective absorption of excess water under pressure into fully hydrated zeolites — the immobilization of commonly occurring radioisotopes such as 90Sr, 137Cs

and 60Co via a “trap-door mechanism” may be realized. By exchanging ions at high pressures, the holes of the zeolites will expand due to the excess water entering the zeolite cages. After pressure release these holes contract again, essentially closing the trap door and sealing the waste inside the zeolite for good.

- *Biocompatible Lasers for Ultrasensitive Detection.* A highly sensitive quantum optics device using a biocompatible semiconductor laser microcavity has been devised that can analyze and characterize spore simulants. This device is based on recent advances in the surface chemistry of semiconductors and the concept of quantum squeezing of light emitted through a spore flowing at high speed in the laser’s microcavity. This light squeezing enables even tiny spores to generate a very large signal which, when analyzed, yields critical biological information including the spore’s protein coat morphology, shape, intracellular granularity, protein density, and uniformity. This field-deployable biolaser should be able to identify different types of spores (for example, anthrax) within a large population of harmless spores rapidly and effectively.
- *Electrocatalyst Design for Fuel Cells.* Electrocatalytic fuel cells at ambient temperature require materials with high catalytic activity and high tolerance to poisons such as carbon monoxide and sulfur. The use of alloys presents inherent limitations including a random distribution of the constituent elements and their propensity to segregate. The use of ordered intermetallics provides stable ordered phases. Based on studies of model systems, it is predicted that the ordered intermetallic bismuth-platinum (BiPt) should exhibit high catalytic activity and greatly reduced poisoning from carbon monoxide. These predictions, based on electronic and geometric effects, respectively, were borne out by experiments. BiPt catalyzes the oxidation of formic acid and is a better material than pure platinum in some ways; moreover, it exhibits catalytic currents about 30 times those on platinum and is virtually immune to carbon monoxide poisoning. Although the focus has been on anode materials, this new design paradigm has clear implications in the design of cathodes as well as reformer catalysts and could usher a new era in fuel cell R&D.

Selected FY 2003 Facility Accomplishments

- The Advanced Light Source (ALS)
  - *Record Low Vertical Emittance Demonstrated.* The emittance is a key parameter that describes the circulating particle beam in a storage ring. Accelerator scientists have reduced the ALS vertical emittance to 5 picometer-radians during accelerator physics experiments. This is the lowest emittance value ever realized in any storage ring. While this emittance is a factor of 20 lower than the value normally used in ALS operation for users, it will be especially important for future spectroscopy studies in which the highest possible resolution is important.
  - *Femtosecond R&D Program Launched.* The study of ultrafast dynamical processes on the time scale of fundamental processes, such as a molecular vibration, is one of the most active areas of modern science. An ALS R&D program was initiated that aims to produce ultrafast x-ray pulses by means of a technique known as electron-beam slicing. To generate x-rays from soft to hard x-ray energies with the maximum intensity, the first narrow-gap in-vacuum undulator will be installed in the ALS.
  - *Beamline Devoted to Study of Soft X-Ray Coherent Science.* Exploitation of the coherence of undulator light has not kept pace with that of other properties, such as brightness. To address this issue at the ALS, a branchline dedicated to coherence has been added to an existing undulator beamline that will produce microwatts of tunable coherent soft x rays. This new capability will allow users to carry out a wide range of experiments in both scattering and fundamental optics.

- *Next-Generation Detector for Synchrotron Radiation Developed.* The brightness of third-generation synchrotron radiation sources often generates huge signal rates that overwhelm the capabilities of existing detector systems. Often, the detector saturation problem both prevents the fullest utilization of the synchrotron light and limits the realization of certain new types of experiments. To overcome this bottleneck, the ALS has developed and successfully tested a high speed (more than 1 GHz), next-generation detector based on high-energy physics technology.

▪ The Advanced Photon Source (APS)

- *A Bull's Eye for Storage Ring Beam Orbit Stability.* Stable x-ray beams are critical for all users of x-ray facilities, particularly those users who microfocus x-rays onto small samples. X-ray beam-position monitors developed for the APS insertion device beamlines are providing beam stability that is now equivalent to firing a stream of bullets through the bull's eye of a target from several miles away.

- *New Information from APS Could Lead to Improved Data Storage.* A surface twisted magnetic state predicted 15 years ago has, for the first time, been confirmed using a new experimental technique at the BES-funded X-ray Operation and Research sector 4 at the APS. Twisted magnetic states of materials have important ramifications for applications in the development of improved magnetic memory.

- *EPICS Collaboration Helps APS and the World.* EPICS (Experimental Physics and Industrial Control System) software developed at two DOE national laboratories is being used worldwide to control complex mechanical systems, from accelerators that reveal the nature of subatomic particles, to observatory telescopes that view distant galaxies, to industrial control processes such as semiconductor wafer manufacturing.

- *Optics Capabilities at the APS Enable New Dynamical Studies of Liquids and Solids.* Inelastic x-ray scattering (IXS) is a synchrotron x-ray tool that opens new vistas for the study of high-temperature materials. The x-ray optics capabilities of the APS have reached a level that makes possible implementation of an IXS spectrometer with exceptional resolving power.

- *A Breath of Fresh Air for Insect Physiology.* A technique that couples phase-enhanced x-ray imaging to the intensity of APS x-ray beams has revealed a previously unknown insect breathing mechanism. Further development of this technique could have important implications for human health care and afford the potential for a wide variety of other materials-related applications, including detecting and studying cracks, voids, and other boundaries inside optically opaque structures; studying fluid flow in rocks and soils for oil exploration and recovery; and characterizing advanced materials, such as ceramics and fiber composites.

▪ The National Synchrotron Light Source (NSLS)

- *High Gain Harmonic Generation (HGHG) FEL Reaches Saturation in Ultraviolet.* The NSLS is pioneering the development of laser seeded Free Electron Lasers (FEL). The HGHG FEL makes uses of a Ti-Sapphire seed laser to produce fully coherent 266 nm light. This marks the first HGHG FEL to successfully reach saturation in the ultraviolet regime and thereby obtaining sub-picosecond pulses with energy in excess of 100 microjoules.

- *New Powder and Single Crystal Diffraction Beamline Completed.* A new bending magnet beamline, X6B, has been completed. The beamline was constructed to meet the increasing demand of nanoscience users for powder and single crystal x-ray diffraction. The beamline consists of a Si(111) monochromator, tunable from 5 keV to 20 keV, and a double focusing mirror. The beamline is designed to perform (a) time-resolved powder diffraction, (b) combined x-ray spectroscopy and x-ray diffraction, (c) single crystal diffraction, and (d) measurement of electron density of excited states.

- *Superconducting Wiggler Beamline Upgraded.* The X17 superconducting wiggler beamline is the only high-energy x-ray insertion device at the NSLS. It serves a large and very productive earth science and high-pressure user community. In FY 2003, two new experimental hutches were constructed so that a materials science instrument, a large volume press instrument, and a diamond anvil cell instrument will each have a dedicated experimental hutch. All three programs will be able to operate simultaneously, thus significantly increasing the amount of beam time available to these user communities.
- *Low-Energy X-Ray Beamline Upgraded.* The low-energy x-ray region is important because it covers the K absorption edges of Si, S, P, Cl, and L edges of 4d transition metals. X-ray spectroscopy and x-ray resonant scattering in this energy range are valuable tools in catalysis, environmental science, magnetism, and bio-materials. A new monochromator was designed and installed in FY 2003 to improve the cooling of the monochromator crystals in X19A beamline. The new design has led to better energy and intensity stability of the beamline.

▪ The Stanford Synchrotron Radiation Laboratory (SSRL)

- *First Beam from the Sub-Picosecond Pulse Source (SPPS) is Achieved.* Ultrafast pulses of x-rays are key tools for probing the electronic and structural changes in materials during fast chemical reactions and phase changes. To this end, the SPPS was installed in the SLAC Final Focus Test Beam Facility, which generates pulses of 8-10 keV x-rays with 10^7 photons/pulse at a pulse rate of 10 pulses per second. The peak brightness of these x-ray pulses exceeds that of any existing x-ray source. The SPPS is planned to operate 3-4 months per year through 2005, when it will be displaced by the construction of the Linac Coherent Light Source, a much more intense source of short x-ray pulses.
- *SSRL's Final Run with SPEAR2 Ends on a Perfect Note.* SSRL's most recent experimental run prior to the decommissioning of SPEAR2 ended very successfully with SPEAR delivery of scheduled beam time to users at the 100% mark during the last week of operations. Even though the FY 2003 run was shortened by about 4 months due to the beginning of the SPEAR3 installation, a total of 813 users came to SSRL during the run to conduct experiments on 32 stations. The up time average for the entire FY 2003 run was 96.8%.
- *SPEAR3 Installation Program Proceeding on Schedule.* The SPEAR3 Installation Program began on schedule on March 31, 2003. The Installation Program involves three phases: demolition of SPEAR2, modification of the facilities to meet SPEAR3 needs, and finally the actual installation of SPEAR3 technical systems and components. Each phase is a complex procedure that is planned in great detail with overall completion by the end of October 2003.
- *New Experimental Station Developed on BL11.* A new experimental station that will be used for both materials scattering and macromolecular crystallography has been commissioned on BL11. This new station will help relieve the significant over subscription on BL7-2 for users performing x-ray structural studies of thin films as well as provide for single- or multi-wavelength anomalous dispersion (SAD and MAD) experiments to be carried out at the Se edge for macromolecular crystallography applications.

- The Intense Pulsed Neutron Source (IPNS)
  - *Upgrades of IPNS Instruments Continue.* IPNS continues to make major instrument upgrades and source improvements to maintain world class science capabilities for U.S. users: 1) an upgrade project for a powder diffractometer, GPPD, has been completed putting the instrument on a par with the fastest powder instruments in the world; 2) installation of a guide on QENS, a quasi-elastic spectrometer boosted flux on sample by a factor of five; 3) redesigning the moderator/reflector assembly resulted in a gain of 60% neutrons-on-sample for small angle scattering applications.
  - *Outstanding Operations at IPNS Continues.* For the sixth consecutive year, the IPNS has exceeded its goal of offering at least 95% reliable operations, achieving a figure of 97% in FY 2002. This reliability assures users that experiments can be performed as planned and offers additional evidence that pulsed neutron sources can be run in a reliable manner.
  - *IPNS Hosts the National Neutron and X-Ray Scattering School.* During the two-week period of August 10-24, 2003, 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 143 applications for the 60 positions available in 2003.
- The Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE)
  - *First Results with the 11-T Magnet at Lujan Center.* The newly commissioned 11-T superconducting magnet provided Lujan Center users with the first results of an intensity image (reflection) of neutron data collected from an antiferromagnetic material on the new Asterix instrument. Significantly, the mass of material contributing to the reflection is only about 100 micrograms. Moreover, exceedingly good thermal stability was achieved during the measurements.
  - *Upgraded NPDF Produces 300 Data Sets.* The Neutron Powder Diffractometer (NPDF) opened its shutter for the first time and produced over 300 experimental data sets during the run cycle. Promising results obtained during the run cycle not only put NPDF at the cutting edge of local-structure determination but also served as a development platform for a new structure-analysis tool based on pair-distribution functions in disordered and nanostructured materials.
  - *Upgrades to SPEAR Improve Reflectivity Measurements.* Upgrades to SPEAR have simplified the operation of the instrument and provided more precise and reproducible reflectivity measurements. SPEAR is a time-of-flight neutron spectrometer ideally suited to study thin organic and inorganic layers in a variety of environments. A recent experiment on SPEAR provided fundamental information about the stability of model biomembranes in the presence of large electric fields.
  - *Upgrades to LQD Enables More Sophisticated Small-Angle Scattering Experiments.* Small-angle scattering has been improved at the Lujan Center to keep apace with the significantly increased cold-neutron flux available to LQD (Low-Q Diffractometer), which has been increased by approximately a factor of five. These upgrades will allow more measurements, higher-quality data, and the ability to perform more sophisticated experiments.

- The High Flux Isotope Reactor (HFIR)
  - *World-Class Triple-Axis Spectrometers Installed at HFIR.* These spectrometers, designated HB-1, HB-1A, and HB-3, are exceeding performance goals and are equal to the highest intensity instruments of their kind in the world. The installation of three additional world-class instruments is under way at the HB-2 shielding tunnel, which was completed in March 2003. The first of the new instruments should be available in early fall 2003 with the other two to follow by the end of 2003.
  - *Construction of the Small Angle Neutron Scattering (SANS) Guide Hall Completed.* The high bay guide hall will house the new 40m and 35m SANS instruments and supporting lab space. It will provide a research environment away from the reactor building that will be used by numerous facility users for physical and biological material studies.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Materials Sciences and Engineering Research....	**252,539**	**263,929**	**275,543**
▪ **Structure and Composition of Materials.........**	**28,915**	**32,954**	**32,183**

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, and corrosion susceptibility.

In FY 2005, major activities 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. One aspect of this will be research towards an optimal platform for Transmission Electron Aberration-corrected Microscopy. This effort is intended to dramatically extend electron scattering capabilities for three-dimensional tomography, local spectroscopy, and *in-situ* sample manipulation and processing. An additional $975,000 is provided for novel

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

analytical technologies to access hydrogen storage materials. State-of-the-art electron microscopy and spectroscopy approaches will be used to monitor atomic-level processes in such materials. Observing these processes under realistic experimental conditions is required to determine basic mechanisms of hydrogen storage and release.

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

The overall decrease for structure and composition of materials is attributable to an increase for research related to hydrogen economy ($+975,000) offset by a decrease in capital equipment for electron microscopy activities ($-1,746,000).

▪ **Mechanical Behavior and Radiation Effects**...	**13,323**	**13,600**	**13,600**

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.

In FY 2005, major activities will include continued development of experimental techniques and methods for the characterization of mechanical behavior including mechanical behavior of matter with nanoscale dimensions, the development of a universal model for mechanical behavior that includes all length scales from atomic through nanoscale to bulk dimensions, and the continued advancement of computer simulations for modeling mechanical behavior and radiation induced degradation.

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

	FY 2003	FY 2004	FY 2005
▪ **Physical Behavior of Materials**.........................	**20,262**	**20,500**	**22,450**

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 field, chemical environment, and proximity of surfaces or interfaces. Included within the activity are research in aqueous, galvanic, and high-temperature gaseous corrosion and their prevention; photovoltaics and photovoltaic junctions and interfaces for solar energy conversion; the relationship of crystal defects to the superconducting properties for high-temperature superconductors; phase equilibria and kinetics of reactions in materials in hostile environments, such as in the very high temperatures encountered in energy conversion processes; 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.

In FY 2005, major activities will continue fundamental studies of corrosion resistance and surface degradation; semiconductor performance based on organic and inorganic materials; high-temperature superconductors; and the interactions, and transport of defects in crystalline matter. An additional $1,950,000 is provided for basic research on the storage of hydrogen using a broad class of complex hydrides. The emphasis will be on understanding the fundamental factors governing bond strength, kinetics, absorption and desorption behavior, and degradation with hydrogen uptake/release cycles. This information will be used to modify the performance of known hydrogen storage materials and to identify new classes of materials. Research on efficient solar energy production of hydrogen using organic photovoltaics with quantum-size organic semiconductors also will be performed. Systematic experimental approaches coupled with theory, modeling, and simulation will be applied to both research areas.

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.

	FY 2003	FY 2004	FY 2005
▪ **Synthesis and Processing Science**	**11,839**	**12,000**	**12,975**

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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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.

The activity includes the operation of the Materials Preparation Center at the Ames Laboratory, which develops innovative and superior processes for materials preparation and provides small quantities of 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 2005, major activities 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 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. An additional $975,000 is provided for research on the design, synthesis, and processing of nanomaterials for the storage and release of hydrogen. By changing the structure of a given chemical compound at the nano-level, materials with different behavior are obtained which can be optimized for hydrogen storage behavior.

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

▪ **Engineering Research**	**15,297**	**14,038**	**13,500**

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. FY 2005 activity will continue laser based generation and

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

characterization of phonons in solids with application to needs in heat transfer, thermoelectric energy conversion, and non-destructive early-warning of impending failure and remaining safe lifetime predictive capabilities. This activity will also support fundamentals of granular systems (which are utilized for powder and particular matter preparation and conveyance, in fluidized bed reactors, and in certain heat transfer applications).

The decrease of funding for Engineering Research is attributable to a decreased emphasis on fluid dynamics of multi-component systems ($-538,000).

▪ **Neutron and X-ray Scattering**	**37,821**	**41,877**	**42,058**

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.

In FY 2005, with an additional $2,437,000, research in the area of nanostructured and novel hydrogen storage media will be performed 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.

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

The overall increase for Neutron and X-ray Scattering is attributable to an increase in Neutron and X-ray Scattering Research for instrumentation related to hydrogen ecology ($+2,437,000) offset by a decreased emphasis on core research ($-2,256,000).

▪ **Experimental Condensed Matter Physics**	**37,205**	**40,500**	**42,449**

This activity supports condensed matter physics with emphasis in the areas of electronic structure, surfaces/interfaces, and new materials. Research includes measurements of the properties of solids, liquids, glasses, surfaces, thin films, artificially structured materials, self-organized structures, and nanoscale structures. This activity includes the design and synthesis of new materials with new and improved properties. The materials examined include magnetic materials, superconductors, semiconductors and photovoltaics, liquid metals and alloys, and complex fluids. The development of new techniques and instruments including magnetic force microscopy,

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

electron microscopic techniques, and innovative applications of laser spectroscopy is a major component of this activity. Measurements can be 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. Research in superconductivity is coordinated with the technology programs in Energy Efficiency and Renewable Energy (EE/RE). Research on magnetism and magnetic materials focuses on hard magnet materials, such as those used for permanent magnets and in motors. This activity provides direct research assistance to the technology programs in EE/RE (photovoltaics, superconductivity, power sources, thermoacoustics, and thermoelectrics), and in the National Nuclear Security Administration (NNSA) (photoemission, positron research, electronic and optical materials, advanced laser crystals, and weapons-related materials). In addition, it supports several DOE technologies and the strategically important information technology and electronics industries through its results 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 2005, major activities will include investigation of fundamental questions in condensed matter physics at the nanoscale. As the size of a nanoscale structure becomes less than the average length for scattering of electrons or phonons, new modes of transport for electrical current and/or heat 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. The potential impacts of understanding the physics are very significant. For example, nanoscale structures provide a path toward the next generation of powerful permanent magnets for more efficient electric motors, better thermoelectric materials, and materials for more efficient solar energy conversion. An additional $1,949,000 is provided for the development of nanomaterials (structure and phase dimensions of 1-100 nanometer) for both energy conversion and hydrogen energy storage, which exhibit size-dependent properties that are not seen in macroscopic solid state materials. Examples include both carbon-based materials, such as nanotubes, nanohorns, fullerenes, and non-carbon-based materials such as semiconductors. Enhanced electrical, thermal, mechanical, optical, and chemical properties have shown that these new materials 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.

▪ **Condensed Matter Theory**................................	**16,993**	**17,000**	**17,975**

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,

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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; ceramics; modeling oxidation processes at surfaces and interfaces; excited state electronic structure and response functions; polymers at interfaces; and quantum transport in molecular and nanoscale systems.

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

In FY 2005, this activity will provide support for theory, modeling, and large-scale computer simulation to explore new nanoscale phenomena and the nanoscale regime. Support for the Computational Materials Sciences Network will be continued with new topical areas as they evolve. An additional $975,000 is provided to advance theoretical understanding of critical processes and reactions in hydrogen systems, which will provide a fundamental basis for new materials design.

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

▪ **Materials Chemistry**...	**40,563**	**42,000**	**44,437**

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 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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

biological approaches may yield materials for advanced separations and energy storage.

In FY 2005, this activity 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. An additional $2,437,000 is provided for research on hydrogen production (by biomolecular materials), storage (in complex hydrides, nanocomposites, nanotubes), and fuel cells (novel electrode and membrane materials and processes).

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

▪ **Experimental Program to Stimulate Competitive Research (EPSCoR)**....................	**11,722**	**7,673**	**7,673**

This activity supports basic research spanning the complete range of activities within the Department in states that have historically received relatively less Federal research funding. The EPSCoR states are Alabama, Alaska, Arkansas, Hawaii, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, South Carolina, South Dakota, Vermont, West Virginia, and Wyoming, and the Commonwealth of Puerto Rico. The states of Delaware, Tennessee and Rhode Island, and the U.S. Virgin Islands may also become eligible for the EPSCoR program in FY 2005. The work supported by the EPSCoR program includes research in materials sciences, chemical sciences, biological and environmental sciences, high energy and nuclear physics, fusion energy sciences, fossil energy sciences, and energy efficiency and renewable energy sciences. The following table shows EPSCoR distribution of funds by state.

EPSCoR Distribution of Funds by State

	(dollars in thousands)		
	FY 2003	FY 2004 Estimate	FY 2005 Estimate
Alabama	946	815	510
Alaska[a]	0	0	0
Arkansas	205	140	0
Hawaii[b]	0	0	0
Idaho	100	0	102
Kansas	881	560	560
Kentucky	1,224	355	224
Louisiana	287	0	198
Maine	0	0	0
Mississippi	685	535	535
Montana	580	515	375
Nebraska	1,155	300	0
Nevada	1,146	250	0
New Mexico[b]	0	0	0
North Dakota	137	0	139
Oklahoma	339	140	135
Puerto Rico	435	375	375
South Carolina	781	140	266
South Dakota	0	0	0
Vermont	1,064	857	709
West Virginia	1,405	360	201
Wyoming	130	0	130
Technical Support	222	100	110
Other	0	2,231 [c]	3,104 [c]
Total	11,722	7,673	7,673

[a] Alaska became eligible for funding in FY 2001.

[b] Hawaii and New Mexico became eligible for funding in FY 2002.

[c] Uncommitted funds in FY 2004 and 2005 will be competed among all EPSCoR states.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **Neutron Scattering Instrumentation at the High Flux Isotope Reactor**	**3,564**	**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)**	**0**	**2,000**	**4,000**

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.

▪ **Nanoscale Science Research Centers**	**100**	**400**	**600**

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.

▪ **SPEAR3 Upgrade**	**9,300**	**0**	**0**

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade (funded in both BES subprograms) was undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The upgrade increased injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decreased beam emittance by a factor of 7 to increase beam brightness; increased operating current from 100 mA to 200 mA to increase beam intensity; and maintained long beam life time (>25 hr). The increased photon flux will greatly improve performance in a variety of applications including powder and thin film diffraction, topographic studies, surface microcontamination studies, x-ray tomographic analysis, x-ray absorption studies, and protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring were replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC was $29,000,000; DOE and NIH equally funded the upgrade with a total Federal cost of $58,000,000. NIH provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and $1,000,000 in FY 2001. This MIE project was completed on schedule and within budget. The SPEAR3 is now being commissioned.

▪ **The Center for Nanoscale Materials**	**0**	**10,000**	**12,000**

Funds are provided for a major item of equipment with a total estimated cost of $36,000,000 for instrumentation, including clean rooms, for the Center for 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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

beamline will be the highest spatial resolution instrument of its kind in the world, which will permit nondestructive examination of magnetic, electronic, and photonic materials important both for basic science and as foundations for future nanotechnologies. The Center will build on ANL's recognized strengths in magnetism, superconductivity, and novel materials with "spintronic" functionality.

	FY 2003	FY 2004	FY 2005
▪ **Instrumentation for the Spallation Neutron Source**	**5,635**	**7,387**	**7,643**

Funds are provided for a major item of equipment with a total estimated cost in the range $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 following completion of Title I design and an External Independent Review in FY 2004. It is anticipated that these five instruments will be installed at the SNS on a phased schedule between FY 2007 – 2011.

	FY 2003	FY 2004	FY 2005
Facilities Operations	**281,013**	**294,517**	**312,854**
▪ **Operation of National User Facilities**	**281,013**	**294,517**	**312,854**

The facilities included in Materials Sciences and Engineering are: Advanced Light Source, Advanced Photon Source, National Synchrotron Light Source, Stanford Synchrotron Radiation Laboratory, High Flux Isotope Reactor, Intense Pulsed Neutron Source, and Manuel Lujan, Jr. Neutron Scattering Center. Research and development in support of the construction of the Spallation Neutron Source is also included. The Combustion Research Facility is funded in the Chemical Sciences, Geosciences, and Energy Biosciences subprogram. The facility operations budget request, presented in a consolidated manner later in this budget, includes operating funds, capital equipment, and accelerator and reactor improvements (AIP) funding under $5,000,000. AIP funding will support additions and modifications to accelerator and reactor facilities that are supported in the Materials Sciences and Engineering subprogram. General plant project (GPP) funding is also required for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. The total estimated cost of each GPP project will not exceed $5,000,000. Capital equipment is needed at the facilities for items such as beam monitors, interlock systems, vacuum systems, beamline front end components, monochromators, and power supplies. A summary of the funding for the facilities included in the Materials Sciences and Engineering subprogram is provided below.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

Facilities

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Advanced Light Source	42,844	43,205	42,200
Advanced Photon Source	90,894	93,410	97,400
National Synchrotron Light Source	36,950	38,325	38,400
Stanford Synchrotron Radiation Laboratory	25,903	30,305	28,100
High Flux Isotope Reactor	36,838	37,805	39,832
Radiochemical Engineering Development Center	6,515	6,305	6,300
Intense Pulsed Neutron Source	16,714	16,655	17,222
Manuel Lujan, Jr. Neutron Scattering Center	9,914	10,110	10,300
Spallation Neutron Source	14,441	18,397	33,100
Total, Facilities	281,013	294,517	312,854

SBIR/STTR	**0**	**13,910**	**14,831**

In FY 2003, $11,897,000 and $714,000 were transferred to the SBIR and STTR programs, respectively. The FY 2004 and FY 2005 amounts shown are the estimated requirements for the continuation of the SBIR and STTR programs.

Total, Materials Sciences and Engineering	**533,552**	**572,356**	**603,228**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Materials Sciences and Engineering Research	
▪ Overall decrease for structure and composition of materials research because of increase for research related to the hydrogen economy ($975,000) and decrease because of reduction in capital equipment for electron microscopy activities ($-1,746,000)	-771
▪ Increase for physical behavior of materials research for research related to the hydrogen economy.	+1,950
▪ Increase in synthesis and processing science research for research related to the hydrogen economy.	+975

	FY 2005 vs. FY 2004 ($000)
▪ Decrease in engineering research because of decreasing emphasis on fluid dynamics of multicomponent systems.	-538
▪ Overall increase in neutron and x-ray scattering research for instrumentation related to hydrogen economy ($2,437,000). Research is decreased ($-2,256,000) to fund the MIE for the ANL Center for Nanoscale Materials and the increase for instrumentation for the Spallation Neutron Source.	+181
▪ Increase in experimental condensed matter physics for research related to the hydrogen economy.	+1,949
▪ Increase in condensed matter theory for research related to the hydrogen economy.	+975
▪ Increase in materials chemistry for research related to the hydrogen economy.	+2,437
▪ Increase for research and development for the Linac Coherent Light Source.	+2,000
▪ Increase for other project costs per schedule associated with the Nanoscale Science Research Centers.	+200
▪ Increase for MIE for the ANL Center for Nanoscale Materials.	+2,000
▪ Increase for Instrumentation for the Spallation Neutron Source.	+256
Total, Materials Sciences and Engineering Research	+11,614

Facilities Operations

▪ Decrease for operations of the Advanced Light Source as a result of a one-time FY 2004 capital equipment increment for new components of the beamline for nanoscience spectroscopy and diffraction..	-1,005
▪ Increase for operations for the Advanced Photon Source.	+3,990
▪ Increase for operations of the National Synchrotron Light Source.	+75
▪ Decrease for operations of the Stanford Synchrotron Radiation Laboratory as a result of a one-time FY 2004 capital equipment increment for a new insertion device for the nanomagnetism beamline	-2,205
▪ Increase for operations for the High-Flux Isotope Reactor	+2,027
▪ Decrease for operations for the Radiochemical Engineering and Development Center	-5
▪ Increase for operations for the Intense Pulsed Neutron Source.	+567
▪ Increase for operations of the Manuel Lujan, Jr. Neutron Scattering Center.	+190
▪ Increase in the Spallation Neutron Source Other Project Costs per FY 2004 project datasheet for the operations.	+14,703
Total, Materials Sciences and Engineering Facilities Operations	+18,337

	FY 2005 vs. FY 2004 ($000)
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in total operating expense funding	+921
Total Funding Change, Materials Sciences and Engineering	+30,872

Chemical Sciences, Geosciences, and Energy Biosciences

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Chemical Sciences, Geosciences, and Energy Biosciences					
Chemical Sciences, Geosciences, and Energy Biosciences Research	205,963	208,221	216,743	+8,522	+4.1%
Facilities Operations	5,935	5,967	6,169	+202	+3.4%
SBIR/STTR	0	5,394	5,510	+116	+2.2%
Total, Chemical Sciences, Geosciences, and Energy Biosciences	211,898	219,582	228,422	+8,840	+4.0%

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 2003 Research Accomplishments

- *Emergence from the Primordial Soup.* Fifty years ago, Miller and Urey (Science, 1953) showed that simple inorganic molecules presumed present in the early earth atmosphere could yield amino acids after exposure to an electric discharge. Subsequent models of the chemical origin of life were complicated by the requirement to explain the asymmetric (chiral) nature of DNA and its components. Both of these elements are addressed in recent work using advanced mass spectrometric tools to study amino acid aggregation and reaction products in the gas phase. The simple amino acid serine is the commonly accepted product of formaldehyde and glycine, both known to exist in interstellar space. Using sonic-spray ionization with mass spectrometric detection, researchers have shown that certain especially stable clusters of serine are homochiral, that is, exclusively one of the possible symmetries. Furthermore, in reactions of the cluster with other important biological molecules, the asymmetry is passed on to the reaction products. These observations rationalize a model of prebiotic chemistry beginning with the assembly of homochiral serine octamers. Following selection of a particular homochiral cluster by an unknown asymmetric species, reactions with other biologically relevant molecules could pass on the asymmetry as further chemical reaction led to the formation of chiral, self replicating, life forms.

- *Designer Solvents.* Ionic liquids have already replaced volatile, polluting hydrocarbon solvents in some industrial processes, and progress is being made in using ionic liquids for inherently safe processing of nuclear fuel and radioactive waste. It is important to understand how chemical reaction patterns are influenced by the unusual environment of ionic liquids. New studies have explored fast reactions in ionic liquids by pulse radiolysis and have shown that charged species, such as a bare electron surrounded by solvent, move more slowly in ionic liquids in comparison to neutral species, just the opposite of what is seen in normal solvents. Also discovered was a reactive and highly mobile form of the electron that exists for only a few trillionths of a second in normal solvents but persists thousands of times longer in ionic liquids.

- *Reactivity within Nanovessels.* The elusive challenge of attaining chemical selectivity close to 100 percent for reactions in aqueous solution may eventually be achieved by mimicking Nature's most selective catalysts – enzymes. Researchers are attempting just that by synthesizing stable and semi-rigid inorganic cage structures that are able to sequester organometallic catalysts in their interior. By using the restrictive environment of the nanovessel cavity, they have shown reactant-selective organic transformations. As a dramatic demonstration of reactant selectivity, they have shown that these encapsulated complexes react with aldehydes with rates that depend on the size of the molecule, unlike the same complexes in solution, which cannot discriminate among aldehydes of different length.

- *Fundamental Studies of Water*. It is difficult to identify a quantity more fundamental to chemistry than the O–H bond dissociation energy of water. Its importance arises from its ubiquity, which ranges from elementary reactions to those in complex environments such as flame chemistry or atmosphere chemistry. A joint experimental/ theoretical study recently revised the value of this bond dissociation energy by a small amount. Although a relatively small change, the impact of this correction is enormous. It will cause changes in the gas-phase acidity of water, several proton affinities, all R-OH bond dissociation energies, reaction enthalpies of all OH reactions, and heats of formation computed relative to H2O or OH bond dissociation energies.
- *Storing Energy in Dendrimer Trees.* Dendrimers are nanoscale molecules constructed from branches connected to a central core. If a dendrimer is built with an electron acceptor in the core and electron donors on the branches, the molecule can capture and temporarily store energy from light by moving electrons from the branches to the core. Further chemistry can then be used to capture the energy permanently before it is dissipated by electron transfer back to the branches. A dendrimeric system has been designed that functions as an electron antenna, absorbing several photons to create a core with a long lifetime. The stored energy can be lost if the electron returns to the "hole" it left behind. However, for dendrimers with branches long enough to allow their tips to touch, the holes are trapped on pairs of molecules at the tips, and the charge-separated state lasts for a long period of time.
- *Coherent Surface Plasmons in Nanoscale Systems.* One of the great promises of nanotechnology is the localization of phenomena on the nanoscale. Theoreticians have recently described the nanoscale analog of a laser in which coherent optical-frequency radiation fields are confined and amplified in nanosystems. They show that quantum generation of surface plasmons for a nanoscale v-shaped metal or semiconductor pattern can lead to stimulated emission and gain for certain highly localized plasmon modes. Such a device has been christened a SPASER, for Surface Plasmon Amplification by Stimulated Emission of Radiation. If realized, the SPASER has enormous potential applications in nanotechnology, including optical detection and information processing.
- *Triple-Action Catalytic Polymerization.* Catalysts that involve multiple functions working in concert at the molecular level offer dramatic advantages over single-function catalysts by reducing intermediate separation steps and achieving unusual reaction selectivity by controlling the competitive interplay of catalytic sites and the various molecular species present in the solution. Triple functions were synthesized on a complex catalytic compound that is active for ethylene polymerization. The terfunctional catalyst produces branched polyethylene with regular structures that cannot be obtained with a single catalyst or a pair of catalysts working in tandem. The extent and type of branching exhibited by the polymers, and therefore the chemical, mechanical, and optical properties of those materials, can be controlled by adjusting the ratios of the different functionalities.
- *Multidimensional Chemical Analysis of Attomole Sample.* Modern applications of chemical analysis, ranging from pollution studies to homeland security, increasingly require the ability to interrogate extremely small sample sizes. These mass-limited situations might arise because the sample is incredibly expensive, unusually toxic (biothreat agents), or inherently difficult to obtain in large quantities (intracellular signaling molecules). Conventional instrumentation is challenged, because their requirement for large sample volumes leads to extremely diluted samples. Researchers are developing solutions to this conundrum by exploiting the special electrokinetic flow properties of tiny cylindrical capillaries to create multilayer chemical instrumentation capable of addressing samples as small as 1,000,000 molecules and below. Because the capillaries are less than 100

nanometers in diameter, they can control fluid flow among layers of microchannels, thereby making it possible to sequentially link separate chemical manipulations. For example, scientists recently demonstrated the use of a nanocapillary molecular gate to detect and capture a 100 attomole (10-16 moles) band from a chip-based electrophoretic separation, establishing a new low for preparative chromatography of mass-limited samples.

- *DNA Transport through a Single Carbon Nanotube.* Carbon nanotubes have been proposed as useful media for a variety of applications such as hydrogen storage, chemical separation, and ultrasensitive sensors. A common research theme among these applications is the need to understand mass transport through such nanoporous materials. In a dramatic demonstration of its separations capability, a single, multiwalled carbon nanotube has been immobilized within an electrophoretic membrane test chamber and the passage of single DNA molecules has been monitored by fluorescence microscopy. Individual DNA molecules having a diameter smaller than the nanotube's opening were observed to readily pass through, whereas larger DNA molecules exhibited behavior consistent with trapping and hindered passage. Because of the simple structure of the nanotubes, modeling can yield insight into the mass transport properties of its very small pores.
- *Actinide Supramolecular Chemistry: Giant Rings for Heaviest Atoms.* Supramolecular chemistry is the controlled formation of large molecular aggregates from smaller subunits. The formation is controlled in order to achieve or optimize specific chemical properties. Actinide ions, the largest metal ions, have unique electron configurations and represent materials that can be extremely useful or extremely dangerous. Supramolecular assemblies called helicates have been created where six thorium ions are encapsulated in a "box" (cluster) that self-assembles from eight smaller assemblies, that will now be investigated for their ability to remove toxic ions such as the actinides from the body.
- *Targeted Recognition of Actinide Ions.* Fundamental research on the selective complexation of specific ions of radioactive elements with disk-like complexants has led to simple and sensitive detection of these ions. Several classes of disk-like complexants create strong bonds between actinide ions, all of which are radioactive, and nitrogen atoms in the cages. These bonds cause transitions in electronic and vibrational spectra that result in visible color changes that occur only when specific actinide ions, in particular ions of neptunium and plutonium, are present. These colored complexes are important because of the changes they cause in electronic and vibrational structure and because they represent opportunities for detection of potentially hazardous radioactive ions that could be released into the environment – or to reassure first-line responders and the public that such species have not been released.
- *Life Cycle of a Water Molecule on an Electrode.* Technological progress towards a future hydrogen economy relies on understanding molecular-level phenomena governing conversion hydrogen formation at the electrodes in electrolyzers and fuel cells. Ruthenium dioxide is unsurpassed at enhancing catalytic activities in room-temperature fuel cell anodes, and it is a very promising electrocatalyst. Using synchrotron x-ray studies, fascinating sequential rearrangements of surface water molecules were discovered, evolving from a loose hydrogen-bonded water layer, to a hydroxide layer, and to a dense form of water, which exist on the ruthenium dioxide surface at different applied potentials. These interfacial forms of water may be the intermediates long suspected to be responsible for promoting oxidation of hydrogen and methanol in the fuel-cell environment as well as promoting the oxygen-evolution reaction. These previously unavailable molecular-level details of the energy-conversion processes provide scientific impetus for a more rational design of high performance electrocatalysts. This first-of-its-kind study was possible

because of the unprecedented level of sensitivity afforded by the high brilliance of today's synchrotron radiation light sources.

- *Identification and Structural Determination of a Novel Protein Motif.* The protein machinery within a biological cell is manufactured via a complex assembly line that stretches from decoding DNA into RNA and translates the message into a polypeptide chain. Subsequent assembly into larger complexes and covalent linkage of the peptide chain with other carbohydrate or lipid components may also occur to provide additional chemical reactivity or specificity. The photosynthetic machinery that captures light energy and turns it into chemical energy is assembled in just such a fashion, with both large and small subunits of the carbon-fixing enzyme, Rubisco, undergoing methylation on lysine residues. A novel protein motif called the SET domain that carries out the methylation of Rubisco has been identified and its structure determined. The SET domain has been found in many other enzymes in a variety of biological contexts ranging from enzyme substrate recognition to scaffolding and stabilizing DNA. The common function of recognizing a molecular structure for subsequent covalent modification may lead to a common code for deciphering regulatory mechanisms of catalysis and molecular recognition.
- *First measurement of how much energy is required to insert a single new protein into a chloroplast.* The presence of internal organelles within the plant cell poses numerous challenges for the coordinated synthesis and trafficking of new proteins, which often must be synthesized in one part of the cell and directed to another sub-cellular compartment. The latter process necessitates the movement of the new protein across one or more membranes. Plant chloroplasts represent a unique opportunity to study the energetics of a mixed transport system that incorporates the cellular challenges of both eukaryotes and microbes. The energetic cost of this process is a fundamental unanswered question in plant biology, since the majority of photosynthetic apparatus proteins are continuously synthesized and imported into the chloroplast, then rapidly degraded. DOE/BES support has led to the first measurement of how much energy is required to insert a single new protein—an astonishingly high proton flux that is equivalent to the energy stored within 10,000 ATP molecules! Thus approximately 3% of the total energy output of the chloroplast from photosynthesis is devoted to maintaining the photosynthetic machinery. This knowledge provides the foundation for future strategies for more efficient light-harvesting applications for renewable energy.

Selected FY 2003 Facility Accomplishments:

- The Combustion Research Facility (CRF)
  - *New Capability Developed for Three-Dimensional Measurements in Turbulent Flames.* Lasers and digital camera systems for imaging of laser-induced fluorescence in two intersecting planes were added to existing systems for line-imaging measurements of temperature and major species in turbulent flames. The combination yields information on the magnitude and effects of three-dimensional scalar dissipation, which is a central quantity in combustion theory and modeling.
  - *Station Established to Generate Periodically Poled Lithium Niobate (PPLN).* A station has been designed and built to pole lithium niobate at the CRF. PPLN is a quasi-phase-matched crystal that is significantly more efficient and tunable than conventional crystals. Recent major advances in nonlinear optical materials have opened up many new possibilities for chemical sensing. In particular, the development of PPLN has sparked the advent of broadly tunable, compact, highly efficient infrared laser sources. This technology could be applied to problems such as medical monitoring or transient molecule detection.

- *Picosecond Lasers Constructed.* Continued progress in understanding combustion processes relies on developing increasingly sophisticated laser diagnostics for detailed understanding of collisional phenomena. To meet this need, CRF scientists have developed three new tunable, short-pulse lasers optimized for pump-probe experiments. These sources are custom-built distributed-feedback dye lasers with sufficient resolution for studying most intermolecular collisional processes.
- *Time- and Frequency-Resolved Fluorescence Microscopy.* Researchers at the CRF have constructed a time- and frequency-resolved photon detection system with fluorescence microscopy to simultaneously measure fluorescence lifetime and spectra. With such correlated time and spectral information, scientists can characterize the fluorescence emission from a microscopic sample in more detail than previously possible, thereby unraveling the uncertainties associated with measuring the fluorescence lifetime and frequency separately.

Detailed Program Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Chemical Sciences, Geosciences, and Energy Biosciences Research	**205,963**	**208,221**	**216,743**
▪ **Atomic, Molecular, and Optical (AMO) Science**	**13,379**	**13,401**	**13,401**

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.

In FY 2005, major activities will include the interactions of atoms and molecules with intense electromagnetic fields that are produced by collisions with highly charged ions or short laser pulses; the use of optical fields to control quantum mechanical processes; atomic and molecular interactions at ultracold temperatures; and the creation and utilization of quantum condensates that provide strong linkages between atomic and condensed matter physics at the nanoscale.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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.

▪ **Chemical Physics Research**	**32,097**	**30,334**	**31,617**

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 optical diagnostics such as degenerate four-wave mixing, cavity ring-down spectroscopies, high-resolution optical spectroscopy, and ion-imaging techniques have been developed to characterize gas phase processes. Other activities at the Combustion Research Facility involve BES interactions with Fossil Energy, Energy Efficiency and Renewable Energy, and industry.

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

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

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

In FY 2005 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 $667,000 in chemical physics research funding will result in a decreased effort in the study of aspects of gas phase chemistry. An additional $1,950,000 is provided for the following activities: the development of quantum chemical and density functional theories for the predictive, molecular-level modeling of

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

catalytic reaction mechanisms relevant to hydrogen production; use of first-principles dynamical calculations to investigate the interaction of hydrogen with storage materials; development of new analytical tools for probing natural hydrogen biocatalysts; and application of molecular modeling capabilities for predictive development of biomimetic catalysts for hydrogen production.

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

▪ **Photochemistry and Radiation Research**	**24,853**	**28,502**	**29,477**

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

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

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

In FY 2005, major activities will include research to expand our knowledge of the semiconductor/liquid interface, colloidal semiconductors, and dye-sensitized solar cells; inorganic/organic donor-acceptor molecular assemblies and photocatalytic cycles; photosynthetic antennae and the reaction center; and radiolytic processes at interfaces, radiolytic intermediates in supercritical fluids, and characterization of excited states by dual pulse radiolysis/photolysis

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

experiments. An additional $975,000 is provided for synthesis and characterization of inexpensive, nanostructured semiconductor materials for conversion of solar radiation to electricity and efficient and direct photocatalytic splitting of water to produce hydrogen through discovery of improved catalytic materials.

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.

▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	**11,797**	**12,133**	**13,108**

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 2005, an additional $975,000 is provided for fundamental research to improve the efficiency and decrease the cost of solar hydrogen production. Exploiting and mimicking components of natural hydrogen-producing systems will enable key improvements in efficiency and reduction in the cost of solar hydrogen production. Capital equipment is included in this request.

▪ **Metabolic Regulation of Energy Production**	**18,665**	**19,195**	**18,695**

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 2005, studies will continue on *Arabidopsis* as a model system for the study of other plant systems with broader utility. Increased emphasis will be placed upon understanding interactions that occur within the nanoscale range; this includes signal reception at biological surfaces and membranes, catalytic and enzyme-substrate recognition, and how these molecules transfer within and

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

between cellular components. This new activity constitutes the fundamental biological advances needed to complement the chemical nanoscale catalysis activities. An emerging area will be the development of new imaging tools and methods to examine metabolic and signaling pathways and to visualize cellular architecture, at both the physical-spatial and temporal scale.

▪ **Catalysis and Chemical Transformation**............	**33,854**	**34,453**	**36,402**

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

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

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

In FY 2005, the activity will continue to address recommendations of the FY 2002 BESAC-sponsored workshop that described new opportunities afforded by progress in the tools and concepts of nanoscience. The availability of new tools for preparation, characterization, and analysis and the merging of concepts drawn from homogeneous (single phase such as solution) catalysis, heterogeneous (between phases such as gas-surface) catalysis, and biocatalysts provide the potential to pioneer new approaches to catalysis design. An additional $1,949,000 is provided for fundamental research into the nature of catalytic processes on designed nanoscale catalysts. 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.

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.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **Separations and Analyses**	**14,547**	**13,517**	**16,441**

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

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

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

Knowledge of molecular level processes is required to characterize and treat extremely complex radioactive mixtures and to understand and predict the fate of associated contaminants in the environment. Though the cold war legacy is the most obvious of the Department's missions, the economic importance of separation science and technology is huge. For example, distillation processes in the petroleum, chemical, and natural gas industries annually consume the equivalent of 315 million barrels of oil. It has been estimated that separation processes account for more than five percent of total national energy consumption. Separations are essential to nearly all operations in the processing industries and are also necessary for many analytical procedures. An analysis is an essential component of every chemical process from manufacture through safety and risk assessment and environmental protection.

In FY 2005, major activities 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. An additional $2,924,000 is provided for research to improve separations with membranes (1) to invent membranes that can enhance the efficiency of gas separations to produce ultra-pure hydrogen; (2) to develop thermally robust inorganic membranes that will enable thermal water splitting cycles for hydrogen production; (3) to improve gas permeability while retaining high proton conductivity of membranes for fuel cells; and (4) to innovate novel high-temperature fuel cells with advanced polymeric and inorganic-ion-conducting membranes. Chemical analysis research will be initiated (1) to study hydrogen-separation materials and processes under realistic environmental conditions, rather than in high vacuum; (2) to achieve high temporal resolution, so that changes can be monitored dynamically; and (3) to enable multiple analytical measurements to be made simultaneously on systems such as fuel cell membranes, which have three percolation networks (proton, electron, and gas).

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

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		
▪ **Heavy Element Chemistry**..................................	**9,974**	**9,375**	**9,375**

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

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

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

Approximately twenty undergraduate students chosen from universities and colleges throughout the U.S. are given introductory lectures in actinide and radiochemistry each summer.

In FY 2005, major activities will include experiment, theory, and modeling to understand the chemical bonding in the heavy elements. Experimental studies will include aqueous and non-aqueous high-pressure chemistry and surface chemistry of these elements. In addition, new beamlines at synchrotron light sources capable of handling samples of these heavy elements will permit detailed spectroscopic studies of specimens under a variety of conditions. The study of the bonding in these heavy elements may also provide new insights into organometallic chemistry, beyond that learned from "standard" organometallic chemistry based on transition metals with d-orbital bonding.

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

▪ **Geosciences Research**..	**20,322**	**20,491**	**20,332**

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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

approaches to understand physical properties of fluids, rocks, and minerals. It seeks fundamental understanding of the physics of wave propagation in complex media ranging from single crystals to the scale of the earth's crust. This activity has pioneered the application of x-ray and neutron scattering to geochemical and geophysical studies.

These studies provide the fundamental science base for new capabilities to locate and monitor oil and gas reservoirs, contaminant migration, and for characterizing disposal sites for energy related wastes. This activity provides the majority of individual investigator basic research funding for the federal government in areas with the greatest impact on unique DOE missions such as high-resolution Earth imaging and low-temperature, low-pressure geochemical processes in the subsurface. This activity provides the basic research component in solid Earth sciences to the DOE's energy resources and environmental quality portfolios.

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.

▪ **Chemical Energy and Chemical Engineering....**	**9,779**	**10,637**	**10,687**

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

Knowledge of bulk behavior of chemicals and mixtures based on molecular properties is required for the design of energy efficient chemical processes in all aspects of plant design across the entire spectrum of industrial activities. The thermophysical and thermochemical properties of molecules provide the basis for developing equations of states and parameters for fluid models that are necessary for the development of engineering designs that maximize the efficiency of all energy production, storage, and consumption devices. These engineering designs are also an essential component of safety and risk assessment and environmental protection.

In the area of energy storage, coordination of fundamental and applied research efforts across the government is accomplished by participation in the Interagency Power Working Group. Close coordination with the Battery and Fuel Cell programs in Energy Efficiency and Renewable Energy's Transportation Technologies program is accomplished through joint program meetings, workshops, and strategy sessions.

In FY 2005, major activities will include research to expand the ability to control electrode structures on the nanometer scale. Preliminary studies have shown that this has a great impact on the electrochemical efficiency of electrode processes and the rate at which they respond to electrochemical potentials. An additional $975,000 is provided for research to understand: the nature of proton transport in high temperature polymer electrolyte membranes; the interaction of complex aqueous, gaseous, and solid interfaces in gas diffusion electrode assemblies; and the origin of the

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

performance-robbing over potential for fuel cell cathodes for hydrogen use. Research in aspects of electrochemical energy storage is reduced by $925,000.

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

	FY 2003	FY 2004	FY 2005
▪ **General Plant Projects (GPP)**..............................	**11,614**	**11,700**	**13,150**

GPP funding is increased in FY 2005 for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems principally at the Ames Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory as part of the Basic Energy Sciences stewardship responsibilities for these laboratories. Funding of this type is essential for maintaining the productivity and usefulness of the Department-owned facilities and in meeting requirements for safe and reliable facilities operation. Additional GPP funding is included in the

Facilities Operations justification in both the Materials Sciences and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram. The total estimated cost of each GPP project will not exceed $5,000,000.

	FY 2003	FY 2004	FY 2005
▪ **General Purpose Equipment (GPE)**	**4,382**	**4,483**	**4,058**

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

	FY 2003	FY 2004	FY 2005
▪ **SPEAR3 Upgrade**	**700**	**0**	**0**

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade (funded in both BES subprograms) was undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The upgrade increased injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decreased beam emittance by a factor of 7 to increase beam brightness; increased operating current from 100 mA to 200 mA to increase beam intensity; and maintained long beam life time (>25 hr). The increased photon flux will greatly improve performance in a variety of applications including powder and thin film diffraction, topographic studies, surface microcontamination studies, x-ray tomographic analysis, x-ray absorption studies, and protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring were replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC was $29,000,000; DOE and NIH equally funded the upgrade with a total Federal cost of $58,000,000. NIH provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and $1,000,000 in FY 2001. This MIE project was completed on schedule and within budget. The SPEAR3 is now being commissioned.

	FY 2003	FY 2004	FY 2005
Facility Operations..	**5,935**	**5,967**	**6,169**

The facility operations budget request, which includes operating funds, capital equipment, and general plant projects is described in a consolidated manner later in this budget. This subprogram funds the

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

Combustion Research Facility. General Plant Project (GPP) funding is also required for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. The total estimated cost of each GPP project will not exceed $5,000,000.

Facilities

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Combustion Research Facility	5,935	5,967	6,169

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
SBIR/STTR	**0**	**5,394**	**5,510**

In FY 2003, $4,687,000 and $281,000 were transferred to the SBIR and STTR programs, respectively. The FY 2004 and FY 2005 amounts shown are the estimated requirements for the continuation of the SBIR and STTR programs.

	FY 2003	FY 2004	FY 2005
Total, Chemical Sciences, Geosciences, and Energy Biosciences	**211,898**	**219,582**	**228,422**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Chemical Sciences, Geosciences, and Energy Biosciences Research	
▪ Overall increase for chemical physics research because of increase for research related to the hydrogen economy ($+1,950,000) and decrease because of decreased emphasis on gas phase chemistry ($-667,000)	+1,283
▪ Increase for photochemistry and radiation research for research related to the hydrogen economy	+975
▪ Increase in molecular mechanisms of natural solar energy conversion for research related to the hydrogen economy.	+975
▪ Decrease in metabolic regulation of energy production research because of decreases in microbial research.	-500
▪ Increase in catalysis and chemical transformations for research related to the hydrogen economy	+1,949

	FY 2005 vs. FY 2004 ($000)
▪ Increase in separations and analyses for research related to the hydrogen economy..	+2,924
▪ Decrease in geosciences research because of decreased research in geophysics........	-159
▪ Overall increase for chemistry and chemical engineering because of increase for research related to the hydrogen economy ($+975,000) and decreases because of decreases in aspects of electrochemical energy storage ($-925,000)..........................	+50
▪ Increase in general plant projects intended to help alleviate recurring maintenance costs by improving infrastructure..	+1,450
▪ Decrease in general purpose equipment because of one time need in FY 2004	-425
Total, Chemical Sciences, Geosciences, and Energy Biosciences Research..............	+8,522
Facilities Operations	
Increase for operations of the Combustion Research Facility.	+202
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in operating expenses	+116
Total Funding Change, Chemical Sciences, Geosciences, and Energy Biosciences ..	+8,840

Construction

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Construction					
SNS	210,571	123,865	80,535	-43,330	-35.0%
Project Engineering Design, NSRCs	11,850	2,982	2,012	-970	-32.5%
Project Engineering Design, LCLS	5,925	7,456	20,075	+12,619	+169.2%
Linac Coherent Light Source (SLAC)	0	0	30,000	+30,000	--
Center for Functional Nanomaterials (BNL)	0	0	18,465	+18,465	--
The Molecular Foundry (LBNL)	0	34,794	32,085	-2,709	-7.8%
Center for Nanophase Materials Science (ORNL)	23,701	19,882	17,811	-2,071	-10.4%
Center for Integrated Nanotechnologies (SNL/LANL)	4,444	29,674	30,897	+1,223	+4.1%
Total, Construction	256,491	218,653	231,880	+13,227	+6.0%

Description

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

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 2003	FY 2004	FY 2005
Construction	**256,491**	**218,653**	**231,880**
▪ **Spallation Neutron Source (SNS)**	**210,571**	**123,865**	**80,535**

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 takes advantage of specialized technical capabilities within the laboratories: Lawrence Berkeley National Laboratory in ion sources; Los Alamos National Laboratory in linear accelerators; Thomas Jefferson National Accelerator Facility in superconducting linear accelerators; Brookhaven National Laboratory in proton storage rings; Argonne National Laboratory in instruments; and Oak Ridge National Laboratory in targets and moderators.

In FY 2001, two grants were awarded to universities for research requiring the design, fabrication, and installation of instruments for neutron scattering. These instruments will be sited at the SNS, with commissioning beginning late in FY 2006, shortly after the SNS facility itself is commissioned. Both awards were made based on competitive peer review conducted under 10 CFR Part 605, Financial Assistance Program. In 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 $5,635,000 in FY 2003, $7,387,000 in FY 2004, and $7,643,000 in FY 2005. These instruments will be built by individual DOE laboratories or consortia of DOE laboratories in collaboration with the SNS based on scientific merit and importance to users from universities, industries, and government laboratories.

Funds appropriated in FY 2002 continued R&D, design, procurement, construction activities, and component installation. Essentially all R&D supporting construction of the SNS was completed, with instrument R&D continuing. Title II design was completed on the linac and was continued on the ring, target, and instrument systems. The completed ion source and portions of the drift tube linac

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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, and installation activities, and to begin system commissioning. The ion source will be commissioned, and the drift tube linac will be installed and commissioning begun. Installation of other linac components will proceed, and installation of ring components will begin. Target building construction and equipment installation will continue in concert with each other. Numerous conventional facilities, including the klystron, central utilities, and ring service buildings as well as the linac and ring tunnels, will be completed. All site utilities will be available to support linac commissioning activities.

FY 2004 budget authority will continue instrument R&D, design, and procurement. The drift-tube linac and cavity-coupled linac portions of the warm linac commissioning will be completed. Other commissioning activities will continue in the linac. Cryogenic refrigerator installation and system cool down will be completed and cryogenic transfer line installation and testing will be completed. Cryogenic module fabrication and installation will continue. High-energy beam transport installation and testing will be completed. Ring fabrication and assembly activities will continue. Target fabrication and assembly activities will continue. Most SNS buildings will be completed with the exception of ongoing construction work in the target and instrument facilities and the central laboratory and office building.

FY 2005 budget authority is requested to continue R&D, procurement, and installation of equipment for instrument systems. The extraction dump, high-energy beam transport, and accumulator ring will be commissioned; installation and testing for the ring-target beam transport system will be performed. Preparation for the ring-target beam transport system accelerator readiness review will begin. Installation and testing will be completed and preparation for the accelerator readiness review will start for target systems. Conventional facilities construction will be completed. Procurement, installation, and testing will continue for integrated control systems.

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**....................................	**11,850**	**2,982**	**2,012**

Funds appropriated in FY 2002, FY 2003 and FY 2004 will 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. Additional information follows later in PED data sheet 02-SC-002.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **Project Engineering and Design, Linac Coherent Light Source**...	**5,925**	**7,456**	**20,075**

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

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

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

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

The proposed LCLS Project requires a 150 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new 120 meter undulator and associated equipment. The preliminary Total Estimated Cost (TEC) is in the range of $220,000,000 to $260,000,000. FY 2005 Project Engineering Design (PED) funding of $20,075,000 and $4,000,000 of research and development budgeted in the Materials Sciences and Engineering subprogram are requested for Title I and Title II design work. Additional information on the LCLS Project is provided in the LCLS PED data sheet, project number 03-SC-002.

	FY 2003	FY 2004	FY 2005
▪ **Linac Coherent Light Source**	**0**	**0**	**30,000**

In FY 2005, $30,000,000 is requested for the LCLS to initiate long-lead procurements. Early acquisition of selected critical path items will support 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. Early acquisition of the injector is required in order that first tests of the free-electron laser can begin. Acquisition of the undulators in FY 2005 will allow delivery in FY 2007, which in turn will enable achievement of performance goals in FY 2008.

	FY 2003	FY 2004	FY 2005
▪ **Nanoscale Science Research Center – The Center for Functional Nanomaterials, Brookhaven National Laboratory**	**0**	**0**	**18,465**

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

FY 2005 funding is requested for the start of 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 2003	FY 2004	FY 2005
▪ **Nanoscale Science Research Center – The Molecular Foundry, LBNL**	**0**	**34,794**	**32,085**

The **Molecular Foundry**, a planned 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, physics, chemistry, biology, and molecular biology. State-of-the-art equipment will include clean rooms; controlled environmental rooms; scanning tunneling microscopes; atomic

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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 is appropriated for the start of construction of the Molecular Foundry at Lawrence Berkeley National Laboratory. FY 2005 funding is requested to continue construction and equipment procurement. 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.

	FY 2003	FY 2004	FY 2005
▪ **Nanoscale Science Research Center – The Center for Nanophase Materials Sciences, ORNL**	**23,701**	**19,882**	**17,811**

The **Center for Nanophase Materials Sciences (CNMS)**, a proposed 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, collaborated with 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 2003 and FY 2004 funding was appropriated for the start of construction of the Center for Nanophase Materials Science to be located at Oak Ridge National Laboratory. FY 2005 funding is requested to continue this construction. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Additional information follows later in construction project data sheet 03-R-312.

	FY 2003	FY 2004	FY 2005
▪ **Nanoscale Science Research Center – The Center for Integrated Nanotechnologies, Sandia National Laboratories/Los Alamos National Laboratory**	**4,444**	**29,674**	**30,897**

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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

FY 2003 and FY 2004 funding was appropriated for the construction for the Center for Integrated Nanotechnologies managed jointly by Sandia National Laboratories and Los Alamos National Laboratory. FY 2005 funding is requested to continue this construction. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Additional information follows later in construction project data sheet 03-R-313.

Total, Construction	**256,491**	**218,653**	**231,880**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Construction	
▪ Decrease in funding for construction of the Spallation Neutron Source at ORNL, representing the scheduled ramp down of activities.	-43,330
▪ 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.	-970
▪ Increase in funding for Project Engineering Design (PED) related to design-only activities for the Linac Coherent Light Source (LCLS) at SLAC, representing the scheduled increase in activities.	+12,619
▪ Increase in funding to initiate long-lead procurements for the LCLS project.............	+30,000
▪ Increase in funding for construction of the Center for Functional Nanomaterials at BNL, representing the start of construction.	+18,465
▪ Decrease in funding for construction of the Molecular Foundry at LBNL, representing the scheduled ramp down of activities.	-2,709
▪ Decrease in funding for construction of the Center for Nanophase Materials Sciences at ORNL, representing the scheduled ramp down of activities....................	-2,071
▪ Increase in funding for construction of the Center for Integrated Nanotechnologies at SNL/LANL, representing the continuation of activities.	+1,223
Total Funding Change, Construction..	+13,227

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 2003	FY 2004	FY 2005	$ Change	% Change
Major User Facilities					
Advanced Light Source	42,844	43,205	42,200	-1,005	-2.3%
Advanced Photon Source	90,894	93,410	97,400	+3,990	+4.3%
National Synchrotron Light Source	36,950	38,325	38,400	+75	+0.2%
Stanford Synchrotron Radiation Laboratory	25,903	30,305	28,100	-2,205	-7.3%
High Flux Isotope Reactor	36,838	37,805	39,832	+2,027	+5.4%
Radiochemical Engineering Development Center	6,515	6,305	6,300	-5	-0.1%
Intense Pulsed Neutron Source	16,714	16,655	17,222	+567	+3.4%
Manuel Lujan, Jr. Neutron Scattering Center	9,914	10,110	10,300	+190	+1.9%
Spallation Neutron Source	14,441	18,397	33,100	+14,703	+79.9%
Combustion Research Facility	5,935	5,967	6,169	+202	+3.4%
Total, Major User Facilities	286,948	300,484	319,023	+18,539	+6.2%

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.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Major User Facilities	**286,948**	**300,484**	**319,023**
▪ Advanced Light Source at Lawrence Berkeley National Laboratory.	42,844	43,205	42,200
▪ Advanced Photon Source at Argonne National Laboratory	90,894	93,410	97,400
▪ National Synchrotron Light Source at Brookhaven National Laboratory.	36,950	38,325	38,400
▪ Stanford Synchrotron Radiation Laboratory at Stanford Linear Accelerator Center.	25,903	30,305	28,100
▪ High Flux Isotope Reactor at Oak Ridge National Laboratory.	36,838	37,805	39,832
▪ Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory.	6,515	6,305	6,300
▪ Intense Pulsed Neutron Source at Argonne National Laboratory.	16,714	16,655	17,222
▪ Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory.	9,914	10,110	10,300
▪ Spallation Neutron Source at Oak Ridge National Laboratory.	14,441	18,397	33,100
▪ Combustion Research Facility at Sandia National Laboratories/California.	5,935	5,967	6,169
Total, Major User Facilities	286,948	300,484	319,023

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Plant Projects	12,461	12,108	13,572	+1,464	+12.1%
Accelerator Improvement Projects	8,957	9,900	9,759	-141	-1.4%
Capital Equipment	82,846	80,681	81,838	+1,157	+1.4%
Total, Capital Operating Expenses	104,264	102,689	105,169	+2,480	+2.4%

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2003	FY 2004	FY 2005	Unapprop-riated Balances
99-E-334, ORNL, Spallation Neutron Source	1,192,700	736,629	210,571	123,865	80,535	41,100
02-SC-002 PED, Nanoscale Science Research Centers	19,844 [a]	3,000	11,850	2,982	2,012	0
03-SC-002, PED, SLAC, Linac Coherent Light Source	36,000 [b]	0	5,925	7,456	20,075	2,544
03-R-312, ORNL, Center for Nanophase Material Sciences	63,882 [c]	0	23,701	19,882	17,811	0
03-R-313, SNL, Center for Integrated Nanotechnologies	73,800[d]	0	4,444	29,674	30,897	4,626
04-R-313, LBNL, The Molecular Foundry	83,700[e]	0	0	34,794	32,085	9,606
05-R-320, SLAC, Linac Coherent Light Source	260,000[b]	0	0	0	30,000	194,000
05-R-321, BNL, Center for Functional Nanomaterials	79,700[f]	0	0	0	18,465	55,253
Total, Construction		739,629	256,491	218,653	231,880	343,129

[a] The full Total Estimated Cost (design and construction) ranges between $266,500,000 and $286,500,000. This estimate is based on conceptual data and should not be construed as a project baseline.

[b] The full TEC Projection (design and construction) ranges between $220,000,000 and $260,000,000. This estimate is based on conceptual design and should not be construed as a project baseline.

[c] Includes $2,488,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

[d] Includes $4,159,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

[e] Includes $7,215,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

[f] Includes $5,982,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2003	FY 2004	FY 2005	Accept-ance Date
SPEAR3 Upgrade	29,000[a]	19,000	10,000	0	0	FY 2004
ANL Center for Nanophase Materials	36,000	0	0	10,000	12,000	FY 2006
SNS Instrumentation[b]	50,000-75,000	0	5,635	7,387	7,643	FY 2007-FY 2011 est.
Total, Major Items of Equipment		19,000	15,635	17,387	19,643	

[a] DOE portion only; total estimated Federal cost, including NIH funding (beginning in FY 1999), is $58,000,000.

[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.

99-E-334, Spallation Neutron Source, Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Changes from FY 2004 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1999 Budget Request (Preliminary Estimate)	1Q 1999	4Q 2003	3Q 2000	4Q 2005	1,138,800	1,332,800
FY 2000 Budget Request	1Q 1999	4Q 2003	3Q 2000	1Q 2006	1,159,500	1,360,000
FY 2001 Budget Request	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,220,000	1,440,000
FY 2001 Budget Request (*Amended*)	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2002 Budget Request	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2003 Budget Request	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2004 Budget Request	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2005 Budget Request (*Current Estimate*)	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700

2. Financial Schedule [a]

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
1999	101,400	101,400	37,140
2000	100,000	100,000	105,542
2001	258,929	258,929	170,454
2002	276,300	276,300	253,059
2003	210,571	210,571	276,887
2004	123,865[b]	123,865[b]	207,139
2005	80,535[b]	80,535[b]	96,081
2006	41,100	41,100	46,398

[a] Beyond the 5 instruments included in the SNS line item project, a broad instrument development program is being executed over the next several years to qualify and provide instruments for the remaining 19 neutron beam lines (the target station is designed to accommodate a total of 24 instruments). Instrument proposals undergo a scientific peer review process to evaluate technical merit; those concepts that are accepted may then establlsh interface agreements with the SNS Project. Expected funding sources include appropriated funds through the Department of Energy and other Federal agencies, private industry, and foreign entities. These instruments will all be delivered after completion of the SNS line item project. The instruments listed below have been initiated with the identified funding sources. As indicated, five of these instruments have been grouped together for the sake of management efficiency to form the "SNS Instruments – Next Generation" (SING) project, which is budgeted in the Basic Energy Sciences program as a Major Item of Equipment.

1. Cold Neutron Chopper Spectrometer – Basic Energy Sciences grant to Pennsylvania State University;
2. Wide Angle Chopper Spectrometer – Basic Energy Sciences grant to California Institute of Technology;
3. High Pressure Diffractometer – Basic Energy Sciences (SING);
4. High Resolution Chopper Spectrometer – Basic Energy Sciences (SING);
5. Single Crystal Diffractometer – Basic Energy Sciences (SING);
6. Hybrid Spectrometer – Basic Energy Sciences (SING);
7. Disordered Materials Diffractometer – Basic Energy Sciences (SING);
8. Fundamental Physics Beam Line – Nuclear Physics; and
9. Engineering Diffractometer – the Canada Foundation for Innovation.

The final 10 SNS instruments will be selected under this process and identified when they are approved and funded.

[b] Construction funding was reduced by $735,140 as a result of the FY 2004 rescission. The reduction is restored in FY 2005 to maintain the TEC and project scope.

3. Project Description, Justification and Scope [a]

The purpose of the Spallation Neutron Source (SNS) Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering and related research in broad areas of the physical, chemical, materials, and biological sciences. The SNS will be a national facility with an open user policy attractive to scientists from universities, industries, and federal laboratories. It is anticipated that the facility, when fully operating, will be used by 1,000-2,000 scientists and engineers each year and that it will meet the national need for neutron science capabilities well into the 21st Century.

The scientific justification and need for a new neutron source and instrumentation in the U.S. were established by numerous studies by the scientific community since the 1970s. These include the 1984 National Research Council study *Major Facilities for Materials Research and Related Disciplines* (the Seitz-Eastman Report), which recommended the immediate start of the design of both a steady-state source and an accelerator-based pulsed spallation source. More recently, the 1993 DOE Basic Energy Sciences Advisory Committee (BESAC) report *Neutron Sources for America's Future* (the Kohn Panel Report) again included construction of a new pulsed spallation source with SNS capabilities among its highest priorities. This conclusion was even more strongly reaffirmed by the 1996 BESAC Report (the Russell Panel Report), which recommended the construction of a 1 megawatt (MW) spallation source that could be upgraded to significantly higher powers in the future.

Neutron scattering enables the determination of the positions and motions of atoms in materials, and it has become an increasingly indispensable scientific tool. Over the past decade, it has made invaluable contributions to the understanding and development of many classes of new materials, from high temperature superconductors to fullerenes, a new form of carbon. The information that neutron scattering provides has wide impacts. For example, chemical companies use neutrons to make better fibers, plastics, and catalysts; drug companies use neutrons to design drugs with higher potency and fewer side effects; and automobile manufacturers use the penetrating power of neutrons to understand how to cast and forge gears and brake discs in order to make cars run better and more safely. Furthermore, research on magnetism using neutrons has led to higher strength magnets for more efficient electric generators and motors and to better magnetic materials for magnetic recording tapes and computer hard drives.

Based on the recommendations of the scientific community obtained via the Russell Panel Report, the SNS is required to operate at an average power on target of at least 1 megawatt (MW); although the designers had aimed for 2 MW, current projections fall between 1 to 2 MW. At this power level, the SNS will be the most powerful spallation source in the world-many times that of ISIS at the Rutherford Laboratory in the United Kingdom. Furthermore, the SNS is specifically designed to take advantage of improvements in technology, new technologies, and additional hardware to permit upgrades to

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[a] As part of the development of Oak Ridge National Laboratory, other buildings may be located on Chestnut Ridge, which is the site of the SNS and is located just across Bethel Valley Road from improvements planned for the main ORNL campus. For example, the Center for Nanophase Materials Sciences (CNMS) will be located on Chestnut Ridge, because research activities at the CNMS will integrate nanoscale science research with neutron science; synthesis; and theory, modeling, and simulation. The CNMS will be adjacent to the SNS Laboratory – Office Building and will be connected to it by a walkway. See construction project datasheet 03-R-312 for further information on the CNMS.

substantially higher power as they become available. Thus, the SNS will be the nation's premiere neutron facility for many decades.

The importance of high power – and consequently high neutron intensity – cannot be overstated. The properties of neutrons that make them an ideal probe of matter also require that they be generated with high flux. (Neutrons are particles with the mass of a proton, with a magnetic moment, and with no electrical charge.) Neutrons interact with nuclei and magnetic fields; both interactions are extremely weak, but they are known with great accuracy. Because they have spin, neutrons have a magnetic moment and can be used to study magnetic structure and magnetic properties of materials. Because they weakly interact with materials, neutrons are highly penetrating and can be used to study bulk phase samples, highly complex samples, and samples confined in thick-walled metal containers. Because their interactions are weak and known with great accuracy, neutron scattering is far more easily interpreted than either photon scattering or electron scattering. However, the relatively low flux of existing neutron sources and the small fraction of neutrons that get scattered by most materials, mean that most measurements are limited by the source intensity.

The pursuit of high-flux neutron sources is more than just a desire to perform experiments faster, although that, of course, is an obvious benefit. High flux enables broad classes of experiments that cannot be done with low-flux sources. For example, high neutron intensity enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions.

The SNS will consist of a linac-ring accelerator system that delivers short (microsecond) pulses to a target/moderator system where neutrons are produced by a nuclear reaction process called spallation. The process of neutron production in the SNS consists of the following: negatively charged hydrogen ions are produced in an ion source and are accelerated to approximately 1 billion electron volts energy in a linear accelerator (linac); the hydrogen ion beam is injected into an accumulator ring through a stripper foil, which strips the electrons off of the hydrogen ions to produce a proton beam; the proton beam is collected and bunched into short pulses in the accumulator ring; and, finally, the proton beam is injected into a heavy metal target at a frequency of up to 60 Hz. The intense proton bursts striking the target produce pulsed neutron beams by the spallation process. The high-energy neutrons so produced are moderated (i.e., slowed down) to reduce their energies, typically by using thermal or cold moderators. The moderated neutron beams are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations.

The primary objectives in the design of the site and buildings for the SNS are to provide optimal facilities for the DOE and the scientific community for neutron scattering well into the 21st Century and to address the mix of needs associated with the user community, the operations staff, security, and safety.

A research and development (R&D) program is required to ensure technical feasibility and to determine physics design of accelerator and target systems that will meet performance requirements.

The objectives stated above will be met by the technical components described earlier (ion source; linac; accumulator ring; target station with moderators; beam transport systems; and initial experimental equipment necessary to place the SNS in operation) and attendant conventional facilities. As the project design and construction progresses, value engineering analyses and R&D define changes that are applied to the technical baseline to maximize the initial scientific capability of the SNS within the currently established cost and schedule. The SNS project will be considered complete when all capital facilities necessary to achieve the initial baseline goals have been installed and certified to operate safely and properly. In addition, to the extent possible within the Total Project Cost, provisions will be made to facilitate a progression of future improvements and upgrades aimed at keeping SNS at the forefront of neutron scattering science throughout its operating lifetime. Indeed, the current design contains a number of enhancements (e.g. superconducting radiofrequency acceleration, best-in-class instruments, more instrument stations, and higher energy ring) that provide higher performance than the conceptual design that was the basis of initial project approval.

The scientific user community has advised the DOE Office of Basic Energy Sciences that the SNS should keep pace with developments in scientific instruments. Since the average cost for a state-of-the-art instrument has roughly doubled in recent years, SNS has reduced the number of instruments provided within the project TEC. Although this translates into an initial suite of five rather than the ten instruments originally envisioned, the cumulative scientific capability of the SNS has actually increased more than ten-fold. In order to optimize the overall project installation sequence and early experimental operations, three of these instruments will be installed as part of the project; the other two will be completed, with installation occurring during initial low power operations. As with all scientific user facilities such as SNS, additional and even more capable instruments will be installed over the course of its operating lifetime.

Funds appropriated in FY 2003 were used to continue R&D and design, procurement, construction, and installation activities, and to begin system commissioning. The ion source was commissioned, and the drift tube linac installation and commissioning were begun. Installation of other linac components proceeded and installation of ring components began. Target building construction and equipment installation continued in concert with each other. Numerous conventional facilities, including the klystron, central utilities, and ring service buildings as well as the linac and ring tunnels, were completed. All site utilities were made available to support linac commissioning activities.

FY 2004 budget authority will continue instrument R&D, design, and procurement. The drift tube linac and coupled cavity linac subsystems will be installed and commissioned. Other commissioning activities will continue in the linac. Cryogenic refrigerator installation and system cool down will be completed, and cryogenic transfer line installation and testing will be completed. Cryogenic module fabrication and installation will continue. The high-energy beam transport installation and testing will be completed. Ring fabrication and assembly activities will continue. Target fabrication and assembly activities will continue. Most buildings will be completed with the exception of ongoing construction work in the target building and the central laboratory and office building.

FY 2005 budget authority is requested to continue R&D, procurement, and installation of equipment for instrument systems. The extraction dump, high-energy beam transport, and accumulator ring will be commissioned; installation and testing for the ring-target beam transport system will be performed. Preparation for the ring-target beam transport system accelerator readiness review will begin. Installation and testing will be completed and preparation for the accelerator readiness review will start for target systems. Conventional facilities construction will be completed. Procurement, installation, and testing will continue for integrated control systems.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design and Management Costs		
Engineering, design and inspection at approximately 20% of construction costs	160,500	159,500
Construction management at approximately 2% of construction costs	15,900	14,000
Project management at approximately 13% of construction costs	104,700	104,700
Construction Costs		
Improvements to land (grading, paving, landscaping, and sidewalks)	31,500	31,500
Buildings	239,800	196,300
Utilities (electrical, water, steam, and sewer lines)	20,900	20,900
Technical Components	520,600	507,200
Standard Equipment	17,500	17,500
Major computer items	5,500	5,500
Design and project liaison, testing, checkout and acceptance	31,000	31,000
Subtotal	1,147,900	1,088,100
Contingencies at approximately 4% of above costs [b]	44,800	104,600
Total, Line Item Costs (TEC)	1,192,700	1,192,700

5. Method of Performance

The SNS project is being carried out by a partnership of six DOE national laboratories, led by Oak Ridge National Laboratory, as the prime contractor to DOE. The other five laboratories are Argonne, Brookhaven, Lawrence Berkeley, and Los Alamos National Laboratories and Thomas Jefferson National Accelerator Facility. Each laboratory is assigned responsibility for accomplishing a well defined portion of the project's scope that takes advantage of their technical strengths: Argonne – Instruments; Brookhaven – Accumulator Ring; Lawrence Berkeley – Ion Source; Los Alamos – Normal conducting linac and RF power systems; TJNAF – Superconducting Linac; Oak Ridge - Target. Project execution is the responsibility of the Associate Laboratory Director with the support of a central SNS Project Office at ORNL, which provides overall project management, systems integration, ES&H, quality assurance, and commissioning support. The SNS Associate Laboratory Director has authority for directing the efforts at all six partner laboratories and exercises financial control over all project activities. ORNL has subcontracted to an Industry Team that consists of an Architect-Engineer for the conventional facilities design and a Construction Manager for construction installation, equipment procurement, testing and

[a] The project is using the appropriated funds included in the TEC to meet or exceed the project performance baseline. The project is also accepting transferred surplus materials and equipment to the extent possible. Examples of the transferred items include ring pumps, lead bricks, concrete blocks, trailers and furniture. The net book value of the surplus materials will be far less than one percent of the TEC over the life of the project. All such transferred materials will be appropriately recorded as non-fund cost and capitalized.

[b] The current baselined contingency level, expressed as a percentage of the remaining effort to complete the line item project, is approximately 20%.

commissioning support. Procurements by all six laboratories are being accomplished, to the extent feasible, by fixed price subcontracts awarded on the basis of competitive bidding.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2003	FY 2004	FY 2005	Outyears	Total
Project Cost						
Facility Cost [a]						
Line Item TEC....................................	566,195	276,887	207,139	96,081	46,398	1,192,700
Other project costs						
R&D necessary to complete project [b]	78,784	3,062	1,442	799	359	84,446
Conceptual design cost [c]...................	14,397	0	0	0	0	14,397
NEPA Documentation costs [d].............	1,958	-30	0	0	0	1,928
Other project-related costs [e]..............	20,696	11,505	18,493	32,158	34,274	117,126
Capital equipment not related construction [f]	846	65	107	85	0	1,103
Total, Other project costs...........................	116,681	14,602	20,042	33,042	34,633	219,000
Total project cost (TPC).............................	682,876	291,489	227,181	129,123	81,031	1,411,700

[a] Construction line item costs included in this budget request are for providing Title I and II design, inspection, procurement, and construction of the SNS facility for an estimated cost of $1,192,700,000.

[b] A research and development program at an estimated cost of $84,446,000 is needed to confirm several design bases related primarily to the accelerator systems, the target systems, safety analyses, cold moderator designs, and neutron guides, beam tubes, and instruments. Several of these development tasks require long time durations and the timely coupling of development results into the design is a major factor in detailed task planning.

[c] Costs of $14,397,000 are included for conceptual design and for preparation of the conceptual design documentation prior to the start of Title I design in FY 1999.

[d] Costs of $1,928,000 are included for completion of the Environmental Impact Statement.

[e] Estimated costs of $117,126,000 are included to cover pre-operations costs.

[f] Estimated costs of $1,103,000 to provide test facilities and other capital equipment to support the R&D program.

7. Related Annual Funding Requirements

	(FY 2007 dollars in thousands)	
	Current Estimate	Previous Estimate
Facility operating costs	45,700	45,700
Facility maintenance and repair costs	24,800	24,800
Programmatic operating expenses directly related to the facility	47,700	40,000
Capital equipment not related to construction but related to the programmatic effort in the facility	14,100	11,800
GPP or other construction related to the programmatic effort in the facility	1,000	1,000
Utility costs	19,400	19,400
Accelerator Improvement Modifications (AIMs)	7,300	7,300
Total related annual funding (4Q FY 2006 will begin operations)	160,000	150,000

During conceptual design of the SNS project, the annual funding requirements were initially estimated based on the cost of operating similar facilities (e.g., ISIS and the Advanced Photon Source) at $106,700,000. The operating parameters, technical capabilities, and science program are now better defined and the key members of the ORNL team that will operate SNS are now in place. Based on these factors, the SNS Project developed a new estimate of annual operating costs, which was independently reviewed by the Department, and provides the basis of the current estimate indicated above. FY 2007 will be the first full year of operations and this estimate is generally representative of the early period of SNS operations. By the time SNS is fully instrumented and the facility is upgraded to reach its full scientific potential, the annual funding requirements will increase by an additional 10-15 percent.

02-SC-002, Project Engineering Design (PED), Various Locations

(Changes from the FY 2004 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost [a] ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete	
FY 2002 Budget Request *(Preliminary Estimate)*	2Q 2002	3Q 2004	N/A	N/A	14,000
FY 2003 Budget Request	2Q 2002	3Q 2003	N/A	N/A	15,000
FY 2004 Budget Request	2Q 2002	3Q 2003	N/A	N/A	20,000
FY 2005 Budget Request *(Current Estimate)*	2Q 2002	4Q 2004	N/A	N/A	19,844

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	3,000	3,000	1,547
2003	11,850	11,850	10,436
2004	2,982	2,982	4,905
2005	2,012	2,012	2,956

3. Project Description, Justification and Scope

This PED request provides for Title I and Title II Architect-Engineering (A-E) services for projects related to the establishment of user centers for nanoscale science, engineering, and technology research. These funds allow designated projects to proceed from conceptual design into preliminary design (Title I) and definitive design (Title II). The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design and working drawings and specifications, and provide construction schedules including procurements. The design effort will ensure that construction can physically start or long-lead procurement items can be procured in the fiscal year in which Title III construction activities are funded.

[a] . . . Based on the results of peer review, the total design cost is $19,844,769, reduced from the FY 2004 President's Request of $20,000,000 due to the general reduction and rescission in FY 2003 and the rescission in FY 2004. The full Total Estimated Cost for each of the four currently proposed NSRC construction projects is identified in the FY 2005 construction datasheets.

Updated PED design projects are described below. Some changes may occur due to continuing conceptual design studies or developments prior to enactment of an appropriation. These changes will be reflected in subsequent years.

Nanoscale Science Research Centers (NSRCs)

To support research in nanoscale science, engineering, and technology, the U.S. has constructed outstanding facilities for *characterization and analysis* of materials at the nanoscale. Most of these world-class facilities are owned and operated by BES. They include, for example, the synchrotron radiation light source facilities, the neutron scattering facilities, and the electron beam microscope centers. However, world-class facilities that are widely available to the scientific research community for nanoscale *synthesis, processing, and fabrication* do not exist. NSRCs are intended to fill that need. NSRCs will serve the Nation's researchers and complement university and industrial capabilities in the tradition of the BES user facilities and collaborative research centers. Through the establishment of NSRCs affiliated with existing major user facilities, BES will provide state-of-the-art equipment for materials synthesis, processing, and fabrication at the nanoscale in the same location as facilities for characterization and analysis. NSRCs will build on the existing research and facility strengths of the host institutions in materials science and chemistry research and in x-ray and neutron scattering. This powerful combination of colocated fabrication and characterization tools will provide an invaluable resource for the Nation's researchers.

In summary, the purposes of NSRCs are to:

- provide state-of-the-art nanofabrication and characterization equipment to in-house and visiting researchers,
- advance the fundamental understanding and control of materials at the nanoscale,
- provide an environment to support research of a scope, complexity, and disciplinary breadth not possible under traditional individual investigator or small group efforts,
- provide a formal mechanism for both short- and long-term collaborations and partnerships among DOE laboratory, academic, and industrial researchers,
- provide training for graduate students and postdoctoral associates in interdisciplinary nanoscale science, engineering, and technology research,
- provide the foundation for the development of nanotechnologies important to the Department.

Centers have been proposed by: Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and a consortium of Los Alamos National Laboratory (LANL) and Sandia National Laboratory (SNL). Based on peer review of the Center proposals, PED funding has been provided for BNL, LBNL, ORNL, and LANL/SNL. Funding for the ANL Center is included as a Major Item of Equipment beginning in FY 2004. Construction funding is also requested for BNL, LBNL, ORNL, and LANL/SNL in FY 2005.

FY 2002 Proposed Design Projects

02-01: Center for Nanoscale Materials – Argonne National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
N/A	N/A	N/A	N/A	0 [a]	0 [a]

Fiscal Year	Appropriations	Obligations	Costs
2002	0 [a]	0[a]	0[a]
2003	0 [a]	0[a]	0[a]

The Center for Nanoscale Materials (CNM) at ANL will consist of conventional facilities, fabrication facilities, characterization instruments, computational capabilities, and a beamline at the Advanced Photon Source (APS). The CNM will be attached to the APS at a location not occupied by one of the standard Laboratory-Office Modules that serve the majority of the APS sectors. The CNM is being coordinated with a State of Illinois effort. The State of Illinois is providing design and construction funding in FY 2002-2004 for the building. For this reason, PED funding is not planned or requested for this effort.

02-02: The Molecular Foundry – Lawrence Berkeley National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
3Q 2002	1Q 2004	2Q 2004	1Q 2007	7,215 [b]	83,700

Fiscal Year	Appropriations	Obligations	Costs
2002	500 [b]	500 [b]	38
2003	6,715 [b]	6,715 [b]	5,263
2004	0	0	1,258
2005	0	0	656

[a] The FY 2002 Request included funding of $1,000,000 in FY 2002 and FY 2003 for this project. Based on results of peer review, funding was not planned for FY 2002 or in the FY 2003 Request. The building portion of the project is being funded by the State of Illinois while DOE plans to fund capital equipment for the Center as one or more MIEs. The CNM is funded at $10,000,000 in FY 2004 President's Request with a MIE TEC of $36,000,000. Funding for the CNM MIE is continued in the FY 2005 Request at $12,000,000.

[b] The FY 2004 Request identified $500,000 for FY 2002 and $6,800,000 for FY 2003. The FY 2003 funding was reduced by $84,531 as a result of the general reduction and rescission. The project received construction funds in FY 2004.

The proposed Molecular Foundry at LBNL will be a new structure near the National Center for Electron Microscopy. The project includes an approximately 89,000 gross square foot research building, a separate approximately 6,000 gross square foot utility center, and special equipment to support nanoscale scientific research. The research building will be an advanced facility for the design, modeling, synthesis, processing, fabrication, and characterization of novel molecules and nanoscale materials. Space in the new facility will support studies in nanostructures by providing offices and laboratories for materials science, physics, chemistry, biology, and molecular biology. These laboratories, equipped with advanced instrumentation and staffed by full-time, dedicated staff scientists and technicians, will be user facilities, available to scientists from universities, industry, and government laboratories whose research proposals have been peer reviewed by a Proposal Study Panel. This combination of advanced equipment, collaborative staff, and breadth across disciplines will allow users to explore the frontiers of nanoscience. New and existing beamlines at the ALS, not part of this PED activity, will support efforts at the Molecular Foundry. Construction funding for this project was initiated in FY 2004.

02-03: Center for Functional Nanomaterials – Brookhaven National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
4Q 2003	4Q 2004	3Q 2005	2Q 2008	5,982[a]	79,700

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	0 [a]	0 [a]	0
2003	988 [a]	988 [a]	733
2004	2,982 [a]	2,982 [a]	2,949
2005	2,012 [a]	2,012 [a]	2,300

The Center for Functional Nanomaterials will be housed in a laboratory/office building of approximately 85,000 square feet that includes class 10 clean rooms, general laboratories, and wet and dry laboratories for sample preparation, fabrication, and analysis. There will be an initial set of equipment necessary to explore, manipulate, and fabricate nanoscale materials and structures. Also included are individual offices, seminar area, transient user space for visiting collaborators with access to computer terminals, conference areas, vending/lounge areas, and other support spaces. Equipment procurement for the project will include equipment needed for laboratory and fabrication facilities for e-beam lithography, transmission electron microscopy, scanning probes and surface characterization, material synthesis and fabrication, and spectroscopy. The building will incorporate human factors into its design to encourage peer interactions and collaborative interchange by BNL staff and research teams from collaborating institutions. In addition to flexible office and laboratory space it will provide

[a] The FY 2002 Request included $1,000,000 in FY 2002 and $2,000,000 in FY 2003 for this project. Based on results of peer review, funding was not planned for FY 2002 or in the FY 2003 Request. Based on the merits of a revised proposal, $988,000 of PED funding was provided in FY 2003, $2,982,000 was provided in FY 2004, and $2,012,000 is requested in FY 2005. PED funding was reduced by $12,000 as a result of the FY 2003 general reduction and rescission and by $17,700 as a result of the FY 2004 rescission.

"interaction areas" a seminar room and a lunch room for informal discussions. This design approach is considered state-of-the-art in research facility design as it leverages opportunities for the free and open exchange of ideas essential to creative research processes. Based on the results of the FY 2001 peer review of the Center for Functional Nanomaterials, PED funding was not planned for FY 2002. Based on the review of a revised proposal, PED funding was provided in FY 2003 and FY 2004 and is requested in FY 2005.

02-04: Center for Nanophase Materials Sciences – Oak Ridge National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002	1Q 2003	3Q 2003	4Q 2006	2,488 [a]	64,000

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	1,500 [a]	1,500 [a]	1,342
2003	988 [a]	988 [a]	1,121
2004	0	0	25

A major focus of the Center for Nanophase Materials Sciences (CNMS) will be the application of neutron scattering for characterization of nanophase materials. In this area, CNMS will be a world leader. With the construction of the new Spallation Neutron Source (SNS) and the upgraded High Flux Isotope Reactor (HFIR), it is essential that the U.S.-based neutron science R&D community grow to the levels found elsewhere in the world and assume a scientific leadership role. Neutron scattering provides unique information about both atomic-scale structure and the dynamics of a wide variety of condensed matter systems including polymers, macromolecular systems, magnetic and superconducting materials, and chemically complex materials, particularly oxides and hydrogen-containing structures. Consequently, the intense neutron beams at HFIR and SNS will make, for the first time, broad classes of related nanoscale phenomena accessible to fundamental study.

The CNMS building (approximately 80,000 gross square feet) will contain wet and dry materials synthesis and characterization laboratories; clean rooms and materials imaging, manipulation, and integration facilities in a nanofabrication research laboratory; computer-access laboratories for nanomaterials theory and modeling; and office space for staff and visitors. The CNMS facility will consist of a multi-story building for materials synthesis and characterization contiguous with a single-story structure for nanofabrication having Class 100, Class 1,000, and Class 10,000 clean areas. The latter portion of the facility will be built using a construction approach that will meet low electromagnetic field, vibration, and acoustic noise requirements for special nanofabrication and characterization equipment. Construction funding for this project was initiated in FY 2003.

[a] Funding of $1,000,000 in FY 2003 and $2,000,000 in FY 2004 was identified in the FY 2003 Request for this project. Based on the results of peer review, this project was funded at $1,500,000 in FY 2002 and $988,000 in FY 2003. PED funding was reduced $12,000 as a result of the FY 2003 general reduction and rescission.

02-06: The Center for Integrated Nanotechnologies (CINT) – Sandia National Laboratories/Los Alamos National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
4Q 2002	2Q 2004	1Q 2004	3Q 2007	4,159 [a]	73,800

Fiscal Year	Appropriations	Obligations	Costs
2002	1,000 [a]	1,000 [a]	167
2003	3,159 [a]	3,159 [a]	3,319
2004	0	0	673

The Center for Integrated Nanotechnologies (CINT), jointly managed by the Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL), has as its primary objective the development of the scientific principles that govern the performance and integration of nanoscale materials, thereby building the foundations for future nanotechnologies. CINT will consist of a core research facility of approximately 95,000 square feet to be located in an unrestricted area just outside the restricted area at SNL and two smaller "gateway" facilities located on the campuses of SNL and LANL. These gateways will provide office space and, in the case of the LANL gateway limited amounts of laboratory space, for researchers who need access to specialized facilities located on these campuses. The SNL gateway will use existing space in SNL's Integrated Materials Research Laboratory; the LANL gateway will require construction of a small building of approximately 34,000 square feet. The CINT gateway to SNL will focus on specialized microfabrication and nanomaterials capabilities and expertise. The CINT gateway to LANL will focus on connecting CINT researchers to the extensive biosciences and nanomaterials capabilities at LANL. The core research facility and the gateways will be managed as one integrated facility by a single management structure led by SNL. The CINT will focus on nanophotonics, nanoelectronics, nanomechnics, and functional nanomaterials. The Center will make use of a wide range of specialized facilities, including the Los Alamos Neutron Science Center and the National High Magnetic Field Laboratory at LANL, and the Microelectronics Development Laboratory and the Compound Semiconductor Research Laboratory at SNL. Construction funding for this project was initiated in FY 2003.

The CINT core facility in Albuquerque will provide an open environment readily accessible by students and visitors, including foreign nationals. This structure will house state-of-the-art clean rooms and an initial set of equipment for nanolithography, atomic layer deposition, and materials characterization along with general purpose chemistry and electronics labs and offices for Center staff and collaborators. The complex will require class 1,000 clean room space for nanofabrication and characterization equipment and an additional class 100 clean room space for lithography activities. This facility will also

[a] The FY 2002 Request included a total of $1,000,000 in FY 2002 and $2,000,000 in FY 2003 for the LANL and SNL components of this combined project. Based on results of peer review, current PED funding plan for the combined project is $1,000,000 for FY 2002 and $3,159,000 in FY 2003. PED funding of $41,000 and construction funding of $56,074 were reduced as a result of the FY 2003 general reduction and rescission.

require general purpose chemistry/biology laboratories and electronic and physical measurement laboratories. To house the Center staff, collaborators, Center-sponsored post docs, visiting students and faculty, and industry collaborators, offices and meeting rooms will be provided.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	14,844	15,000
Design Management costs (15.1% of TEC)	3,000	3,000
Project Management costs (10.1% of TEC)	2,000	2,000
Total Design Costs (100% of TEC)	19,844	20,000
Total, Line Item Costs (TEC)	19,844	20,000

5. Method of Performance

Design services are obtained through competitively awarded fixed price contracts. M&O contractor staff may be utilized in areas involving security, production, proliferation, etc. concerns.

6. Schedule of Project Funding

	(dollars in thousands)				
	Prior Year Costs	FY 2003	FY 2004	FY 2005	Total
Facility Cost					
PED	1,547	10,436	4,905	2,956	19,844
Other project costs					
Conceptual design cost[b]	1,490	0	0	0	1,490
Total, Project Costs	3,037	10,436	4,905	2,956	21,334

[a] This cost estimate is based on direct field inspection and historical cost estimate data, coupled with parametric cost data and completed conceptual studies and designs when available. The cost estimate includes design phase activities only. Construction activities will be requested as individual line items on completion of Title I design.

[b] Only Conceptual Design Costs associated with the NSRCs are included. Other project costs are identified for individual NSRCs on the individual construction project data sheets for Project 03-R-312, Center for Nanophase Materials Sciences; Project 04-R-313, Molecular Foundry; Project 03-R-313, Center for Integrated Nanotechnologies; and 05-R-321, Center for Functional Nanomaterials.

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

(Changes from the FY 2004 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost[a] ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Project Complete	
FY 2003 Budget Request *(Preliminary Estimate)*	1Q 2003	2Q 2005	N/A	N/A	33,500
FY 2004 Budget Request	1Q 2003	4Q 2006	N/A	N/A	36,000
FY 2005 Budget Request *(Current Estimate)*......	2Q 2003	4Q 2006	N/A	N/A	36,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2003	5,925 [b]	5,925	3,644
2004	7,456 [b]	7,456	9,000
2005	20,075 [b]	20,075	17,756
2006	2,544 [b]	2,544	5,600

3. Project Description, Justification and Scope

These funds allow the Linac Coherent Light Source (LCLS), located at the Stanford Linear Accelerator Center (SLAC), to proceed from conceptual design into preliminary design (Title I) and definitive design (Title II). The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design, working drawings and specifications, and provide construction schedules including procurements. The design effort will ensure that construction can physically start or long-lead procurement items can be procured in the fiscal year in which Title III construction activities are funded.

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[a] The full TEC Projection (design and construction) ranges between $220,000,000 and $260,000,000. This is a preliminary estimate; the baseline TEC will be established at Critical Decision 2 (Approve Performance Baseline).

[b] PED funding was reduced as a result of the FY 2003 general reduction and rescission by $74,765 and as a result of the FY 2004 rescission by $44,250. This total reduction is restored in FY 2005 and FY 2006 to maintain the TEC and project scope.

The purpose of the LCLS Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray free-electron-laser (FEL) in the 1.5 – 15 Angstrom range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems. This will be the world's first such facility.

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

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

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

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

The proposed LCLS Project requires a 135 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one-third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new undulator and associated equipment. Two new experimental buildings, the Near Hall and the Far Hall will be constructed and connected by a beam line tunnel. A Central Laboratory and Office Building will be constructed to provide laboratory and office space for LCLS users and serve as a center of excellence for basic research in x-ray physics and ultrafast science.

4. Details of Cost Estimate[a]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	26,000	26,000
Design Management costs (13.9% of TEC)	5,000	5,000
Project Management costs (13.9% of TEC)	5,000	5,000
Total Design Costs (100% of TEC)	36,000	36,000
Total, Line Item Costs (TEC)	36,000	36,000

5. Method of Performance

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

[a] This cost estimate includes design phase activities only. Construction funding is requested as an individual line item on completion of Title I design.

The design of technical systems is being accomplished by the three collaborating laboratories. The conventional construction design aspect (experimental halls, tunnel connecting the halls, and a Central Laboratory and Office Building) will be contracted to an experienced Architect/Engineering (A/E) firm to perform Title I and II design in FY 2004. The A/E contract will be awarded under full and open competition to pre-qualified offerors using fixed-priced contracts.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2003	FY 2004	FY 2005	Outyears	Total
Facility Cost						
PED	0	3,644	9,000	17,756	5,600	36,000
Other project costs						
Conceptual design cost	1,470	0	0	0	0	1,470
Research and development costs	0	0	2,000	4,000	0	6,000
NEPA documentation costs	30	0	0	0	0	30
Total, Other Project Costs	1,500	0	2,000	4,000	0	7,500
Total Project Cost (TPC)	1,500	3,644	11,000	21,756	5,600	43,500

03-R-312, Center For Nanophase Materials Sciences
Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Changes from FY 2004 Congressional Budget Request are denoted with a vertical line in the left margin.)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2003 Budget Request *(Preliminary Estimate)*...........................	2Q2002	1Q2003	3Q2003	4Q2006	64,000	65,000
FY 2004 Budget Request.......................	2Q2002	1Q2003	3Q2003	4Q2006	64,000	65,000
FY 2005 Budget Request *(Current Estimate)*.................................	2Q2002	1Q2003	3Q2003	4Q2006	63,882[a]	64,882[a]

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering & Design (PED)			
2002	1,500	1,500	1,342
2003	988[b]	988[b]	1,121
2004	0	0	25
Construction			
2003	23,701[b]	23,701[b]	1,160
2004	19,882[b]	19,882[b]	18,267
2005	17,811	17,811	19,215
2006	0	0	22,752

[a] The TEC and TPC are reduced by $118,000 due to the FY 2004 Rescission.

[b] PED and construction funding were reduced by $12,000 and $299,062, respectively, as a result of the FY 2003 general reduction and rescission and by $118,000 as result of the FY 2004 rescission.

3. Project Description, Justification and Scope

This proposed Center for Nanophase Materials Sciences (CNMS) will establish a nanoscale science research center at Oak Ridge National Laboratory (ORNL) that will integrate nanoscale science research with neutron science, synthesis science, and theory/modeling/simulation of nanophase materials. The total gross area of the new building will be approximately 80,000 square feet, providing state-of-the-art clean rooms, and general laboratories for sample preparation, fabrication and analysis. Included will be initial equipment for nanoscale materials research such as surface analysis equipment, nanofabrication facilities, etc. The facility, co-located with the Spallation Neutron Source complex, will house ORNL staff members and visiting scientists from academia and industry. There are no existing buildings at ORNL that could serve these needs.

The CNMS's major scientific thrusts will be in nano-dimensioned soft materials, complex nanophase materials systems, and the crosscutting areas of interfaces and reduced dimensionality that become scientifically critical on the nanoscale. A major focus of the CNMS will be to exploit ORNL's unique facilities and capabilities in neutron scattering to determine the structure of nanomaterials, to develop a detailed understanding of synthesis and self-assembly processes in "soft" materials, and to study and understand collective (cooperative) phenomena that emerge on the nanoscale. Neutron scattering provides unique information (complementary to that provided by other methods) about both the atomic-scale structure and the dynamics of a wide variety of condensed matter systems including polymers, macromolecular systems, magnetic and superconducting materials, and chemically complex materials, particularly oxides and hydrogen-containing structures. The intense neutron beams available at the upgraded High Flux Isotope Reactor and the new Spallation Neutron Source will make broad classes of related nanoscale phenomena accessible to fundamental study.

Since the late 1980s, there has been a recognized need to enhance U.S. capabilities in the synthesis of materials. These concerns are exacerbated by the challenges of controlled synthesis of nanophase materials. There is currently a critical, unmet national need for the synthesis of high quality nanophase research materials. It is also recognized that the existence of capabilities for science-driven synthesis of novel materials has played a central role in some of the most spectacular recent discoveries of new phenomena, including high-temperature superconductivity, the quantum and fractional quantum Hall effects, conducting polymers, and colossal magnetoresistance. Therefore, synthesis and characterization of nanophase materials (including copolymers and macromolecular systems, multilayered nanostructures, ceramics, composites, and alloys with nanoscale spatial charge and/or magnetic ordering) will be an essential component of the CNMS. With these capabilities the CNMS will become a national resource for nanophase materials for use by researchers across the nation.

The CNMS project scope includes preliminary and final design, as well as procurement of an initial set of experimental capital equipment and construction of facilities. PED funding was allocated in FY 2002 and FY 2003 to complete design of the CNMS. FY 2003 construction funding was used to initiate construction and equipment procurement. FY 2004 and FY 2005 funding will be used to continue funding the conventional construction and equipment procurement.

4. Details of Cost Estimate[a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design Costs	2,067	1,700
Design Management Costs (0.6% of TEC)	366	200
Project Management Costs (0.1% of TEC)	55	100
Total, Design Costs	2,488	2,000
Construction Phase		
Improvements to Land	125	500
Buildings	27,269	19,700
Special Equipment[b]	21,149	26,000
Utilities	500	500
Inspection, design and project liaison, testing, checkout and Acceptance	1,638	1,800
Construction Management (2.8% of TEC)	1,800	900
Project Management (1.7% of TEC)	1,100	800
Total, Construction Costs	53,581	50,200
Contingencies		
Design Phase (0% of TEC)	0	500
Construction Phase (12.2% of TEC)	7,813	11,300
Total, Contingencies (12.2% of TEC)	7,813	11,800
Total, Line Item Costs (TEC)	63,882	64,000

5. Method of Performance

Design will be performed by an architect-engineer utilizing a fixed price subcontract. Construction will be performed by a fixed-price construction contractor administered by the ORNL operating contractor. Procurement of research capital equipment will be performed by the ORNL operating contractor. Project and construction management, inspection, coordination, utility tie-ins, testing and checkout witnessing, and acceptance will be performed by the ORNL operating contractor.

[a] The annual escalation rates are: FY 2002 – 2.6%, FY 2003 – 2.8%, FY 2004 – 2.8%, FY 2005 – 2.9% and FY 2006 – 2.9% as directed by DOE.

[b] Initial research equipment, including testing and acceptance.

6. Schedule of Project Funding

	(dollars in thousands)					
	Prior Years	FY 2003	FY 2004	FY 2005	Outyears	Total
Project Cost						
Facility Cost						
Design	1,342	1,121	25	0	0	2,488
Construction	0	1,160	18,267	19,215	22,752	61,394
Total, Line item TEC	1,342	2,281	18,292	19,215	22,752	63,882
Other project costs						
Conceptual design costs	150	0	0	0	0	150
NEPA documentation Costs	5	0	0	0	0	5
Other project related Costs [a]	320	100	250	100	75	845
Total, Other Project Costs	475	100	250	100	75	1,000
Total, Project Cost (TPC)	1,817	2,381	18,542	19,315	22,827	64,882

7. Related Annual Funding Requirements

	(FY 2006 dollars in thousands)	
	Current Estimate	Previous Estimate
Annual facility operating costs	18,000	18,000
Total related annual funding	18,000	18,000

[a] Experimental research will begin at the time of beneficial occupancy of the facility. These research costs are not part of the TPC and will be funded by BES.

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

(Changes from FY 2004 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

The revisions in the approximate square footages of both the Core Facility (95,000 GSF) and the Gateway to Los Alamos Facility (34,000 GSF) from those presented in the FY 2004 CINT Project Data Sheet are the result of the completion of Title I design.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2004 Budget Request *(Preliminary Estimate)*	3Q 2002	2Q 2004	3Q 2004	3Q 2007	73,800	75,800
FY 2005 Budget Request *(Current Estimate)*	4Q 2002	2Q 2004	1Q 2004	3Q 2007	73,800	75,800

2. Financial Schedule [a]

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering and Design (PED)			
2002	1,000	1,000	167
2003	3,159 [b]	3,159 [b]	3,319
2004	0	0	673
Construction			
2003	4,444 [c]	4,444 [c]	0
2004	29,674 [d]	29,674 [d]	11,747
2005	30,897 [c]	30,897	40,908
2006	4,626 [d]	4,626	15,667
2007	0	0	1,319

3. Project Descriptions, Justification and Scope

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

CINT will be a distributed Center that is jointly operated by SNL and LANL. Its primary objective is to develop the scientific principles that govern the performance and integration of nanoscale materials, thereby building the foundations for future nanotechnologies. The distinguishing characteristic of the Center is its focus on exploring the path from scientific discovery to the integration of nanostructures into the micro and macro worlds. This path involves experimental and theoretical exploration of behavior, understanding new performance regimes and concepts, testing designs, and integrating

[a] This project was submitted in the FY 2004 President's Request as project 04-R-314. In FY 2003 Congress appropriated construction funds for this project (after the FY 2004 Request was submitted to Congress) under project 03-R-313.

[b] PED funding was reduced $41,000 as a result of the FY 2003 general reduction and rescission. This total reduction/rescission is restored in the FY 2005 request to maintain the TEC and project scope.

[c] Construction funding was reduced by $56,074 as a result of the FY 2003 general reduction and rescission. This total reduction/rescission is restored in the FY 2005 request to maintain the TEC and project scope.

[d] Construction funding was reduced by $176,115 as a result of the FY 2004 rescission. This rescission is restored in FY 2006 to maintain the TEC and project scope.

nanoscale materials and structures. This Center works closely with the other NSRCs to ensure that their discoveries are evaluated in the context of integrated functional systems. This approach offers a unique role for the DOE in support of the National Nanotechnology Initiative.

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

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

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

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

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

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

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

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

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

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

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

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs	2,507	2,640
Design Management Costs (1.1% of TEC)	806	540
Project Management Costs (1.0% of TEC)	710	400
Total, Design Costs (5.5% of TEC)	4,023	3,580
Construction Phase		
Buildings	34,415	35,990
Improvements to Land[b]	1,430	0
Utilities[b]	1,777	0
Special Equipment[c]	16,645	15,760
Standard Equipment	2,178	1,540
Inspection, Design and Project Liaison, Testing, Checkout and Acceptance	3,151	2,900
Construction and Project Management (1.6% of TEC)	1,212	1,030
Total, Construction Costs	60,808	57,220
Contingencies		
Design Phase (0.2% of TEC)	136	620
Construction Phase (12.0% of TEC)	8,833	12,380
Total, Contingencies (12.2% of TEC)	8,969	13,000
Total, Line Item Costs (TEC)	73,800	73,800

[a] This cost estimate is based on direct field inspection and historical cost estimate data, coupled with parametric cost data and completed conceptual studies and designs. Escalation rates are taken from the DOE construction project and operating expense escalation rate assumptions (as of January 27, 2002).

[b] This cost was previously included in the cost estimate for the element "Buildings." The current cost estimate is based on a completed Title II design, vendor bids, and independent project review of site utilities conducted September 2003.

[c] Initial research equipment including testing and acceptance.

5. Method of Performance

Contracted Architect-Engineering (AE) support was used for development of the design concept and associated narrative and supporting material for the Conceptual Design Report. Design Criteria and other documents required during the conceptual phase for the Core Facility were done by SNL personnel with external support as needed. The outcome of this phase of the project was all necessary information to acquire CD-1 approval. Title I and II design for the Core Facility is being provided by contracted A-E support. The construction contractor shall be selected using a competitive best value process. The process will consider the contractors' qualifications and experience and the quoted price. The resultant contract will likely be fixed price (incentive) type.

Performance specifications have been prepared by LANL staff with contracted support for the Gateway to Los Alamos Facility. A design-build contract will be awarded to a construction contractor selected using a competitive best value process. The process will consider the contractors' qualifications, experience, and the quoted price.

SNL and LANL personnel are providing project management, design management, and project controls support.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 2003	FY 2004	FY 2005	Outyears	Total
Project Cost						
Facility Cost						
Design	167	3,319	673	0	0	4,159
Construction	0	0	11,747	40,908	16,986	69,641
Total, Line item TEC	167	3,319	12,420	40,908	16,986	73,800
Other Project Costs						
Conceptual design cost	330	0	0	0	0	330
NEPA documentation costs	199	0	0	0	0	199
Other project-related costs [a]	271	0	150	500	550	1,471
Total, Other Project Costs	800	0	150	500	550	2,000
Total, Project Costs (TPC)	967	3,319	12,570	41,408	17,536	75,800

[a] Includes tasks such as Safety documentation, ES&H Monitoring, Operations and Maintenance Support, Readiness Assessment, and Pre-operational Start-up. Experimental research will begin at the time of beneficial occupancy of the facilities. These research costs are not part of the TPC and will be funded by the BES program.

7. Related Annual Funding Requirements [a]

(FY 2006 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs	18,500	18,500
Total related annual funding	18,500	18,500

[a] These costs are preliminary and based on the conceptual design.

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

(Changes from the FY 2004 Congressional Budget Request denoted with a vertical line in the left margin)

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2004 Budget Request *(PreliminaryEstimate)*	3Q 2002	1Q 2004	2Q 2004	2Q 2006	83,700	85,000
FY 2005 Budget Request *(Current Estimate)*	3Q 2002	1Q 2004	2Q 2004	1Q 2007	83,700	85,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering And Design (PED)			
2002	500	500	38
2003	6,715 [a]	6,715 [a]	5,263
2004	0	0	1,258
2005	0	0	656
Construction			
2004	34,794 [b]	34,794 [b]	15,813
2005	32,085 [a]	32,085 [a]	43,263
2006	9,606 [b]	9,606 [b]	17,204
2007	0	0	205

[a] PED funding was reduced by $84,531 as a result of the FY 2003 general reduction and rescission. This total reduction/rescission is restored in the FY 2005 request to maintain the TEC and project scope.

[b] Construction funding was reduced by $206,500 as a result of the FY 2004 rescission. This reduction is restored in FY 2006 to maintain the TEC and project scope.

3. Project Description, Justification and Scope

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

The goals and operation of the Molecular Foundry are consistent with DOE guidance and address the research challenges described in the reports *Nanoscale Science, Engineering and Technology Research Directions* and *Complex Systems: Science for the 21st Century*. The Foundry's laboratories will be designed and constructed to facilitate collocation of research activities in a wide variety of fields, as required for progress in this new area of science. The Foundry will support a broad research effort focusing on both "hard" nanomaterials (nanocrystals, tubes, and lithographically patterned structures) and "soft" nanometer-sized materials (polymers, dendrimers, DNA, proteins, and whole cells), as well as design, fabrication, and study of multi-component, complex, functional assemblies of such materials.

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

FY 2004 funding is being used to initiate construction to complete site preparation, and for equipment procurement.

FY 2005 funding will be used to continue conventional construction and equipment procurement.

4. Details of Cost Estimate[a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary Design & Final Design	4,877	4,300
Design Management costs (1.9% of TEC)	1,570	1,650
Total, Design Costs (7.7% of TEC)	6,447	5,950
Construction Phase		
Building & Improvements to land	47,450	43,300
Special Equipment[b]	15,000	15,300
Inspection, design and project liaison, check out	2,446	1,700
Construction Management & Project Management (2.5% of TEC)	2,106	2,150
Total, Construction Costs	67,002	62,450
Contingencies		
Design Phase (0.3% of TEC)	768	1,330
Construction Phase (12.0% of TEC)	9,483	13,970
Total, Contingencies (12.2% of TEC)	10,251	15,300
Total, Line Item Costs (TEC)	83,700	83,700

5. Method of Performance

An Architect Engineering firm (AE) with appropriate multi-disciplinary design experience has prepared a building program and design criteria with the support of the LBNL Facilities Department. The AE also prepared Title I and II design and will provide technical oversight during Title III construction. A Construction Management (CM) contractor will perform cost, schedule, and constructability reviews during design. Selection of the CM contractor during the design phases was based on competitive bidding of the Construction General Conditions. The CM contract has an option for management of the construction process. At the completion of design, the CM contractor will bid out the design to subcontractors. The University will have the option to proceed with the CM contractor or bid the project to a separate subcontractor. Construction subcontract(s) will be awarded on a competitive basis using best value source selection criteria that will include price, safety, and other considerations.

[a] This cost estimate is based on Title I design. The annual escalation rates assumed in the FY 2004 estimate for FY 2003 through FY 2007, are 2.1%, 2.5%, 2.9%, 2.8% and 2.6% respectively.

[b] Initial research equipment.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Years	FY 2003	FY 2004	FY 2005	Outyears	Total
Facility Cost						
PED	38	5,263	1,258	656	0	7,215
Construction	0	0	15,813	43,263	17,409	76,485
Total, Line Item TEC	38	5,263	17,071	43,919	17,409	83,700
Other Project Costs						
Conceptual design cost	730	0	0	0	0	730
NEPA Documentation Costs	40	0	0	0	0	40
Other project-related costs[a]	150	12	0	0	368	530
Total, Other Project Costs	920	12	0	0	368	1,300
Total, Project Costs (TPC)	958	5,275	17,071	43,919	17,777	85,000

7. Related Annual Funding Requirements

(FY 2006 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs	18,000	18,000
Total related annual funding	18,000	18,000

[a] Includes tasks such as safety documentation, ES&H monitoring, operations and maintenance support, readiness assessment, and preoperational start-up. Experimental research will begin at the time of beneficial occupancy of the facility. These research costs are not part of the TPC and will be funded by the BES program.

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

A Performance Baseline has been established for long-lead procurements in order to request funds to initiate these procurements in FY 2005. Thus, the funds requested for FY 2005 will ensure that selected critical path items can be procured in that year. The overall cost and schedule for the LCLS Project are only preliminary estimates. Plans call for a cost and schedule Performance Baseline to be developed during FY 2004 and approved by the Acquisition Executive at the completion of preliminary design (Critical Decision 2 – Approve Performance Baseline). The outyear funding projections (FY 2006-FY 2008) will support the completion of the LCLS at the Stanford Linear Accelerator Center and will be adjusted as necessary at Critical Decision 2 to support the Performance Baseline.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost [a] ($000)	Total Project Cost [a] ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2005 Budget Request *(Current Estimate)*	2Q 2003	4Q 2006	1Q2006	4Q2008	260,000	315,000

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering Design			
2003	5,925 [b]	5,925 [b]	3,644
2004	7,456 [b]	7,456 [b]	9,000
2005	20,075 [b]	20,075	17,756
2006	2,544 [b]	2,544	5,600
Construction			
2005	30,000 [c]	30,000	24,000
2006	83,000	83,000	76,000
2007	83,000	83,000	80,500
2008	28,000	28,000	43,500

[a] The TEC and TPC are currently projections based on ranges of $220,000,000 to $260,000,000 for the TEC and $265,000,000 to $315,000,000 for the TPC. The baseline TEC and TPC will be established at Critical Decision 2 (Approve Performance Baseline).

[b] PED funding was reduced by $74,765 as a result of the FY 2003 general reduction and rescission and by $44,250 as a result of the FY 2004 rescission. This total reduction is restored in FY 2005 and FY 2006 to maintain the TEC and project scope.

[c] FY 2005 funding is for long lead procurements. Project construction begins in FY 2006.

3. Project Description, Justification and Scope

These funds allow the Linac Coherent Light Source (LCLS), located at the Stanford Linear Accelerator Center (SLAC), to proceed from conceptual design into preliminary design (Title I), final design (Title II), and construction. The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design, working drawings and specifications, and provide construction schedules including procurements.

The purpose of the LCLS Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray FEL in the 1.5 - 15 Angstrom range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems described below. This will be the world's first such facility.

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

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

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

The proposed LCLS Project requires a 135 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one-third of the linac will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new undulator and associated equipment. Two new experimental buildings, the Near Hall and the Far Hall, will be constructed and connected by the beam line tunnel. A Central Laboratory

Office Building will be constructed to provide laboratory and office space for LCLS users and serve as a center of excellence for basic research in x-ray physics and ultrafast science.

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

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

Construction funding in FY 2005 is for long-lead procurements. Early acquisition of selected critical path items will support pivotal schedule and technical aspects of the project. These include acquisition of the 135 MeV injector linac, acquisition of the undulator modules and the measurement system needed for verification of undulator performance, and acquisition of main linac magnets and radiofrequency systems required to produce electron beams meeting the stringent requirements of the LCLS free-electron laser (FEL). Early acquisition of the 135 MeV injector is required in order that first tests of the FEL can begin. Acquisition of the undulators in FY 2005 will allow delivery in FY 2007, which in turn will enable achievement of performance goals in FY 2008. The main linac magnets and radiofrequency systems must be ready for operation shortly after the linac has reached its performance goals.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	18,500	N/A
Design Management costs (2.0% of TEC)	5,000	N/A
Project Management costs (2.0% of TEC)	5,000	N/A
Total Design Costs	28,500	N/A
Construction Phase		
Improvements to Land	8,000	N/A
Buildings	36,300	N/A
Other Structures	1,800	N/A
Special Equipment	98,000	N/A
Inspection, design and project liaison, testing, checkout and acceptance	4,500	N/A
Construction Management (2.3% of TEC)	6,000	N/A
Project Management	11,700	N/A
Total, Construction Costs	166,300	N/A
Contingencies		
Design Phase (2.9% of TEC)	7,500	N/A
Long Lead Procurements (2.3% of TEC)	6,000	N/A
Construction Phase (20.0% of TEC)	51,700	N/A
Total, Contingencies (25.1% of TEC)	65,200	N/A
Total, Line Item Costs (TEC)	260,000	N/A

5. Method of Performance

A Conceptual Design Report (CDR) for the project has been completed and reviewed. Key design activities are being specified in the areas of the injector, undulator, x-ray optics and experimental halls to reduce the risk of the project and accelerate the startup. Also, the LCLS management systems are being put in place and tested during the Project Engineering Design (PED) phase. These activities are managed by the LCLS Project Office at SLAC, with additional portions of the project being executed by staff at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL). The design of technical systems is being accomplished by the three collaborating laboratories. The conventional construction design aspect (experimental halls, tunnel connecting the halls, and a Central Laboratory and Office Building) will be contracted to an experienced Architect/Engineering (A/E) firm

[a] Long-lead procurements are scheduled for FY 2005. The outyear (FY 2006-FY 2008) construction costs are estimates only. A baseline for outyear construction costs will be established when Critical Decision 2 for the LCLS Project is approved.

to perform Title I and II design in FY 2004. The A/E contract will be awarded under full and open competition to pre-qualified offerors using fixed-priced contracts.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2003	FY 2004	FY 2005	Outyears[a]	Totals
Facility Cost						
PED	0	3,644	9,000	17,756	5,600	36,000
Long-Lead Procurements	0	0	0	24,000	6,000	30,000
Construction	0	0	0	0	194,000	194,000
Total, Line Item TEC	0	3,644	9,000	41,756	205,600	260,000
Other project costs						
Research & Development	0	0	2,000	4,000	0	6,000
Conceptual Design	1,470	0	0	0	0	1,470
NEPA documentation costs	30	0	0	0	0	30
Pre-operations	0	0	0	0	39,500	39,500
Spares	0	0	0	0	8,000	8,000
Total, Other Project Costs	1,500	0	2,000	4,000	47,500	55,000
Total Project Cost (TPC)	1,500	3,644	11,000	45,756	253,100	315,000

7. Related Annual Funding Requirements

(FY 2009 dollars in thousands)

	Current Estimate	Previous Estimate
Annual facility operating costs	$50,000	N/A
Total related annual funding	$50,000	N/A

FY 2009 is expected to be the first full year of LCLS facility operations. The current estimate is preliminary and based on historical experience with operating similar types and sizes of facilities. This estimate will be refined as the LCLS Project matures.

[a] The outyear (FY 2006-FY 2008) construction costs are estimates only. A baseline for outyear construction costs will be established when Critical Decision 2 for the LCLS Project is approved.

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

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 2005 Budget Request *(Current Estimate)*	4Q 2003	4Q 2004	3Q 2005	2Q 2008	79,700	81,000

2. Financial Schedule

(Dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering & Design (PED)			
2003	988 [a]	988 [a]	733
2004	2,982 [a]	2,982 [a]	2,949
2005	2,012	2,012	2,300
Construction			
2005	18,465 [a]	18,465	12,000
2006	36,553 [a]	36,553	30,000
2007	18,700	18,700	27,200
2008	0	0	4,518

3. Project Description, Justification and Scope

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

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[a] PED funding was reduced by $12,000 as a result of the FY 2003 general reduction and rescission and by $17,700 as a result of the FY 2004 rescission. This total reduction is restored in FY 2005 and FY 2006 to maintain the TEC and project scope.

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

The design and scope of the CFN will fulfill DOE mission needs and incorporate input from potential users, gained through many channels including outreach efforts such as workshops. An essential component of the project is to establish an organizational infrastructure open to external users based on peer review. In this way a truly national nanomaterials effort can create breakthrough opportunities. The laboratory areas are organized into seven clusters established to provide the necessary primary user service. Cluster functions cover a wide range of physical and chemical synthesis and characterization. They are designated Nanopatterning, Ultrafast Optical Sources, Electron Microscopy, Materials Synthesis, Proximal Probes, Theory and Computing, and CFN Endstations at NSLS. The CFN will allow users to control processes, tailoring the properties of materials structured on the nanoscale. Some of these materials, all relevant to the BES mission, include piezoelectrics, ferroelectrics, organic films and conductors, magnetic nanocomposites, and catalysts.

This effort began with preliminary engineering (Title I) and detailed engineering design (Title II) necessary to construct a BNL Center for Functional Nanomaterials. The engineering effort includes all engineering phase activities, including field investigation, preliminary design, specifications and drawings for conventional construction, final design, preparation of procurement documents for experimental equipment, and construction/equipment procurement estimates.

The completed design will enable construction of a new two-story Laboratory/Office building of approximately 85,000 gross square feet. The facility will include clean rooms, general laboratories, and wet and dry laboratories for sample preparation, fabrication, and analysis. Included will be some of the equipment necessary to explore, manipulate and fabricate nanoscale materials and structures. Also included are individual offices and landscape office areas, seminar area, transient user space for visiting collaborators with access to computer terminals, conference areas on both floors, and vending/lounge areas. In addition it will include circulation/ancillary space, including mechanical equipment areas, corridors, and other support spaces.

Technical procurement for the project will include laboratory equipment for the CFN laboratory clusters Nanopatterning, Ultrafast Optical Sources, Electron Microscopy, Materials Synthesis, Proximal Probes, and Theory and Computing as well as for the cluster designated CFN Endstations at the NSLS.

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

4. Details of Cost Estimate[a]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications at $2,340K)..	3,105	N/A
Project Management costs (2.3% of TEC)	1,820	N/A
Design Management Costs (0.5% of TEC)	415	N/A
Total, Design Costs (6.7% of TEC)	5,340	N/A
Construction Phase		
Technical Facilities		
Equipment	29,480	N/A
Inspection, design & project liaison, testing, checkout and acceptance	330	N/A
Project Management (0.2% of TEC)	135	N/A
Total, Technical Costs	29,945	N/A
Conventional Facilities		
Improvements to Land	945	N/A
Building Construction	23,465	N/A
Site Utilities	4,420	N/A
Standard Equipment	920	N/A
Removal less salvage	0	N/A
Inspection, design & project liaison, testing, checkout and acceptance	875	N/A
Project Management (2.2% of TEC)	1,725	N/A
Total, Construction Costs	32,350	N/A
Contingencies		
Design Phase (0.8% of TEC)	642	N/A
Construction Phase (14.3% of TEC)	11,423	N/A
Total Contingencies	12,065	N/A
Total, Line Item Costs (TEC)	79,700	N/A

5. Method of Performance

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

[a] The annual escalation rates assumed for FY 2004 through FY 2007 are 2.5 2.9, 2.8, and 2.6 percent, respectively, using DOE FY 2004 Guidance, January 2002 Update.

6. Schedule of Project Funding

	(dollars in thousands)					
	Prior Years	FY 2003	FY 2004	FY 2005	Outyears	Total
Project Cost						
Facility Cost						
Design	0	733	2,949	2,300	0	5,982
Construction	0	0	0	12,000	61,718	73,718
Total, Line Item TEC	0	733	2,949	14,300	61,718	79,700
Other Project Costs						
Conceptual design cost [a]	280	0	0	0	0	280
NEPA Documentation Costs	10	0	0	0	0	10
Other project-related costs	10	0	0	0	1,000	1,010
Total, Other Project Costs	300	0	0	0	0	1,300
Total, Project Costs	300	733	2,949	14,300	62,718	81,000
Total, Project Cost (TPC)	300	733	2,949	14,300	62,718	81,000

7. Related Annual Funding Requirements

	(FY 2008 dollars in thousands)	
	Current Estimate	Previous Estimate
Annual facility operating costs	18,500	N/A
Total annual operating funding	18,500	N/A

[a] Experimental research will begin at the time of beneficial occupancy of the facility. These research costs are not part of the TPC and are funded by BES.

Advanced Scientific Computing Research

Funding Profile by Subprogram

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Advanced Scientific Computing Research					
Mathematical, Information, and Computational Sciences	160,367	200,490	-1,198[a]	199,292	204,340
Laboratory Technology Research	2,818	3,000	0	3,000	0
Subtotal, Advanced Scientific Computing Research	163,185	203,490	-1,198[a]	202,292	204,340
Use of Prior Year Balances	0	-481	0	-481	0
Total, Advanced Scientific Computing Research	163,185[bcd]	203,009	-1,198[a]	201,811	204,340

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

Mission

In the past two decades leadership in scientific computation has become a cornerstone of the Department's strategy to ensure the security of the nation and succeed in its science, energy, environmental quality, and national security missions. 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 is critical to the economic health of the nation. The mission of the Advanced Scientific Computing Research (ASCR) program is to underpin DOE's world leadership in scientific computation by supporting research in applied mathematics, computer science and high-performance networks and providing the high-performance computational and networking resources that are required for world leadership in science.

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

[a] Excludes $1,197,753 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003.
[b] Excludes $4,017,000 which was transferred to the SBIR program and $241,000 which was transferred to the STTR program.
[c] Excludes $1,115,315 for a rescission in accordance with the Consolidated Appropriations Resolution, FY 2003.
[d] Excludes $3,029,000 transferred for Department of Homeland Security activities in FY 2003.

through the application of terascale computing to advanced scientific applications. High-performance computing provides a new window for researchers to observe the natural world at a fidelity that could only be imagined a few years ago. Research investments in advanced scientific computing equip researchers with premier computational tools to advance knowledge and to solve the most challenging scientific problems facing the Nation.

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 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, to advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences, and to 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)

Within the ASCR program, the Mathematical, Information and Computational Sciences subprogram 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. This subprogram 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 Disovery 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 translate the world into a computer 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. The collaboratory activity, which is one component of the integrated ASCR Network Environment, provides the tools that enable scientists to discover, coordinate, and safely use the resources on the network.

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 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
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. [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. [Not 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 - FY04 – <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 - FY05 – <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	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 Scientific Discovery through Advanced Computing (SciDAC) effort. FY04 – >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 Scientific Discovery through Advanced Computing (SciDAC) effort. FY05 – >50%

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
			Environmental Research and Basic Energy Sciences programs, respectively, of submitted proposals. [Met]		
			Maintained and operated facilities, including NERSC and ESnet, so the unscheduled downtime on average is less than 10 percent of the total scheduled operating time. [Met]	Focus usage of the primary supercomputer at the National Energy Research Scientific Computing Center (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 - FY04 – 50%	Focus usage of the primary supercomputer at the National Energy Research Scientific Computing Center (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 - FY05 – 50%
	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. [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. [Met]			
Developed advanced computing capabilities, computational algorithms, models, methods, libraries, and advanced visualization and data management systems that enabled new computing applications to science. [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. [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. [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.

The ASCR program will support fundamental, innovative, peer-reviewed research to create new knowledge in areas of advanced computing research that are important to DOE. In addition, the ASCR program 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 Scientific Discovery through Advanced Computing (SciDAC) initiative with Basic Energy Sciences (BES) and Biological and Environmental Research (BER) in the areas of nanotechnology and Genomics: GTL. 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) 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; (4) unanticipated failures, for example, 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 (DARPA, EPA, NASA, NIH, NSA, and NSF) through the Computing Information and Communications R&D subcommittee of the National Science and Technology Council (NSTC), under the auspices of 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) Assessment

In the PART review, OMB gave the Advanced Scientific Computing Research (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. Although ASCR is establishing 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, this committee has not yet met. Once the COV issues a report, ASCR will develop an action plan to respond to the findings and recommendations within 30 days. The assessment found that ASCR has developed a limited number of adequate performance measures. However, OMB noted concerns regarding the collection and reporting of performance data. To address these concerns, ASCR will work with its Advisory Committee to develop research milestones for the long-term performance goals, will include the long term research goals in grant solicitations, will work to improve performance reporting by grantees and contractors, and will work with the CFO to improve ASCR sections of the Department's performance documents. OMB also found that the ASCR Advisory Committee is underutilized. ASCR will meaningfully engage the Advisory Committee in thorough assessments of research performance and in regularly revisiting the strategic priorities for the program. ASCR's role in providing scientific research facilities is strongly supported by the Administration. Funding is provided in FY 2005 to operate the program's facilities at maximum capacity.

Funding by General and Program Goal

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
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	160,367	199,292	204,340	+5,048	+2.5%
Laboratory Technology Research	2,818	3,000	0	-3,000	-100.0%
Total, Program Goal 05.23.00.00, Deliver forefront computational and networking capabilities	163,185	202,292	204,340	+2,048	+1.0%
Use of Prior-Year Balances	0	-481	0	+481	+100.0%
Total, Advanced Scientific Computing Research	163,185	201,811	204,340	+2,529	+1.3%

Overview

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

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

ASCR's other principal responsibility is to provide the high-performance computational and networking resources that are required for world leadership in science. Recent dramatic advances in scientific computation by researchers and computer companies underscore the importance of strengthening our position in computational sciences in strategic areas. In March 2002, Japan's NEC Earth Simulator became operational. With a peak speed of 40 teraflops and a demonstrated sustained capability of over 25 teraflops, it is faster by approximately a factor of 50 than the most advanced supercomputer for civilian science in the United States. The potential long-term implications of the Earth Simulator on DOE's computational sciences capability was the principal message of the report on this subject delivered to the Director of the Office of Science by the Advanced Scientific Computing Advisory Committee. To strengthen the program's position in this area, the ASCR program is proposing a new effort in Next Generation Computer Architecture (NGA) to identify and address major bottlenecks in the performance of existing and planned DOE science applications.

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),*** established on August 12, 1999, provides valuable, independent advice to the Department of Energy on a variety of complex scientific and technical issues related to the ASCR program. The ASCAC is charged with providing advice on: promising future directions for advanced scientific computing research; strategies to couple advanced scientific computing research to other disciplines; and the relationship of the DOE program to other Federal investments in information technology research. ASCAC's recommendations include advice on long-range plans, priorities, and strategies to address more effectively the scientific aspects of advanced scientific computing including the relationship of advanced scientific computing to other scientific disciplines, and maintaining appropriate balance among elements of the program. This advisory committee plays a key role in assessing the scientific and programmatic merit of presently funded activities and in evaluating plans for the future. The Committee formally reports to the Director, Office of Science and includes representatives from universities, national laboratories, and industries who are involved in advanced computing research. Particular attention is paid to obtaining a diverse membership with a balance among scientific disciplines, institutions, and geographic regions. ASCAC operates in accordance with the Federal Advisory Committee Act (FACA, Public Law 92-463; 92nd Congress, H.R. 4383; October 6, 1972) and all applicable FACA Amendments, Federal Regulations and Executive Orders.

The activities funded by the ASCR program are coordinated with other Federal efforts through the *Interagency Principals Group*, chaired by the President's Science Advisor, and the *Information Technology Working Group (ITWG).* The ITWG evolved through an interagency coordination process that began under the 1991 High Performance Computing Act as the High Performance Computing, Communications, and Information Technology (HPCCIT) Committee. The Federal IT R&D agencies have established a 10-year record of highly successful collaborative accomplishments in multiagency projects and in partnerships with industry and academic researchers. The multiagency approach leverages the expertise and perspectives of scientists and technology users from many agencies who are working on a broad range of IT research questions across the spectrum of human uses of information technology. DOE has been an active participant in these coordination groups and committees since their inception and the ASCR program will continue to coordinate its activities through these mechanisms including an active role in implementing the Federal IT R&D FY 2002-2006 Strategic Plan under the auspices of the National Science and Technology Council and the President's Science Advisor.

ASCR is a participant in the Interagency Committee for Extramural Mathematics Programs (ICEMAP), a coordinating committee with representatives from Federal agencies that manage programs in mathematical research, including the National Science Foundation, DOE (through ASCR), the National Aeronautics and Space Administration, the National Institute for Standards and Technology, the Air Force Office of Scientific Research, the Army Research Office, and the Office of Naval Research. Meetings are held to coordinate activities across mathematical research programs, ensuring that the Federal agencies coordinate their investments in basic mathematical research. The ASCR program regards ICEMAP as an important component in their efforts to maintain coordination with other Federal agencies.

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/evnt/reports/toc.htm); and
- ASCR Strategic Planning Workshop (http://www.fp-mcs.anl.gov/ascr-july03spw).

Facility Operations Reviews

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

NERSC, operated by the Lawrence Berkeley National Laboratory, annually serves about 2,000 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 Office of Science goals and objectives and the readiness of the proposed application to fully utilize the computing resources being requested.

The ESnet, managed and operated by the Lawrence Berkeley National Laboratory, is a high-speed network serving thousands of Department of Energy scientists and collaborators worldwide. A pioneer in providing 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 the Office of Science programs. All program offices in the Office of Science appoint members, who represent their scientific communities, to serve on the ESSC. The ESSC is responsible for reviewing and prioritizing network requirements, for establishing performance objectives, and for proposing innovative techniques for enhancing ESnet capabilities. In addition to the ongoing oversight from the ESSC, ASCR conducts external peer reviews of ESnet performance on a three year interval. The last such review was chaired by a member of ASCAC and took place in September 2001.

Advanced Computing Research Testbeds (ACRTs) play a critical role in testing and evaluating new computing hardware and software. Current testbeds are located at Oak Ridge National Laboratory (IBM Power-4 Technology and CRAY X1 technology). In FY 2002, ASCAC conducted a review of 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 Office of Science over the next three to five years?

The essential finding of the Subcommittee was that NERSC and the ACRTs are among the best worldwide in their respective categories. 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 the 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 Center for Computational Sciences (CCS) at the Oak Ridge National Laboratory. The findings from this review validated the contributions that the CCS made to the Advanced Computing Research Testbed activity within the ASCR program.

Program Reviews

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

In FY 2003, ASCR conducted a peer review of the Numerical Linear Algebra, Optimization, and Predictability Analysis areas within the Applied Mathematics activity. These areas represent 33 percent of this activity. In FY 2004, ASCR will conduct a peer review of the Differential Equations and Advanced Numerical Methods for High Performance Computing areas within the Applied Mathematics activity, representing an additional 33 percent of this activity. In FY 2005, ASCR will conduct a peer review of the remaining 34 percent of the Applied Mathematics activity, which consists of Computational Fluid Dynamics and Meshing Techniques. 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 percent of the ASCR SciDAC budget. In FY 2004, ASCR will initiate a comprehensive review of the Computer Science base research activity.

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 Lawrence Berkeley National Laboratory (LBNL) to manage and operate the National Energy Research Scientific Computing Center for FY 2002 – FY 2006.

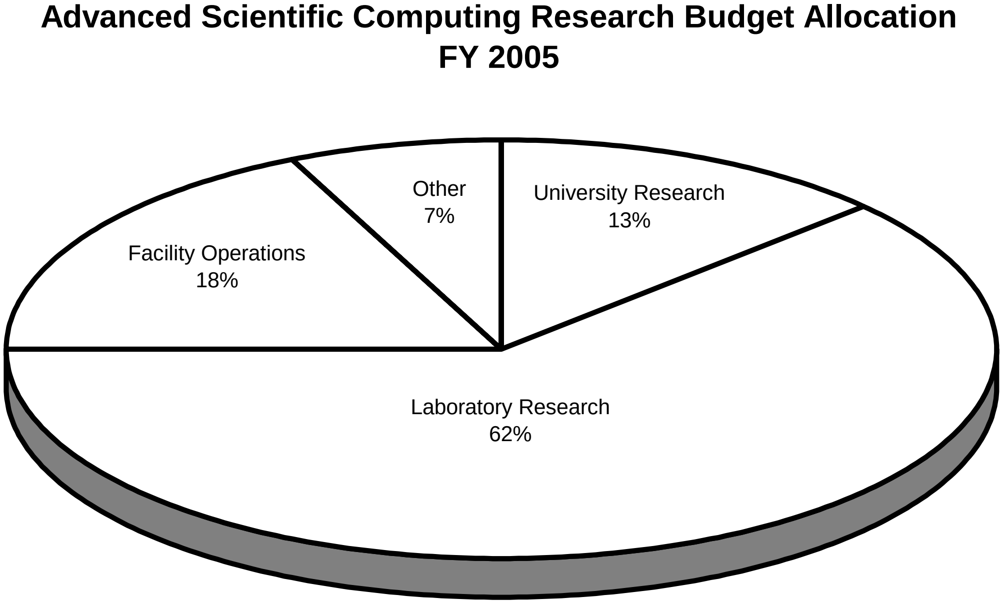
Planning and Priority Setting

The ASCR program must coordinate and prioritize a large number of goals from agency and interagency strategic plans. One of the most important activities of ASCAC is the development of a framework for the coordinated 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 Office of Science Strategic Plan, as updated through program collaborations and joint advisory committee meetings. (***http://www.science.doe.gov/production/bes/strat_pln.htm)***;
- Scientific Discovery through Advanced Computing (SciDAC) plan delivered to Congress in March 2000. (***http://www.science.doe.gov/scidac/)***;
- The Interagency Working group for Information Technology Five Year Plan – FY 2002-FY 2006 (with key appendixes); and
- ASCAC report on the Japanese Earth Simulator. (***http://www.sc.doe.gov/ascr/ascac.reports.htm)***

How We Spend Our Budget

The ASCR program budget has two subprograms: Mathematical, Information and Computational Sciences (MICS) and Laboratory Technology Research (LTR). The MICS subprogram has two major components: research and facility testbed and network operations. The FY 2005 budget request continues the core and SciDAC research efforts and strengthens the research partnerships with other SC offices. The testbed and network operations expenditures account for 37 percent of the National Laboratory Research, or 24 percent of the total ASCR budget. The LTR subprogram will be brought to a successful completion in FY 2004.



Research

Over 74 percent of the ASCR program's FY 2005 funding will be provided to scientists at universities and laboratories to conceive and carry out the research or to fund advanced computing testbeds and network operations. National laboratory research scientists work together with the other programs of the Office of Science to develop the tools and techniques that allow those programs to take advantage of terascale computing for scientific research. The laboratories provide state-of-the-art resources for testbeds and novel applications. The division of support between national laboratories and universities is adjusted to maximize scientific productivity.

- ***University Research***: University researchers play a critical role in the nation's research effort and in the training of graduate students. During FY 2002, the ASCR program supported over 150 grants to the nation's university researchers and graduate students engaged in civilian applied mathematics, large-scale network and computer science research. 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 2002, ASCR selected 24 new graduate fellows representing 17 universities and 13 states and expects to make up to forty awards to early career principal investigators. Approximately one-half of those who received Ph.D.'s in the Computational Sciences Graduate Fellowship program between 1991 and 2001 are pursuing careers outside universities or national labs. ASCR also provides support to other Office of Science research programs.

  The university grants program is proposal driven, similar to the computer science and applied mathematics programs at NSF. However, ASCR grant solicitation notices are focused on topics that have been identified as important for DOE missions. ASCR funds the best among the ideas submitted in response to grant solicitation notices (**http://www.science.doe.gov/production/grants/**). 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 Ames, Argonne, Brookhaven, Los Alamos, Lawrence Berkeley, Lawrence Livermore, Oak Ridge, Pacific Northwest, and Sandia National Laboratories. The directions of laboratory research programs are driven by the needs of the Department and the unique capabilities of the laboratories to support large scale, multidisciplinary, collaborative research activities. In addition, laboratory-based research groups are highly tailored to the major scientific programs at the individual laboratories and the computational research needs of the Office of Science. Laboratory researchers collaborate with laboratory and academic researchers, and are important for developing and maintaining testbeds and novel applications of high performance computing and networking in Office of Science research. At Los Alamos, Livermore and Sandia, ASCR funding plays an important role in supporting basic research that can improve the applied programs, such as the Accelerated Strategic Computing Initiative (ASCI) and the Science Stockpile Stewardship program.

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

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.

Research efforts initiated in FY 2001 in Scientific Discovery through Advanced Computing (SciDAC) will be continued, as planned. In FY 2005, ASCR will continue efforts initiated in FY 2004 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 near term activities are represented by enhancements to NERSC while the longer term activities are a part of the Next Generation Computer Architecture (NGA). This effort will continue to increase the delivered computing capability available to address the Office of Science mission through optimization of computer architectures to meet the special requirements of scientific problems. This investment positions the nation to realize extraordinary scientific opportunities in computing for science and enable new classes of scientific problems to be addressed. The NGA effort complements SciDAC and integrates advanced computer architecture researchers and engineers, application scientists, computer scientists, and applied mathematicians. The NGA efforts, as well as the enhancement of NERSC are aligned with the plan developed by the High End Computing Revitalization Task Force (HECRTF) established by the Office of Science and Technology Policy. These efforts will play a critical role in enabling potential future Leadership Class Machines, which could lead to solutions for scientific and industrial problems beyond what would be attainable through a continued simple extrapolation of current computational capabilities.

The FY 2005 budget request includes $7,500,000 for continued support of the Genomics: GTL research program, in partnership with the Biological and Environmental Research program; and $2,600,000 for the Nanoscale Science, Engineering and Technology initiative led by the Basic Energy Sciences program. ASCR's contributions to these partnerships will consist of advancing the mathematics and developing new mathematical algorithms to simulate biological systems and physical systems at the nanoscale. In addition to this continued partnership support, the FY 2005 request includes $1,350,000 to expand SciDAC partnerships with the Fusion Energy Sciences Program to lay the groundwork for the Fusion Simulation Project (FSP). The FSP will be a focused, interdisciplinary effort, whose objective is to develop the capability to predict reliably the behavior of fusion plasmas.

The FY 2005 budget also includes $8,500,000 for the new "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 the Office of Science.

In FY 2005, the Mathematical, Information and Computational Sciences subprogram will continue to support core research activities in applied mathematics, computer science, network research, collaboratory tools and collaboratory pilot projects at current levels.

The Laboratory Technology Research subprogram was brought to a successful conclusion in FY 2004 as planned with orderly completion of all existing 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 2005 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.

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 research focus of ASCR SciDAC activities includes Integrated Software Infrastructure Centers (ISICs) and collaboratories. 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. Collaboratories address complex science projects undertaken in the SciDAC program that involve geographically distributed computing resources, research teams, and science. Progress includes development of GridFTP, a high-performance data transport program that has become the de facto standard for data transport on the Grid. In high-energy physics, collaboratory technology enabled a single job to generate 1.5 million simulated events for the Compact Muon Solenoid. The three Mathematics ISICs, now 1.5 years into their 3-5 year life, are bringing a new level of mathematical sophistication to computational problems throughout the Office of Science. One of these, the Terascale Optimal Partial Differential Equations (PDE) Simulations (TOPS) Center, is combining the Hyper and Portable Extensible Tool kit 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, advection equations for combustion simulation, and so forth. 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.

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 Office of Science 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. Total funding for the NGA was $38,268,000 in FY 2004 and $38,212,000 in FY 2005. The goal of the NGA is to identify and address major architectural bottlenecks, such as internal data movement in very large systems, in the performance of existing and planned DOE science applications. Emphasis will be placed on understanding the impact of alternative computer architectures on application performance with particular attention paid to data movement from memory to processor and between processors in highly parallel systems. Software research will be initiated to improve application performance and system reliability through innovative approaches to next generation operating systems. Emphasis will also be placed on hardware evaluation testbeds of sufficient size to understand key issues impacting application performance scalability and portability. These testbeds will also enable significant scientific progress by delivering significant increases in performance to critical DOE mission applications. These testbeds will also enable industrial researchers to find opportunities for virtual prototypes and simulation of industrial processes that result in enhanced competitive position because of sharply reduced 'time to market.' 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. This effort is aligned with the HECRTF plan.

Scientific Facilities Utilization

The ASCR program request includes support to the National Energy Research Scientific Computing Center (NERSC), a component of the Office of Science-wide Facilities Optimization effort. This investment 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 Office of Science research programs.

	FY 2001	FY 2002	FY 2003	FY 2004 Est.	FY 2005 Est.
Maximum Hours – NERSC	8,760	8,760	8,760	8,760	8,760
Scheduled Hours – NERSC....................	8,497	8,585	8,585	8,585	8,585
Unscheduled Downtime – NERSC	1%	1%	1%	1%	1%

Workforce Development

The R&D Workforce Development mission is to ensure the supply of computational and computer science and Ph.D. level scientists for the Department and the Nation through graduate student and postdoctoral research support. In FY 2005, this program will support approximately 800 graduate students and post doctoral investigators, of which 500 will be supported at Office of Science user facilities.

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

	FY 2001	FY 2002	FY 2003	FY 2004 est.	FY 2005 est.
# University Grants...........	170	163	144	140	142
Size, Duration...................	$157,000/yr-3yrs	$157,000/yr-3yrs	$197,000/yr-3yrs	$197,000/yr-3yrs	$197,000/yr-3yrs
# Lab Groups....................	226	209	165	165	165
# Grad Students	370	354	354	354	354
# PhD's Awarded.............	660	604	675	675	675

Mathematical, Information, and Computational Sciences

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Mathematical, Information, and Computational Sciences					
Mathematical, Computational, and Computer Sciences Research	68,748	83,301	86,405	+3,104	+3.7%
Advanced Computation, Communications Research and Associated Activities	91,619	110,553	112,389	+1,836	+1.7%
SBIR/STTR	0	5,438	5,546	+108	+2.0%
Total, Mathematical, Information, and Computational Sciences	160,367	199,292	204,340	+5,048	+2.5%

Description

The Mathematical, Information, and Computational Sciences (MICS) subprogram is responsible for carrying out the mission of the ASCR program: discovering, developing, and deploying advanced scientific computing and communications tools and operating the high performance computing and network facilities that researchers need to analyze, model, simulate, and — most importantly — predict the behavior of complex natural and engineered systems of importance to the Office of Science and to the Department of Energy.

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. High-performance computing provides a new window for researchers to observe the natural world at a fidelity that could only be imagined a few years ago. Research investments in advanced scientific computing equip researchers with premier computational tools to advance knowledge and to solve the most challenging scientific problems facing the Nation.

Supporting Information

The computing and the networking required to meet Office of Science needs exceed the state-of-the-art by a wide margin. Furthermore, the algorithms, software tools, the software libraries and the software environments needed to accelerate scientific discovery through modeling and simulation are beyond the realm of commercial interest. To establish and maintain DOE's modeling and simulation leadership in scientific areas that are important to its mission, the MICS subprogram employs a broad, but integrated research strategy. The MICS subprogram's basic research portfolio in applied mathematics and computer science provides the foundation for enabling research activities, which includes efforts to advance networking, to develop software tools, software libraries and software environments. Results from enabling research supported by the MICS subprogram are used by computational scientists supported by other Office of Science and other DOE programs. This link to other DOE programs provides a tangible assessment of the value of the MICS subprogram for advancing scientific discovery and technology development through simulations.

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

The Early Career Principal Investigator (ECPI) activity was initiated in FY 2002 for scientists and engineers in tenure track positions at U.S. universities. Seventeen (17) awards were made in FY 2002. Additional awards will be made in FY 2003 for this activity pending peer reviews of applications. The goal of the ECPI activity is to support Office of Science mission-related research in applied Mathematics, computer science and high-performance networks performed by exceptionally talented university investigators, who are at an early stage in their professional careers.

Accomplishments

- *New Robust WAN File Replication and Movement Available for Large Scientific Data* - Terascale computing and large scientific experiments produce enormous quantities of data that require effective and efficient management for large scientific collaborations dispersed across wide-area networks. Using storage resource management (SRM) technology developed at Lawrence Berkeley Laboratory, it is now possible to achieve continuous replication of hundreds of files with a single request with no further human intervention. The SciDAC funded Earth System Grid is using this technology for a generalized data access for climatologists. The technology also provides an important feature--interoperability of archival systems at DOE laboratories and the National Center for Atmospheric Research. The replication process relies on GridFTP, developed at Argonne National Laboratory as part of the Globus Toolkit® for the reliable, secure and policy-aware large-scale data movement. GridFTP servers are used to stage input data and move results to mass storage systems. This software has become the de facto standard worldwide for the movement of large data.
- *Commodity Grid Kits Make Grids Easy to Program and Use* - Many scientific applications, including climate modeling, astrophysics, high energy physics, structural biology, and chemistry need numerous distributed resources to make advances in multidisciplinary scientific research. The Grid provides an infrastructure that can be used to accomplish this. Work at Argonne National Laboratory and Lawrence Berkeley National Laboratory has built on commodity technologies (Java and Python) already in use by thousands of scientists to access the Grid from higher level programming frameworks. These frameworks form the basis for scientific portals promoting collaboration between large scientific teams and allow the harnessing of distributed resources that are needed as part of the scientific problem solving process. The new Commodity Grid (CoG) Kit technology has been used while building a number of scientific portals to the Grid. Indeed, it already has become the de facto community standard for developing Grid portal applications. Examples of applications relying on this technology include the SciDAC funded Particle Physics Data Grid and Earth System Grid projects, portals for astrophysical black-hole simulations, and portals for structural biology.
- *Increased Scientific Productivity through Advanced Collaborative Environments* - The SciDAC funded National Fusion Collaboratory Project has deployed a production computational and data grid that is accelerating scientific understanding and innovation towards the design of an attractive new fusion energy source. The design of this persistent infrastructure to enable scientific

collaboration is being put forth by the U.S. as the design template for ITER, the International Thermonuclear Experimental Reactor that is planned as the one next generation experimental device for the worldwide magnetic fusion community.

- *ParamBench demonstrates the significant impact of concurrent memory accesses* - Computer scientists at the Lawrence Livermore National Laboratory, in collaboration with researchers at the University of Utah and North Carolina State University have implemented ParamBench, low-level benchmarks of memory performance in symmetric multiprocessors (SMPs). These benchmarks measure the raw memory performance of SMPs, including the effect of multiple processors accessing the memory system concurrently. Results with this benchmark suite demonstrate that standard latency-hiding techniques, such as hardware prefetching, are less effective in SMPs, even with a crossbar-based memory interconnection.
- *New Analysis Tools for Innovative Materials* - Mathematicians at the Oak Ridge National Laboratory have extended the class of materials science problems that can be solved by a powerful technique known as the "Boundary Element Method." This numerical method significantly reduces the number of operations that are needed to solve materials science problems, but has traditionally been applicable only to homogeneous materials. The researchers derived the fundamental solution to a set of integral equations for "Functionally Graded Materials," an important class of materials that are not homogeneous, but whose properties vary smoothly. These materials already play an important role in many applications, including coatings for protecting turbine blades, special optical materials, and dental implants and other bio-materials.
- *Scientific Data Objects: A Common Language for Exchanging Parallel Data* - Arrays, or matrices, are one of the basic data structures of scientific computing. In large-scale simulations, arrays are often so large that they must be distributed across many processors. In order for different software modules to work together on a distributed array, a method must exist to precisely describe the distribution of the data. As part of the SciDAC Center for Component Technology for Simulation Software, researchers at the Oak Ridge National Laboratory developed such a description, thus greatly simplifying the development of components that need to exchange distributed array data objects with other components. The new interface specification is capable of describing the layouts used by a wide range of distributed array tools, including CUMULVS (ORNL), Global Arrays (PNNL), High Performance Fortran, A++/P++ (LLNL), and others.
- *New Scientific Data Index Performs 100 Times Faster Than Commercial Database Systems* - Terascale computing and large scientific experiments produce enormous quantities of data that require effective and efficient management. The task of managing scientific data is overwhelming. Researchers at the Lawrence Berkeley National Laboratory have developed a specialized index for accessing very large datasets that contain a large number of attributes that may be queried. This new index performs 12 times faster than the previous best-known method, and 100 times faster than conventional indexing methods in commercial database systems. The prototype index is being used by researchers in high energy physics and combustion modeling.
- *Faster Reconstruction Methods are Making Waves* - Mathematicians at the Lawrence Berkeley National Laboratory have developed efficient and fast techniques for solving the problem of multiple arrivals; that is, detecting and separating the arrival of waves that have taken differing paths through a medium. Example applications include geophysical analysis, which is important for oil exploration, and antenna design. The methods are fast enough that they can be embedded inside

"inverse solvers," computer codes that use information about the arriving waves to deduce the characteristics of an unknown body between the source and detector. This will result in new computational tools to examine hidden objects, accurately reconstruct inaccessible regions, and rapidly test proposed models.

- *Increasing Scientific Productivity through Automated Optimization* - Many complex problems in science, engineering and business require the solution of optimization problems, but the conventional approach to solving such problems can be extremely time-consuming and difficult to apply. Researchers at Argonne National Laboratory have developed the Network-Enabled Optimization System (NEOS) that allows users to solve optimization problems over the Internet with state-of-the-art software and without tedious downloading and linking of specialized optimization code. Because of its ease of use, the NEOS server has gained widespread popularity with more than 5,000 job requests each month from users around the world. Recent NEOS applications include circuit simulation, protein folding, circuit design, brain modeling, airport crew scheduling, and modeling of electricity markets.
- *Open Source Cluster Application Resources (OSCAR) Cluster Software Distribution A Big "Hit" Worldwide* - The Open Source Cluster Application Resources package, OSCAR, is a collection of software tools for managing Linux-based computer clusters developed by a consortium of academic, research, and industry members led by scientists at the Oak Ridge National Laboratory. According to the Top 500 Clusters web site, OSCAR has become the most used cluster computing distribution available today. OSCAR is also used as the core cluster base package in the MacNeil Schwindler (MSC) Linux commercial cluster distribution as well as the NCSA "in-a-box" series of cluster computing solutions. OSCAR has a "market share" of over 30% according to the poll – more than twice its nearest competitor. OSCAR has been downloaded over 53,000 times and has received over 140,000 web page hits during the past year.
- *Tiled Displays: Automatic Calibration of Scalable Display Systems* - Today's scientific simulations and rich multimedia collaborative environments can easily produce tens of millions of pixels for display. Tiled display systems built by combining the images from arrays of projectors can provide massive numbers of pixel elements to visually represent large amounts of information. Multiprojector tiled arrays can be a cost-effective way to create these displays, and they may be the only practical way to create large information dense displays. But, it is difficult to create the illusion of a unified seamless display for a variety of reasons, including projector-to-projector color and luminosity differences, variation of luminosity across the image from a single projector, and optical distortion of the individual projector images caused by imperfections in the lenses and misalignment of projectors. Researchers at Argonne National Laboratory have developed methods to attack these fundamental issues providing an efficient and optimized measurement process using inexpensive components that is tolerant of a wide range of imperfections in components and measurement setup such as lighting conditions and camera optics.
- *Center for Computational Sciences (CCS) Deploys CrayX1 Computer System* - The Center for Computational Sciences at ORNL has acquired and begun deployment of a CrayX1 system to test its effectiveness in solving scientific problems of national scale in climate, biology, nanoscale materials, fusion, and astrophysics. "This partnership with Cray is one of the first steps in the initiative to explore computational architecture essential to 21st century scientific leadership," said the Director of the Office of Science. The Cray X1 is the first U.S. computer to offer vector processing and

massively parallel processing capabilities in a single architecture. The system has been specifically designed for scientific applications. Preliminary results on climate applications show the potential for significant improvements in performance over current generation computers.

- *NERSC Improves Supercomputer Performance* **-** The Department of Energy's National Energy Research Scientific Computing Center (NERSC) at the Lawrence Berkeley National Laboratory has doubled the peak performance of its IBM RS/6000 SP supercomputer. The 10 teraflop/s (10 trillion calculations per second) NERSC-3E (enhanced) is now the most powerful computer for unclassified research in the United States. The supercomputer named *Seaborg* has 6,656 processors and has the largest aggregate memory of any unclassified computer in the U.S. – 7.8 terabytes (trillion bytes) – with 44 terabytes of disk storage.
- *Supernova Factory Makes Rapid Discoveries* - At the January 2003 meeting of the American Astronomical Society in Seattle, the Nearby Supernova Factory (SNfactory) based at Lawrence Berkeley National Laboratory announced that it had discovered 34 supernovae during its first year of operation — all but two of them in the last four months alone. This discovery rate of eight per month had been achieved by other supernova search projects only after years of work. The SNfactory processed a quarter-million images in its first year and archived 6 terabytes (trillion bytes) of compressed data at the National Energy Research Scientific Computing Center (NERSC) at Berkeley Lab — one of the few centers with an archive large enough to store this much data.
- *Computational Simulation Finds Correct Theoretical Model* - After three decades of uncertainty, the origins of at least some gamma-ray bursts (GRBs) are being revealed, thanks to a new generation of orbiting detectors, fast responses from ground-based robotic telescopes, and a new generation of computers and astrophysics software. A GRB detected on March 29, 2003 has provided enough information to eliminate all but one of the theoretical explanations of its origin. Computational simulations based on that model were already being developed at the National Energy Research Scientific Computing (NERSC) Center at Lawrence Berkeley National Laboratory when the discovery was made.
- *Improved Algorithm Speeds Up Fusion Code by a Factor of 5* - The NIMROD project, funded by the DOE Office of Fusion Energy Sciences and the SciDAC Center for Extended Magneto-hydrodynamic Modeling, is developing a modern computer code suitable for the study of long-wavelength, low-frequency, nonlinear phenomena in fusion reactor plasmas. The project's primary high-end computing resource is the 10 teraflop/s IBM SP (Seaborg) at the National Energy Research Scientific Computing (NERSC) Center at Lawrence Berkeley National Laboratory. Through a collaboration with members of the SciDAC Terascale Optimal PDE Simulations (TOPS) Center to implement the SuperLU linear solver software within NIMROD it now runs four to five times faster for cutting-edge simulations of tokamak plasmas, with a corresponding increase in scientific productivity.
- *ESnet deploys next general protocol* – ESnet has deployed Internet Protocol Version 6 (IPv6) on its production network. Enabling IPv6 on the network brings a new level of security (e.g. packet encryption and source authentication) and supports real-time traffic, such as video conferencing. IPv6 is expected to become the protocol of choice throughout the Internet.
- *ESnet deploys global Public Key Infrastructure (PKI)* – ESnet has played a key role in coordination and deployment of a Public Key Infrastructure for use by the new computational grids being developed around the world. ESnet is actively working with the Global Grid Forum, the European

Data Grid and Cross Grid Certificate Authority to ensure that the service has the widest possible acceptance.

Awards

Lovelace Medal Awarded to ANL Scientist - An Argonne National Laboratory scientist and colleague of the Information Sciences Institute at the University of Southern California were named as recipients of the prestigious Lovelace Medal, given by the British Computer Society (BCS). BCS cited "their work with the Globus Project and Grid computing," in giving the award for contributions with major significance in the advancement or development of information systems. This is the first time that this award has been given to a DOE-funded researcher. Previous recipients include the developer of the computer mouse and graphic interface; and the developer of the Linux operating system.

Sidney Fernbach Award goes to ORNL Scientist **-** An internationally recognized quantum chemist from ORNL, who is the principal architect of the Northwest Computational Chemistry Software (NWChem), was named the 2002 recipient of the IEEE Computer Society's Sidney Fernbach Award. The Sidney Fernbach Award was established by the IEEE Computer Society in 1992 and is awarded for outstanding contributions in the application of high performance computers using innovative approaches.

Scientific Computing Research Investments

High-performance computing hardware is important for meeting DOE's modeling and simulation needs. However, computer hardware can only enable scientific advances when the appropriate algorithms, scientific software tools, libraries, software environments, and the networking infrastructure are easy to use and are readily available to the users. The MICS subprogram differs from high performance computing efforts in other Federal agencies because of its management focus to integrate research investments to enable new science. Desktop systems realize advances in computing power primarily through increases in the processor's clock speed. High performance computers employ a different strategy for achieving performance, complicating the architecture and placing stringent requirements on software. The MICS subprogram supports software research over a broad range, but that research is tailored to DOE's science needs. Research is underway to improve the performance of simulations on high-end computers, to remove constraints on the human-computer interface and to discover the specialized information management and analysis techniques that scientists need to manage, analyze and visualize extremely large data sets.

Technology trends and business forces in the U.S. computer industry over the past decade caused most domestic vendors to curtail or abandon the development of high-end systems designed to meet the most demanding requirements of scientific research. Instead, large numbers of smaller commercial systems were combined and integrated into terascale computers to achieve the peak performance levels required for agency missions in computational science. The hardware is complicated, unwieldy and not balanced for scientific applications. Enabling software has been developed for scientists to take advantage of these new computers. However, this software is extraordinarily complex and can be a barrier to scientific progress. Consequently, the DOE, primarily through the MICS subprogram, and other Federal agencies whose missions depend on high-performance computing, must make basic research investments to adapt high-performance computing and networking hardware into tools for scientific discovery.

The NGA represents the first step in the adjustment to our strategy that is required to enable future progress in computational science. Continued emphasis on developing software-based solutions to enable scientific simulations on large clusters of computers designed for mid-range applications is no longer the basis for a sustainable strategy for many high-end applications. Rather, our emphasis needs to broaden to include computer hardware technology, architecture, and design trends motivated from a scientific and industrial user perspective. This can be accomplished by making research investments that couple computational scientists, computer scientists, and industrial researchers with U.S. computer vendors to orient future computer architectures towards the needs of science and industry. Additional research investments must be made to ensure the availability of software takes full advantage of these future computer architectures. The status of the technology, the conditions of the current business market for computing, and the success of the Earth Simulator supercomputer in Japan are strong indicators that this strategy can provide tangible near-term benefits for scientific simulation. While NGA will be instrumental in removing some architectural bottlenecks to performance on actual scientific simulations, others will remain and possibly become persistent obstacles in the future.

To illustrate the complexities involved, think of a high-performance computer as a large number of conference rooms distributed around a region. Each conference room is connected through the region's transportation and communications infrastructure. Now, the task of a successful scientific application is analogous to getting everyone in the region to a pre-assigned conference room on time. Instructions are given to each participant (systems software). Results from each conference (calculations) will be documented (stored in memory) for distribution. New conferences are convened, new instructions are given and new decisions are made. Now repeat this process trillions of times, as occurs in a scientific simulation! As one can appreciate, this process can only work if the region's infrastructure is properly configured and operating efficiently. That is, the buses, subways, taxicabs, roads, elevators and telephones can efficiently handle the demand. Most of the systems available from computer vendors are analogous to small regions, a limited number of conference rooms and an inefficient infrastructure. Computers for scientific simulation on the other hand, must be analogous to large cities, large numbers of conference rooms, and an efficient infrastructure, with alternative modes of transportation and communication.

Advances in *computer science* research can enable scientists to overcome these remaining barriers. For example:

- efficient, high-performance operating systems, compilers, and communications libraries for high-end computers;
- software to enable scientists to store, manage, analyze, visualize, and extract scientific understanding from the enormous (terabyte to petabyte) data archives that these computers will generate;
- software frameworks that enable scientists to reuse most of their intellectual investment when moving from one computer to another and make use of lower-level components, such as runtime services and mathematical libraries, that have been optimized for the particular architecture;
- scalable resource management and scheduling software for computers with thousands of processors;
- performance monitoring tools to enable scientists to understand how to achieve high performance with their codes; and
- computational scientists with tools, options, and strategies to obtain the maximum scientific benefit from their computations.

Research advances in computer science do not provide the full range of capabilities that computational scientists need, especially for the complex problems faced by the Office of Science. Significant efforts in the applied mathematical research activity will be required for the Department to satisfy its mission requirements for computational science. Historically, improvements in mathematical algorithms have yielded at least as much increase in performance as have improvements in hardware. A large proportion of these advances resulted from the MICS subprogram applied mathematics research activity. The requirements of scientific domains for new algorithms that can scale to work effectively across thousands of processors and produce the most science in the fewest number of computer operations drives the need for improved mathematical algorithms and the supporting software libraries that must be made available for ready use by scientists. In this area of research, the MICS applied mathematics activity is the core of the nationwide effort.

The MICS subprogram research activities that respond to these challenges are described below in the Detailed Program Justification section of the MICS subprogram budget under the headings:

- Applied Mathematics
- Computer Science
- Advanced Computing Software Tools

High Performance Networking, Middleware and Collaboratory Research Investments

Advances in network capabilities and network-enabled technologies now make it possible for large geographically distributed teams to effectively collaborate on solutions to complex problems. It is now becoming possible to harness and integrate the collective capabilities of large geographically distributed data archives, research teams, and computational resources. This collective capability is especially important for the teams using the major experimental facilities, computational resources, and data resources supported by DOE because all of the necessary resources are not available at one location. To successfully realize the potential of this collective research capability, additional research is needed to bring network, data, and computational resources to the members of a distributed team in a manner that is easy to use and guarantees end-to-end performance. For example:

- Significant research is needed to augment the capability of the Internet to support distributed high-end data-intensive applications and to secure large-scale scientific collaborations. The requirements of high-performance networks that support distributed data-intensive computing and scientific collaborations on a national and international scale are very different than the requirements of the current commercial networks where millions of users are moving small web pages. The MICS-supported research on high-performance networks includes research on high-performance protocols, network-aware operating system services, advanced network coprocessors, network measurement and analysis.
- Research is also needed for the development and testing of high-performance middleware needed to seamlessly couple scientific applications to the underlying transport networks. These include high-performance middleware such as advanced security services for grid computing, ultra-high-speed data transfer services, services to guarantee Quality of Service (QoS) for delay sensitive applications, and grid resources discovery. This high-performance middleware provides the scalable software components needed to integrate data, visualization, computation and high-speed networks into a scalable and secure scientific collaborative environment.

The MICS subprogram will address these challenges through fundamental research in networking; software tools that integrate networking and computer science to enable scientific collaboration (collaboratory tools); partnerships with key scientific disciplines; and advanced network testbeds.

Specific responses to these challenges are described in the Detailed Program Justification section of the MICS subprogram budget under the headings:

- Networking
- Collaboratory Tools
- National Collaboratory Pilot Projects

Enhancements to High Performance Computing and Networking Facilities

To realize the scientific opportunities offered by advanced computing, enhancements to the Office of Science's computing and networking facilities are also required. The MICS subprogram supports a suite of high-end computing resources and networking resources for the Office of Science:

- *Production High Performance Computing Facilities.* The National Energy Research Scientific Computing Center (NERSC) provides high performance computing for investigators supported by the Office of Science. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support.
- *Energy Sciences Network (ESnet).* ESnet provides worldwide access to Office of Science facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, high-end computing facilities, massive data resources and other leading-edge instruments and facilities.
- *Advanced Computing Research Testbeds.* The Advanced Computing Research Testbeds (ACRTs) consist of high performance, advanced architecture computing platforms for testing and evaluation to ascertain the prospects for meeting future general, or specialized, computational science needs of the Office of Science. In FY 2005, the ACRTs will provide hardware resources for the NGA activity. Two types of computing platforms will be evaluated - early systems from vendors, and experimental systems. Based on an analysis of vendor offerings and a peer review of the potential that such offerings can meet Office of Science computational needs, hardware will be acquired at sufficient scale to address key performance and software scaling issues. The evaluation process will include computer science studies and tests of leading-edge Office of Science computational science applications, such as those being developed under SciDAC. In addition, the ACRTs will provide computing resources to SciDAC teams.
- *Trends for Future Supercomputing and Networking Resources.* The need for high performance computational resources will increase in future years as applications transition from the software development and testing phase to using the software to generate new science. As the peak performance of the computers increase, the amount of data produced in a simulation increases as well. Therefore, focused enhancements to the Office of Science's network infrastructure are required to enable scientists to access and understand the data generated by their software and by large-scale science experiments.

The MICS subprogram activities that respond to these challenges are described later in the Detailed Program Justification section of the MICS subprogram budget under the headings:

- National Energy Research Scientific Computing Center (NERSC)
- Advanced Computing Research Testbeds
- Energy Sciences Network (ESnet)

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Mathematical, Computational, and Computer Sciences Research	**68,748**	**83,301**	**86,405**
▪ **Applied Mathematics**...	**21,332**	**22,635**	**29,363**

This activity supports research on the underlying mathematical understanding of physical, chemical and biological systems, and on advanced numerical algorithms that enable effective description and prediction of such systems on terascale computing systems. Research in Applied Mathematics supported by MICS underpins computational science throughout DOE. Historically, the numerical algorithms developed under this activity have produced more scientific advances through simulation than improvements in computer hardware. This activity supports research at DOE laboratories, universities, and private companies. Many of the projects supported by this activity involve research partnerships between DOE's national laboratories and universities. The activity supports research in a wide variety of areas of mathematics, including: ordinary and partial differential equations and solutions methods, including techniques to convert equations into discrete elements and boundary integral methods, advanced treatment of interfaces and boundaries, (fast marching and level set methods, and front tracking); numerical linear algebra (advanced iterative methods, general and problem-specific preconditioners, sparse solvers, and dense solvers); fluid dynamics (compressible, incompressible and reacting flows, turbulence modeling, and multiphase flows); optimization (linear and nonlinear programming, interior-point methods, and discrete and integer programming); mathematical physics; control theory (differential-algebraic systems, order reduction, and queuing theory); accurate treatment of shock waves; "fast" methods (fast multipole and fast wavelet transforms); mixed elliptic-hyperbolic systems; dynamical systems (chaos theory, optimal control theory, and bifurcation theory); and automated reasoning systems.

The FY 2005 budget continues the Computational Sciences Graduate Fellowship program at the current level of $3,500,000.

The FY 2005 budget also includes $8,500,000, for the new "Atomic to Macroscopic Mathematics" (AMM) research effort to provide the research support in applied mathematics needed to break through the current barriers in our understanding of complex physical processes that occur on a wide range of interacting length- and time-scales. The current state-of-the-art in the theory and modeling of complex physical systems generally requires that the physical phenomena being modeled either occur at a single scale, or widely separated scales with little or no interaction. Complex physical systems frequently involve highly nonlinear interactions among many

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

phenomena at many different scales. Increases in computational power over the last decade have enabled scientists to begin the process of creating sophisticated models with fewer simplifying assumptions. These new models cannot succeed without a deeper understanding of the mathematics of phenomena at multiple scales and how they interact, from the atomic scale through the mesoscopic to the macroscopic. Achieving this basic mathematical understanding will provide enabling technology to virtually every challenging computational problem faced by the Office of Science.

Progress in AMM will best be achieved through a combination of investments, including (1) funds for innovative approaches to multiscale mathematics at universities throughout the country, (2) investments in partnerships between university researchers and investigators at the national laboratories, and (3) additional investments in multidisciplinary teams at the national laboratories. Category (1) represents investment in relatively high-risk / high-payoff approaches. Categories (2) and (3) follow the SciDAC model of building teams that involve national laboratory researchers in various critical applications. AMM research will support the development of new high-fidelity simulations that are crucial to our improved understanding of important problems across the Office of Science, including fuel cell design, understanding of microbial cells and communities, accelerator design and optimization, combustion processes including clean and efficient engine design, fusion reactor design and optimization, design of materials atom-by-atom, and many more.

	FY 2003	FY 2004	FY 2005
▪ **Computer Science**	**17,489**	**23,680**	**23,680**

This activity supports research in computer science to enable researchers to effectively utilize high-performance computers to advance science in areas important to the DOE mission. DOE has unique requirements for high performance computing that significantly exceed the capability of software products from computer vendors. This activity supports computer science research in two general areas: the underlying software to enable applications to make effective use of computers with hundreds or thousands of processors as well as computers that are located at different sites; and large scale data management and visualization under circumstances where the underlying resources and users are geographically distributed. The first area includes research in protocols and tools for interprocessor communication and parallel input/output (I/O) as well as tools to monitor the performance of scientific applications and advanced techniques for visualizing very large-scale scientific data. Researchers at DOE laboratories and universities, often working together in partnerships, propose and conduct this research.

Beginning in FY 2004, this activity incorporates the software research component of NGA to improve application performance and system reliability through innovative approaches to next generation operating systems. In FY 2005, NGA effort in this activity also includes $2,000,000 transferred from Scientific Applications Partnerships for applications teams working in close partnership with systems evaluation teams. Total funding for the NGA software research component research is $6,659,000.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **Advanced Computing Software Tools**....................	**19,362**	**20,256**	**19,362**

This activity supports research that builds on the results from research in applied mathematics and computer science to develop integrated software tools that computational scientists can use to develop high performance applications (such as characterizing and predicting phase changes in materials). These tools, which enable improved performance on high-end systems, are critical to the ability of scientists to attack the complex scientific and engineering problems that can only be solved with high-end computing systems.

In FY 2005, this activity will continue to support the Integrated Software Infrastructure Centers (ISICs), a SciDAC activity, competitively selected in FY 2001. The ISICs funded under this activity focus on: structured and unstructured mesh generation for large simulations and high performance tools for solving partial differential equations on parallel computers; tools for analyzing the performance of scientific simulation software that uses thousands of processors; the development of data management and visualization software capable of handling terabyte scale data sets extracted from petabyte scale data archives, and software for managing computers with thousands of processors; and software component technology to enable rapid development of efficient, portable, high performance parallel simulation software.

These Integrated Software Infrastructure Centers are a critical component in DOE's SciDAC strategy. The ISICs are responsible for the entire lifecycle of the software that they develop. These software tools must be reliable, understandable and well documented. Also, the scientific user community needs these tools to be maintained, bug-free and upgraded, as necessary. Software tools for high performance scientific simulations have no commercial market. The Integrated Software Infrastructure Centers initiated in FY 2001 provide the only means for developing and deploying these tools to the scientific community.

There is a decrease of $894,000 in the last year of the SciDAC program for ISICs resulting from accelerated rampdown of selected efforts. This decrease is required to support an Office of Science 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.

▪ **Scientific Applications Partnerships**	**10,565**	**16,730**	**14,000**

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 mission of SC. This effort tests the usefulness of advances in computing research, transfers the results of this research to the scientific disciplines, and helps define opportunities for future research. The FY 2005 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 Integrated Software Infrastructure Centers. Areas under investigation include design of particle accelerators with the High Energy Physics (HEP) and Nuclear Physics (NP) programs; plasma turbulence in tokamaks with the Fusion Energy Sciences (FES) program; global climate

(dollars in thousands)			
	FY 2003	FY 2004	FY 2005

change with the Biological and Environmental Research (BER) program; and combustion chemistry with the Basic Energy Sciences (BES) program.

The FY 2005 request includes funds to continue at a reduced level the partnership with the Biological and Environmental Research Genomics: GTL and the partnership with the Basic Energy Sciences program in nanoscale science. The FY 2005 request also includes $1,350,000 to expand SciDAC partnerships with the Fusion Energy Sciences program to lay the groundwork for the Fusion Simulation Project (FSP). The FSP will be a focused, interdisciplinary effort, whose objective is to develop the capability to predict reliably the behavior of fusion plasma. The NGA effort ($2,000,000) for applications teams working in close partnership with systems evaluation teams is shifted to the Computer Science activity FY 2005.

	FY 2003	FY 2004	FY 2005
Advanced Computation, Communications Research, and Associated Activities	**91,619**	**110, 553**	**112,389**
▪ **Networking**	**8,736**	**7,066**	**5,784**

The DOE national laboratories, the unique instruments and facilities at those laboratories, and the university community contributing to the DOE missions create a complex, distributed system that is conducting scientific research on a wide range of problems that depend, increasingly, on high-performance network infrastructure. This program activity is one component of an integrated ASCR effort to develop and deploy a scalable, secure, integrated environment to support these network-intensive science applications, a Network Environment. The components of this effort are the MICS activities: Network Research, Collaboratory Tools, and Collaboratory Pilots. Together, these activities support research and development in high performance networking and middleware along with collaboratory pilots and testbeds that are largely partnerships with other program offices to test, demonstrate, and validate the technologies that derive from that research.

This activity advances the Network Environment vision by supporting research and development in high-performance networks needed to develop and deploy advanced networking capabilities to address challenging issues such as ultra-high-speed data transfers, remote visualization, real-time remote instrumentation, and large-scale scientific collaboration. Networking research is carried out at national laboratories and universities and consists of two major elements:

Network R&D – to address the fundamental issues of high-performance networks to support access to the next generation of scientific facilities, terascale computing resources and distributed petabyte-scale data archives. Network R&D focuses on leading-edge networking technologies such as ultra optical transport protocols and services for ultra high-speed data transfers; techniques and tools for ultra high-speed network measurement and analysis; advanced network tools and services to enable network-aware, high-end scientific applications; and scalable cyber-security technologies for open science environment.

Advanced experimental networking – to accelerate the adoption of emerging networking technologies and to transfer networking R&D results into production networks that support science applications. It includes activities such as experimental networking testbeds, advanced deployment and evaluation of new networking technologies, and exploration of advanced

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

networking concepts. A rapid adoption of emerging network capabilities into production networks will enable scientists pushing the limits of today's networks capabilities to use networking technologies to conduct far-reaching experiments.

There is a decrease of $1,282,000 in the level of support for network research activities in FY 2005. This will reduce research activities at universities and laboratories in high performance network protocols and optical networks. This decrease is required to support an Office of Science 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.

▪ **Collaboratory Tools**	**7,403**	**5,527**	**5,527**

The DOE national laboratories, the unique instruments and facilities at those laboratories, and the university community contributing to the DOE missions create a complex, distributed system that is conducting scientific research on a wide range of problems that depend, increasingly, on high-performance network infrastructure. This program activity is one component of an integrated ASCR effort to develop and deploy a scalable, secure, integrated environment to support these network-intensive science applications, a Network Environment. The components of this effort are the MICS activities: Network Research, Collaboratory Tools, and Collaboratory Pilots. Together, these activities support research and development in high performance networking and middleware along with collaboratory pilots and testbeds that are largely partnerships with other program offices to test, demonstrate, and validate the technologies that derive from that research.

This activity advances the network environment vision by supporting research that builds on results of fundamental research in computer science and networking to develop an integrated set of software tools to support scientific collaborations. These tools provide a new way of organizing and performing scientific work that offers the potential for increased productivity and efficiency and will also enable broader access to important DOE facilities and data resources by scientists and educators throughout the country. It is particularly important to provide for efficient, high-performance, reliable, secure, and policy-aware management of large-scale data movement. This research includes an effort to develop a set of essential middleware services required to support large-scale data-intensive collaboratory applications. This research also includes an effort to research, develop, and integrate the tools required to support a flexible, secure, seamless collaboration environment that supports the entire continuum of interactions between collaborators. The goal is to seamlessly allow collaborators to locate each other; use asynchronous and synchronous messaging; share documents, progress, results, and applications; and hold videoconferences. There is also research for developing and demonstrating an open, scalable approach to application-level security in widely distributed, open network environments that can be used by all the collaboratory tools as well as by the advanced computing software tools whenever access control and authentication are issues.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
▪ **National Collaboratory Pilot Projects**....................	**9,380**	**10,857**	**8,013**

The DOE national laboratories, the unique instruments and facilities at those laboratories, and the university community contributing to the DOE missions create a complex, distributed system that is conducting scientific research on a wide range of problems that depend, increasingly, on high-performance network infrastructure. This program activity is one component of an integrated ASCR effort to develop and deploy a scalable, secure, integrated environment to support these network-intensive science applications, a Network Environment. The components of this effort are the MICS activities: Network Research, Collaboratory Tools, and Collaboratory Pilots. Together, these activities support research and development in high performance networking and middleware along with collaboratory pilots and testbeds that are largely partnerships with other program offices to test, demonstrate, and validate the technologies that derive from that research.

This activity advances the Network Environment vision by supporting research that tests, validates, and applies collaboratory tools in real-world situations in partnership with other DOE programs. The competitively selected partnerships involve national laboratories, universities, and U.S. industry. It is important to demonstrate and test the benefits of collaboratory tools' evolving technology in order to promote their widespread use and enable more effective access to the wide range of resources within the Department, from light sources to terascale computers to petabyte data storage systems. The partnerships that were initiated in FY 2001 focus on developing user environments where collaboration is ubiquitous and distributed computing is seamless and transparent for DOE mission applications. The Particle Physics Data Grid is developing middleware infrastructure to support High Energy Physics (HEP) and Nuclear Physics (NP) communities, and to enable grid-enabled data-management ("manipulation") and analysis capabilities "at the desk of every physicist." It is building one unified system that will be capable of handling the capture, storage, retrieval and analysis of particle physics experiments at the five most critical research facilities, a key collaboratory issue being the highly distributed access to, and processing of, the resulting data by a worldwide research community. In another scientific community, the Earth System Grid II is developing a virtual collaborative environment linking distributed centers, models, data, and users that will facilitate exchange among climatologists all over the world and provide a needed platform for the management of the massive amounts of global climate data that are being generated. Development of this and similar concepts is essential for rapid, precise, and convincing analysis of short- and long-term weather patterns, particularly in the period when increasing pollution introduces changes that may affect us for generations to come. The National Fusion Collaboratory is centered on the integration of collaborative technologies appropriate for widely dispersed experimental environments and includes elements of security, distributed systems, and visualization. All three of these pilot collaboratories will rely on the DOE Science Grid to provide the underpinnings for the software environment, the persistent grid services that make it possible to pursue innovative approaches to scientific computing through secure remote access to online facilities, distance collaboration, shared petabyte datasets and large-scale distributed computation.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

There is a decrease of $2,844,000 in the level of support for National Collaboratory Pilot projects due to the accelerated rampdown of selected efforts. This decrease is required to support an Office of Science 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.

▪ **National Energy Research Scientific Computing Center (NERSC)**...	**22,515**	**31,906**	**37,868**

Located in a single facility at the Lawrence Berkeley National Laboratory (LBNL), NERSC delivers high-end capability computing services and support to the entire DOE Office of Science (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 the Office of Science SciDAC program. The Center serves 2,000 users working on about 700 projects; 35 percent of users are university based, 61 percent are in National Laboratories, 3 percent are in industry, and 1 percent in other government laboratories. The major computational resource at NERSC is an IBM SP computer. The initial installation of hardware, which was completed in FY 2001 following a fully competitive process, provided a peak performance of 5 trillion floating point operations per second (teraflops) to its users. The capability of this system was increased to 10 teraflops following the acquisition of additional computer hardware in FY 2003. The FY 2005 funding will support the continued operation of the IBM SP computer at 10 teraflops peak performance. These computational resources are integrated by a common high performance file storage system that facilitates interdisciplinary collaborations. Related requirements for capital equipment, such as high-speed disk storage systems, archival data storage systems, and high performance visualization hardware, and general plant projects (GPP) funding are also supported. FY 2005 capital equipment requirements for these types of capital equipment remain at the same level as in FY 2004.

In FY 2004 and FY 2005, the NERSC budget is increased as a part of an Office of Science 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. This enhancement will enable NERSC to competitively procure a significant new high performance computer to support the missions of the Office of Science. The enhancement at NERSC will deliver an increase of approximately 30% in the high performance computing resources available to scientists as well as associated improvements in storage and network systems to enable scientists to most effectively use NERSC resources.

▪ **Advanced Computing Research Testbeds (ACRTs)**	**25,934**	**36,909**	**36,909**

This activity supports the acquisition, testing and evaluation of advanced computer hardware testbeds to assess the prospects for meeting future computational needs of the Office of Science, such as SciDAC and special purpose applications. The ACRT activity will provide two types of

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

computer testbeds for evaluation - early systems and experimental systems. Each testbed will involve significant research and architecture design activities. These research and evaluation (R&E) prototypes have been identified as a critical element in the HECRTF plan because they enable early partnership with vendors to tailor architectures to scientific requirements. The results from these partnerships also play a key role in the choice of both high performance production systems and potential leadership class systems government-wide.

The FY 2005 request continues an enhanced scope for the hardware evaluation testbed in the Next Generation Architecture (NGA) research activity as a part of an Office of Science 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. A goal of these testbeds is to identify and address major architectural bottlenecks, such as: internal data movement in very large systems, to the performance of existing and planned DOE science applications. Total funding for the testbed activities in the NGA is $31,553,000. Emphasis will be placed on understanding the impact of alternative computer architectures on application performance with particular attention paid to data movement from memory to processor and between processors in highly parallel systems. The enhanced scope in the hardware evaluation testbed will improve our ability to understand key issues impacting application performance scalability. The NGA activity will be coordinated with other Federal agencies to gain additional insight into research directions, optimize the utilization of resources, and establish the framework for a national effort and is aligned with the goals of the HECRTF plan. Funding for these testbeds will be allocated through peer reviewed competition. These testbeds, coupled with the NGA software research, play a critical role in enabling potential future leadership class scientific computing facilities for open science.

▪ **Energy Sciences Network (ESnet)**	**17,651**	**18,288**	**18,288**

ESnet is a Wide Area Network (WAN) project that supports the scientific research mission of the Department of Energy. 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 in support of the agency's science research missions. 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 Office of Science researchers and research facilities, including: light sources; neutron sources; particle accelerators; fusion reactors; spectrometers; supercomputers; and other high impact scientific instruments. ESnet provides the communications fabric that interconnects geographically distributed research facilities and large-scale scientific collaborations. ESnet supplies the critical infrastructure that links DOE researchers worldwide and forms the basis for advanced experimental research in networking, collaboratory tools, and distributed data-intensive scientific applications testbeds such as the national collaboratory pilot projects. ESnet provides network services through contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM), Synchronous Optical Networks (SONET) and Dense Wave Division Multiplexing (DWDM). ESnet provides interfaces between the network fabric it provides and peering arrangements with other Federal,

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		

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 2005, funds will be used to operate ESnet and to continue support for upgrading the capability of the ESnet backbone to 10,000 million bits per sec (Mbps) from its current capability of 155 Mbps. Remaining funds will be used to upgrade networking hardware and services at high priority ESnet sites to exploit the enhanced performance capabilities of the backbone. FY 2005 capital equipment requirements remain at the same level as in FY 2004.

	FY 2003	FY 2004	FY 2005
SBIR/STTR	**0**	**5,438**	**5,546**

In FY 2003, $3,942,000 and $236,000 were transferred to the SBIR and STTR programs, respectively. The FY 2004 and FY 2005 amounts are the estimated requirement for the continuation of the SBIR and STTR program.

	FY 2003	FY 2004	FY 2005
Total, Mathematical, Information, and Computational Sciences	**160,367**	**199,292**	**204,340**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Mathematical, Computational, and Computer Sciences Research	
▪ **Applied Mathematics**. Provides an increase to support initiation of Atomic to Macroscopic Mathematics research effort ($+8,500,000). The increase is offset by a decrease of $1,772,000 from the existing program.	+6,728
▪ **Computer Science.** Core research is decreased $2,000,000 to support an Office of Science 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. This decrease is offset by NGA funding of $2,000,000 transferred from Scientific Application Partnerships.	0
▪ **Advanced Computing Software Tools.** Decrease in last year of SciDAC program for ISICs resulting from rampdown of selected efforts. This decrease is required to support an Office of Science 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.	-894

	FY 2005 vs. FY 2004 ($000)
▪ **Scientific Application Partnerships.** The change in this activity includes reductions in partnerships with BER ($-367,000) and BES ($-472,000) and an increase of $1,350,000 to expand SciDAC partnerships with the Fusion Energy Sciences program to lay the groundwork for the Fusion Simulation Project (FSP). The NGA effort for applications teams working in close partnership with systems evaluations teams is shifted to the Computer Science activity in FY 2005 ($-2,000,000). A decrease in core research ($-1,241,000) is required to support an Office of Science 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.	-2,730
Advanced Computation, Communications Research, and Associated Activities	
▪ **Network Research**. Decrease in level of support for network research activities. This will reduce research activities at universities and laboratories in high performance network protocols and optical networks. This decrease is required to support an Office of Science 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.	-1,282
▪ **National Collaboratory Pilots.** Decrease in the level of support for National Collaboratory Pilot projects because of accelerated rampdown of selected efforts. This decrease is required to support an Office of Science 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.	-2,844
▪ **National Energy Research Scientific Computing Center.** Provides an increase to enable installation of a major new resource for computational scientists with an architecture different from the current NERSC resource. This increase supports an Office of Science 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.	+5,962
SBIR/STTR	
▪ Increase in SBIR/STTR due to increase in operating expenses.	+108
Total Funding Change, Mathematical, Information, and Computational Sciences	**+5,048**

Laboratory Technology Research

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Laboratory Technology Research	2,818	2,916	0	-2,916	-100%
SBIR/STTR	0	84	0	-84	-100%
Total, Laboratory Technology Research	2,818	3,000	0	-3,000	-100%

Description

The Laboratory Technology Research (LTR) subprogram will be brought to a successful conclusion in FY 2004 with orderly completion of all existing CRADAs. The mission of the Laboratory Technology Research 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 the Office of Science (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 the Office of Science; therefore these processes are now integrated into the other programs and the LTR subprogram is no longer needed.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Laboratory Technology Research	**2,818**	**2,916**	**0**

This activity supported research to advance the fundamental science at the Office of Science (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 2003	FY 2004	FY 2005
SBIR/STTR	**0**	**84**	**0**

In FY 2003, $75,000 and $5,000 were transferred to the SBIR and STTR programs, respectively. The FY 2004 amount is the estimated requirement for the continuation of the SBIR and STTR program.

	FY 2003	FY 2004	FY 2005
Total, Laboratory Technology Research	**2,818**	**3,000**	**0**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Laboratory Technology Research	
▪ The Laboratory Technology Research subprogram will be brought to a successful completion in FY 2004, as planned.	-2,916
SBIR/STTR	
▪ Decrease in SBIR/STTR due to completion of the LTR subprogram.	-84
Total Funding Change, Laboratory Technology Research	**-3,000**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Capital Equipment (total).........................	3,962	6,290	6,250	-40	-0.6%

Science Laboratories Infrastructure

Funding Profile by Subprogram

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Science Laboratories Infrastructure					
Laboratories Facilities Support	32,194	33,456	-186[a]	33,270	17,911
Excess Facilities Disposition	7,900	6,055	-35[a]	6,020	6,100
Oak Ridge Landlord	5,015	5,079	-30[a]	5,049	5,079
Health & Safety Improvements	0	10,000	-59[a]	9,941	0
Subtotal, Science Laboratories Infrastructure	45,109	54,590	-310[a]	54,280	29,090
Use of Prior Year Balances	0	-1,998	0	-1,998	0
Total, Science Laboratories Infrastructure	45,109[b]	52,592	-310[a]	52,282	29,090

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 to maintain the general purpose infrastructure (GPI) and the clean-up and removal of excess facilities. The program also supports SC landlord responsibilities for the 36,000 acre Oak Ridge Reservation; provides Payments 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 Oak Ridge Reservation, including the Federal facilities in the town of Oak Ridge, primarily by addressing general purpose facilities and infrastructures needs.

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[a] Excludes $310,110 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003.

[b] Excludes $296,000 for a rescission in accordance with the Consolidated Appropriations Resolution, FY 2003.

Significant Program Shifts

Progress in Line Item Projects – One project was completed in FY 2003: ORNL Electrical Systems Upgrades. Six projects are scheduled for completion 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 System Upgrades; and the ANL-E Fire Safety Improvements, Phase IV. In FY 2005, two projects are scheduled for completion: ORNL Research Support Center; and the ANL-E Mechanical and Control Systems Upgrades-PH I.

In FY 2004, Congress appropriated $10,000,000 to address the OSHA and NRC identified health and safety deficiencies and recommendations for improved health and safety practices at SC laboratories. This $10,000,000 is sufficient to 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.

Laboratories Facilities Support

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Laboratory Facilities Support					
General Purpose Facilities	18,868	24,619	9,283	-15,336	-62.3%
Environment, Safety and Health	12,319	7,140	7,108	-32	-0.5%
Payment in Lieu of Taxes (PILT)	1,007	1,511	1,520	+9	+0.6%
Total, Laboratories Facilities Support	32,194	33,270	17,911	-15,359	-46.2%

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.

Benefits

This subprogram improves the mission readiness of SC laboratories by funding line item construction projects to refurbish or replace general purpose facilities and site-wide infrastructure. The subprogram also provides Payments in Lieu of Taxes (PILT) assistance as required by law for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory –East.

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 over 2,400 buildings (including 787 trailers and 150 excess buildings) with a total square footage of over 21,000,000 square feet. The LFS subprogram also provides Payments in Lieu of Taxes (PILT) assistance for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East.

Capital investment requirements for SC laboratories are identified in laboratory Strategic Facilities Plans. These plans assume the full modernization/revitalization of the infrastructure of the laboratories will be completed over a ten-year period and include priority lists of proposed facilities and infrastructure needs. The backlog of line item construction modernization needs as summarized in SC's 2003 Update of the "*Infrastructure Frontier Report: A Quick Look Survey of the Office of Science Laboratory Infrastructure*," is on the order of $1 billion. Nearly 85% of this total is to rehabilitate or replace buildings.

The large backlog of line item construction needs is attributable to:

- the age of the facilities (over 69% of the buildings are 30 years old or older, and 43% are 40 years old or older);

- the use of wood and other non-permanent building materials in the original construction of the laboratories in the 40's and 50's;
- changing research needs that require:
  - different kinds of space (e.g., nuclear facilities including hot cells are in less demand while facilities that foster interaction and team-based research are in high demand); and
  - higher quality of space (e.g., reduced vibration sensitivity and temperature variability, and increased air quality and power demand for computers and other electronic equipment);
- 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.

For each budget, all candidate construction projects for funding by the LFS subprogram are scored using the DOE Life Cycle Asset Management (LCAM) Cost-Risk-Impact Matrix that takes into account risk, impacts, and mission need. The projects that have ES&H as the principal driver are further prioritized using the Risk Prioritization Model from the DOE ES&H and Infrastructure Management Plan process. Based on these scores, the LFS subprogram prioritizes the projects. The prioritized list is further evaluated for SC science program mission impact by an integrated infrastructure management team composed of the LFS subprogram and SC research program offices. Projects are then proposed from this list consistent with budget availability.

The LFS subprogram ensures that the funded projects are managed effectively and completed within the established cost, scope and schedule baselines. Performance will be measured by the number of all SLI projects completed within the approved baseline for cost (at or below the appropriated Total Estimated Cost), scope (within 10%), and schedule (within six months). One project scheduled for completion in FY 2003 was completed within the approved baselines for cost, scope, and schedule.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
General Purpose Facilities	**18,868**	**24,619**	**9,283**

Provides funding to support the continuation of two FY 2003 subprojects under the Science Laboratories Infrastructure (MEL-001) Project Engineering and Design (PED) and construction project data sheets. These are summarized below. More details are provided in the data sheets presented later.

Ongoing :

- LBNL Building 77 Rehabilitation of Structures and Systems, Phase II ($4,825,000)
- BNL Research Support Building, Phase I ($4,458,000)

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Environment, Safety and Health	**12,319**	**7,140**	**7,108**

Provides funding to support the continuation of one FY 2004 subproject under the Science Laboratories Infrastructure (MEL-001) construction project data sheet. It is summarized below. More details are provided in the data sheet presented later.

Ongoing:

- SLAC Safety and Operational Reliability Improvements ($7,108,000)

	FY 2003	FY 2004	FY 2005
PILT	**1,007**	**1,511**	**1,520**

Provide Payments in Lieu of Taxes (PILT) to support assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East. PILT payments are negotiated between the Department and local governments based on land values and tax rates.

	FY 2003	FY 2004	FY 2005
Total, Laboratories Facilities Support	**32,194**	**33,270**	**17,911**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
General Purpose Facilities (GPF)	
▪ Reduction in the General Purpose Facilities (GPF) area reflects the cancellation of the PNNL Laboratory Systems Upgrades subproject. The facilities to be rehabilitated under this subproject are now scheduled for removal under the River Corridor clean-up project and further investment is unnecessary. The remaining funds are redirected to two ongoing subprojects: TJNAF CEBAF Center Addition – Phase I and the BNL Research Support Building – Phase I, in FY 2004. This reduced the funding required for FY 2005 mortgages for these projects. Also, funding for two on-going subprojects, the BNL Research Support Building and the LBNL Building 77 Rehab, is reduced, extending funding schedules for both into FY 2006.	-15,336
Environmental Safety & Health (ES&H)	
▪ Reduction in the ES&H area reflects the completion of several ES&H projects resulting from significant past ES&H investment and shifting of SC program priorities. Funding is included for the SLAC Safety and Operational Reliability Improvements project.	-32

	FY 2005 vs. FY 2004 ($000)
PILT	
▪ PILT is continued close to the FY 2004 level.	+9
Total Funding Change, Laboratories Facilities Support	**-15,359**

Excess Facilities Disposition

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Excess Facilities Disposition	7,900	6,020	6,100	+80	+1.3%

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 will also clean-up facilities for reuse where such reuse is economical and can provide needed functionality.

Benefits

This subprogram reduces the long-term costs, risks and liabilities at the SC laboratories associated with excess facilities by removing them and 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 composed of the EFD subprogram and SC research program offices. The estimated backlog of non-contaminated or slightly contaminated facilities at the beginning of FY 2005 will be approximately $12,000,000.

The EFD subprogram does not fund projects that replace currently active and occupied buildings (e.g., old, deteriorated and marginally functional ones that are still used but are to be replaced by new modern buildings). Such building replacement projects are funded under the previously described LFS subprogram and would include removal of the old buildings as part of the justification for the project.

It should be noted that the EFD subprogram does not include projects involving cleanout and stabilization of contaminated facilities proposed for transfer to the Office of Environmental Management (EM) for ultimate disposition. At issue are 29 process-contaminated facilities at SC laboratories with an estimated decontamination and decommissioning (D&D) cost of $175,000,000. The Department is currently reviewing its existing facility transfer policies.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Excess Facilities Disposition..	**7,900**	**6,020**	**6,100**

In FY 2003, funding of $7,900,000 supports the 8 projects listed below and allows for the clean-up/removal of an estimated 460,000 square feet of space:

- ANL-E ($1,100,000) – Decontamination of Building 306 C132A&B; Decontamination of Building 306 Room D-001 and D-002 Cell; Partial Disposal of Building 202 (Kennels) (approximately 9,000 sq. ft.)
- BNL ($1,025,000) – Demolition of Buildings 89, 90, 91, 158, 184 and 206 (approximately 57,000 sq. ft.)
- FNAL ($362,000) – Demolition of four muon enclosures, Laser Building and Laboratory G trailer and slab, and Shed B at Site 50 (approximately 7,800 sq. ft.)
- LBNL ($2,450,000) – Removal of B51A beamline and demolition of Structure 51B External Proton Beam (EPB) Hall (approximately 48,000 sq. ft.) which are part of the retired Bevatron accelerator complex.
- LLNL ($250,000) – Demolition of the Magnetic Fusion Energy bridge and utility lines (approximately 1,000 sq. ft.)
- ORNL ($2,155,000) – Cleanout of Buildings 9204-1, 9999-3, 2011 and 9204-1 Scrap Yard; Demolition of Buildings 0961, 2093 and 3013 (approximately 270,000 sq. ft.)
- SLAC ($13,000) – Cleanout of Lauritsen Laboratory at California Institute of Technology (approximately 55,000 sq. ft.)
- PPPL ($545,000) – Removal of Princeton Beta Experiment Modification (PBX) Princeton Large Torus (PLT) control room and initial subsystems (approximately 12,000 sq. ft.)

In FY 2004, funding of $6,020,000 will support the 9 projects listed below and allows for the clean-up/removal of an estimated 84,000 square feet of space:

- Ames ($150,000) - Waste Handling Facility Closeout and Demolition, Phase 1
- ANL-E ($749,000) – Building 202 (N&P Kennels) Partial Disposal, Building 202,D-149 Lead Vault Demolition, and Building 205 G101 Junior Cave Remediation (approximately 4,400 sq. ft.)
- BNL ($725,000) – Demolition of Buildings 206/207/208/457/458 (approximately 34,000 sq. ft.)
- FNAL ($233,000) – Bubble Chamber Demolition (approximately 3,000 sq. ft.)
- LBNL ($500,000) – Remove Upper Layer Roof Concrete Shielding Blocks & Beamline Components from Building 51 of the retired Bevatron accelerator complex.
- LLNL ($250,000) – Demolition of Magnetic Fusion Energy Legacy Facilities at Building 445, Phase I (approximately 8,000 sq. ft.)

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

- ORNL ($760,000) – Demolition of Buildings 2069 and 7009 (approximately 17,000 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) - Demolish Portion of Sector 17 "Boneyard" (approximately 4 acres)
- Unallocated ($1,523,000) – To be allocated to other priority projects in FY 2004. $1,000,000 of the reserve is designated for the 88" cyclotron at LBNL in accordance with the FY 2004 appropriation committee report language. Because the 88" cyclotron will continue to operate in FY 2004 and FY 2005, a request has been submitted to Congress to apply these funds for the continued clean-out of retired Bevatron accelerator complex at LBNL.

In FY 2005, funding of $6,100,000 will support at least the 9 projects listed below and allow for the clean-up/removal of more than 61,000 square feet of space:

- Ames ($150,000) - Waste Handling Facility Closeout and Demolition, Phase 2 (approximately 9,000 sq. ft.)
- ANL-E ($2,120,000) - Building 40 (Instrument Calibration) Disposal and Partial Facility Demolitions (approximately 8,000 sq. ft.)
- BNL ($300,000) - Demolition of Buildings 428 and 492, and partial demolition of Buildings 197 and 244 (approximately 6,000 sq. ft.)
- FNAL ($125,000) – Demolition of two muon enclosures (approximately 2,000 sq. ft.)
- LBNL ($1,360,000) - Removal of portions of the retired Bevatron accelerator complex including a trailer, small building and injector (approximately 7,000 sq. ft.)
- LLNL ($300,000) - Demolition of Magnetic Fusion Energy Legacy Facilities at Building 445, Phase 2 (approximately 7,000 sq. ft.)
- ORISE ($565,000) – Demolition of Building SC-2, Isotope Laboratory (approximately 550 sq. ft.)
- ORNL ($780,000) - Demolition of Buildings 5000, 2018, 7010, 2016, 3008 and 3111 (approximately 19,000 sq. ft.)
- SLAC - ($400,000) – Demolition of HRS Detector in Building 660 (approximately 2,000 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 2003	FY 2004	FY 2005
Total, Excess Facilities Disposition	**7,900**	**6,020**	**6,100**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Excess Facilities Disposition	
▪ Excess Facilities Disposition is continued close to the FY 2004 level.	+80

Oak Ridge Landlord

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Oak Ridge Landlord	5,015	5,049	5,079	+30	+0.6%

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).

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 Payments 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 2003	FY 2004	FY 2005
Roads, Grounds and Other Infrastructure and ES&H Support and Improvements	**2,424**	**2,458**	**1,602**
Road maintenance, reservation mowing, bridge inspections, and records management.			
General Purpose Equipment...	**0**	**0**	**150**
Replacement of two aging high maintenance fuel tanker trucks.			
General Plant Projects...	**0**	**0**	**736**
Major road repair and renovation of the Federal Building including electrical systems, restrooms, and exterior shell.			
Payments in Lieu of Taxes (PILT)	**2,300**	**2,300**	**2,300**
Payments in Lieu of Taxes (PILT) to the City of Oak Ridge, and Anderson and Roane Counties.			

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Reservation Technical Support	**291**	**291**	**291**

Includes recurring activities such as site mapping, National Archives Records Administration, support for legacy legal cases, and real estate activities.

	FY 2003	FY 2004	FY 2005
Total, Oak Ridge Landlord	**5,015**	**5,049**	**5,079**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Oak Ridge Landlord	
▪ Landlord activities are continued close to the FY 2004 level.	+30

Health and Safety Improvement

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Health and Safety Improvement..................	0	9,941	0	-9,941	-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.

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 2003	FY 2004	FY 2005
Health and Safety Improvements	**0**	**9,941**	**0**

The deficiencies include: 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 2005 vs. FY 2004 ($000)
Health and Safety Improvements	
It is expected that the FY 2004 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.	-9,941

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Plant Projects (ORO Landlord)	0	0	736	+736	--
Capital Equipment (ORO Landlord)	0	0	150	+150	--
Capital Equipment (Excess Facilities Disposition)	75	0	0	0	--
Total, Capital Operating Expenses..................	75	0	886	+886	--

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2003	FY 2004	FY 2005	Unapprop. Balance
Project – 03-SC-001 Laboratories Facilities Support Project						
FY 2003 PED Datasheet.......................	N/A	N/A	3,313	0	0	0
Project – 04-SC-001 Laboratories Facilities Support Project						
FY 2004 PED Datasheet.......................	N/A	N/A	0	1,988	0	0
Project - MEL-001 Laboratories Facilities Support Project						
FY 2005 Construction Datasheet	N/A	N/A	27,874	29,771	16,391	15,869
Total, LFS Construction...............................	N/A	N/A	31,187	31,759	16,391	15,869

MEL-001 – Science Laboratories Infrastructure Project, Various Locations

(Changes from FY 2004 Congressional Budget Request are denoted with a vertical line in the left margin.)

Significant Changes

Subproject 18 – Laboratory Systems Upgrades (PNNL) is cancelled. The buildings that were to be rehabilitated under this project will be removed under the Office of Environmental Management funded Corridor Clean-up project at the Hanford Site.

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
N/A -- See subproject details						

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Project Engineering & Design (PED)			
Prior Years	3,183[a]	3,183	1,374
FY 2003	3,313[b]	3,313	2,663
FY 2004	1,988[c]	1,988	3,259
FY 2005	0	0	1,188
Construction			
Prior Years	21,111	21,111	12,162
FY 2003	27,874	23,924	20,733
FY 2004	29,771	31,742	28,682
FY 2005	16,391	16,391	23,945
FY 2006	15,869	15,869	16,015
FY 2007	0	0	7,500

[a] Title I and Title II Design funding of $880,000 (Subproject 18); $803,000 (Subproject 17); and $1,500,000 (Subproject 25) provided under PED Project No. 02-SC-001.

[b] Title I and Title II Design funding of $1,679,000 (Subproject 27); $1,089,000 (Subproject 28); $545,000 (Subproject 33) requested under PED Project No. 03-SC-001.

[c] Title I and Title II Design funding of $1,988,000 requested under PED Project No. 04-SC-001.

3. Project Description, Justification and Scope

This project funds two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and user support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Projects to correct Environment, Safety, and Health (ES&H) deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades and electrical system replacements.

General Purpose Facilities Projects:

a. Subproject 15 – Laboratory Facilities HVAC Upgrade (ORNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
7,055	3,500	3,555	0	0	0	3Q 2002 – 2Q 2004

This project will provide improvements to aging (average 38 years old) HVAC systems located throughout the 13 buildings which comprise ORNL's central research complex, thereby improving the research environment and reducing operations and maintenance costs. Work will include: 1) installation of a primary/secondary Central Chilled Water Plant pumping system by replacing existing inefficient primary and booster pumps with a variable volume distribution system and 2-way chilled water control valves; 2) installation of a chilled water cross-tie to Buildings 4501/4505 from the underground tie-line between Buildings 4500N and 4509 to address low capacity problems; 3) upgrading of a corroded hot water reheat distribution system which supplies reheat water for zone control of the primary air handlers; 4) upgrade of deteriorated air handlers in selected buildings with new filters, steam and chilled water coils, and controls; 5) installation of new chilled water coils and chilled water supply piping for the east wing of Building 3500 to replace the refrigerant system that has high maintenance requirements; and 6) replacement of control valves in various buildings to improve system efficiency.

b. Subproject 18 – Laboratory Systems Upgrades (PNNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
880	880 [a]	0 [b]	0 [b]	0	0	Project Cancelled [b]

This project will upgrade or replace 20-50 year old mechanical system components in eight high

[a] Title I and Title II Design funding provided under PED Project No. 02-SC-001.

[b] Project cancelled. The buildings that were to be rehabilitated under this project will be removed under the Office of Environmental Management funded River Corridor Clean-up project at the Hanford Site. FY 2003 Unobligated balances of $3,950,000 and $2,141,000 of FY 2004 Construction funds have been redirected in FY 2004 as follows: $5,105,000 to complete CEBAF center addition subproject MEL-001-33 and $986,000 to Research Support building MEL-001-27.

occupancy facilities, replacing them with more efficient and better performing systems to enhance the quality of science while reducing maintenance and energy costs. This upgrade will include: replacement of HVAC supply and exhaust fans; replacement, rehabilitation or modification of numerous chemical exhaust fume hoods; and installation of computerized, remote, digital controls on various systems to improve operations.

c. Subproject 25 – Research Support Center (ORNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
16,041	1,500 [a]	4,941	9,600	0	0	2Q 2003 – 2Q 2005

This project will construct a 50,000 sq. ft. facility to house the core support service facilities and serve as the cornerstone and focal point of the East Research Campus envisioned in the ORNL Facility Revitalization Project. This building will include an auditorium and conference center (currently there is no adequate auditorium/conference space available at ORNL), cafeteria, visitor reception and control area, and offices for support staff. It will facilitate consolidation of functions, which are presently scattered throughout the Laboratory complex in facilities that are old (30-50 years), undersized, poorly located, or scheduled for surplus. The facility will serve as a modern center for meeting, collaborating, and exchanging scientific ideas for ORNL staff and nearly 30,000 visitors, guests, and collaborators that use ORNL facilities each year. The new cafeteria will replace the existing cafeteria, which was constructed in 1953. The existing cafeteria is poorly located to serve the current staff and is adjacent to the original production area of the laboratory now undergoing decontamination. The estimated simple payback is seven years.

d. Subproject 27 – Research Support Building, Phase I (BNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
18,200	0	3,206 [b]	5,971	4,458	4,565	2Q 2004 – 3Q 2007

This 70,000 sq. ft. facility is intended to consolidate Staff Services, Public Affairs, Human Resources, Credit Union, Library and other support functions in a central quadrangle to provide staff and visiting scientists with convenient and efficient support. This facility, the first of four phases in the BNL Master Revitalization Plan, will include a lobby with a visitor information center to assist visiting scientists, and a coordinated office layout of related support services. After completion of this project, 21,100 sq. ft. of World War II era structures will be torn down. Based on total life-cycle costs, productivity gains, avoided energy and maintenance costs, the Research Support Building will provide a return on investment of 10% and a simple payback of 8.4 years.

[a] Title I and Title II Design funding of $1,500,000 provided under PED Project No. 02-SC-001.

[b] Title I and Title II Design funding of $1,679,000 requested under PED Project No. 03-SC-001.

e. Subproject 28 – Building 77 Rehabilitation of Structures and Systems, Phase II (LBNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
13,360	0	1,735 [a]	2,000	4,825	4,800	3Q 2004 – 2Q 2007

This project will provide for rehabilitation to correct mechanical, electrical and architectural deficiencies in Buildings 77 (a 39 year old, 68,000 sq. ft. high-bay industrial facility) and 77A (a 14 year old, 10,000 sq. ft. industrial facility). Both buildings house machine shop and assembly operations in which production of highly sophisticated research components for a variety of DOE research projects is performed. Current work includes precision machining, fabrication and assembly of components for the Advanced Light Source, the Dual-Axis Radiographic Hydrodynamic Test Facility (DAHRT) project, the Spallation Neutron Source, and the ATLAS Detector. Infrastructure systems installed by this project will include HVAC, power distribution, lighting, and noise absorption materials. The improvements are necessary to satisfy urgent demands for high levels of cleanliness, temperature and humidity control, and OSHA and reliability requirements. This is the second of two projects; the first project, funded in FY 1999 and completed in FY 2002, corrected structural deficiencies in Bldg. 77.

f. Subproject 33 – Continuous Electron Beam Accelerator Facility (CEBAF) Center Addition, Phase I (TJNAF)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
10,500	0	1,481 [b]	9,019 [c]	0	0	2Q 2005 – 2Q 2007

This project is Phase I of three phases to provide for additions to the CEBAF Center office building. The purpose of the three phases is to provide additional critical computer center space and to eliminate off-site leases and existing trailers to collocate staff for enhanced productivity. This first addition will add 59,000 sq. ft. of computer center (7,600 sq. ft.) and office space, and eliminate 22,000 sq. ft. of aging trailers with a 7.4-year simple payback and a 10% rate of return. Phase I will provide additional space for 182 users and 50 staff personnel.

ES&H Projects:

a. Subproject 12 - Site-wide Water Distribution System Upgrade (LBNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
8,264	5,400	2,864	0	0	0	2Q 2002 –1Q 2004

[a] Title I and Title II Design funding of $1,089,000 requested under PED Project No. 03-SC-001.
[b] Title I and Title II Design funding of $545,000 requested under PED Project No. 03-SC-001.
[c] Includes $3,950,000 of FY 2003 unobligated balances and $1,155,000 of planned FY 2004 funds redirected from subproject MEL-001-018.

This project will rehabilitate the Laboratory's High Pressure Water (HPW) System that supplies over 100 facilities at LBNL. The HPW System provides domestic water, fire water, treated water, cooling tower water and low conductivity water. It consists of 9.6 km of pipe (1.4 km of cast iron pipe, 6.3 km of ductile iron pipe, and 1.9 km of cement lined coated steel pipe), associated valves, pumps, fittings etc. and two 200,000 gallon emergency fire water tanks. This project will: replace all cast iron pipe, which is in imminent danger of failing, with ductile iron pipe; electrically isolate pipe and provide cathodic protection; replace leaking valves and add pressure reducing stations to prevent excessive system pressure at lower laboratory elevations; add an emergency fire water tank to serve the East Canyon; and provide the two current emergency fire water tanks with new liners and seismic upgrades.

b. Subproject 13 - Groundwater and Surface Water Protection Upgrades (BNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
6,033	4,652	1,381	0	0	0	2Q 2002 - 1Q 2004

This project will implement a backlog of ground and surface water protection projects that are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; and other Suffolk County Article 12 upgrades.

c. Subproject 14 - Fire Protection Systems Upgrades (ORNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
5,892	3,704	2,188	0	0	0	3Q 2002 – 4Q 2004

This project will upgrade the 36 year-old fire protection system with improved, more reliable fire alarm capabilities by: replacing deteriorated, obsolete systems; replacing the single 16-inch water main in the east central section of ORNL with a looped system (4,000 lf of 16 inch pipe); and by extending coverage of automatic alarm systems to areas not previously served. New fire alarm equipment will provide emergency responders with greatly improved annunciation of the causes and locations of alarms and will provide code compliant occupant notification evacuation alarms for enhanced life safety. It will also include timesaving, automatic diagnostic capabilities that will reduce maintenance costs. The new occupant notification systems will comply with the Americans with Disabilities Act. The fire alarm receiving equipment at the site fire department headquarters will be upgraded to ensure its reliability, modernize its technology, and meet the demands of an expanded fire alarm system network.

d. Subproject 16 – Electrical Systems Modifications, Phase II (BNL)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
6,734	3,855	2,879	0	0	0	2Q 2002 – 1Q 2004

This project is the second phase of the modernization and refurbishment of the Laboratory's deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 24 kV switchgear to increase system reliability/safety; reconditioning of 50 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of 10 13.8 kV air breakers with new vacuum technology.

e. Subproject 17 – Mechanical and Control Systems Upgrade, Phase I (ANL-E)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
8,962	803[a]	3,007	5,152	0	0	3Q 2003 – 3Q 2005

This project will upgrade and replace 30-40 year old mechanical system components in various facilities. It will optimize capacity, enhance system reliability and performance, improve safety, and reduce maintenance and repair costs of primary building mechanical equipment and control systems. The mechanical systems designated for replacement are no longer adequate, reliable, or efficient, and do not meet current ES&H standards (i.e. failure of laboratory exhaust systems could lead to the release of radioactive material). Specifically, this project will: upgrade HVAC systems in Buildings 221 and 362, including heating and cooling coils, fans, filter systems, ductwork, controls, and variable frequency drive fans; upgrade lab exhaust systems in Buildings 202 and 306, including new fans, ductwork, and controls; upgrade corroded drainage systems in Buildings 200, 205 and 350; and upgrade steam and condensate return systems in 12 facilities in the 360 area. This will include high and low pressure steam supply piping and associated pressure reducing stations, valves, and accessories; and replacing condensate pumping systems including piping, valves and system controls.

f. Subproject 36 – Safety and Operational Reliability Improvements (SLAC)

TEC	Prev.	FY 2003	FY 2004	FY 2005	Outyear	Construction Start/ Completion Dates
15,600	0	0	1,988[b]	7,108	6,504	3Q 2003 – 3Q 2007

[a] Title I and Title II Design funding of $803,000 provided under PED Project No. 02-SC-001.
[b] Title I and Title II Design funding of $1,988,000 requested under PED Project No. 04-SC-001.

This project has two components:

- Underground Utility Upgrades - this component will replace deteriorated sections of cooling water, low conductivity water, drainage, natural gas, compressed air and fire protection which are critical to the operation of the linear accelerator and the B-Factory rings which produce the essential collisions needed for the Parity Violation studies (one of the pillars of the current US High Energy Physics program also carried out competitively at KEK in Japan). There have been five pipe failures over the last two years and the failure rate is expected to increase in these 35 year-old systems as they continue to age. When the pipes fail, research is slowed or halted until repairs are completed.
- Seismic Upgrades – this component will install seismic upgrades necessary to bring various building structures into compliance with the seismic standards of the Uniform Building Code. The seismic hazard in the Bay Area is high. 19 "essential" facilities, i.e., those that will minimize the time required for the Laboratory to recover from an earthquake, will be retrofitted for a total of 229,000 sq. ft.

Payback is 11.2 years for the entire project.

4. Details of Cost Estimate

N/A

5. Method of Performance

To the extent feasible, construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids.

6. Schedule of Project Funding

N/A

7. Related Annual Funding Requirements

N/A

Fusion Energy Sciences

Funding Profile by Subprogram

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Fusion Energy Sciences					
Science	136,198	150,660	0	150,660	150,815
Facility Operations	66,198	86,087	-1,555[a]	84,532	85,495
Technology	38,299	27,363	0	27,363	27,800
Subtotal, Fusion Energy Sciences	240,695	264,110	-1,555[a]	262,555	264,110
Use of Prior Year Balances	0	-529	0	-529	0
Total, Fusion Energy Sciences	240,695[bc]	263,581	-1,555[a]	262,026	264,110

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 basic research effort to advance plasma science, fusion science, and fusion technology—the knowledge base needed for an economically and environmentally attractive fusion energy source.

Benefits

Fusion is the energy source that powers the sun and stars. In the fusion process, nuclei of light elements such as hydrogen, fuse together to make heavier elements such as helium, giving off tremendous amounts of energy. Fusion could play a key role in U.S. long-term energy plans because it offers the potential for plentiful, safe and environmentally benign energy. A fusion power plant would produce no greenhouse gas emissions, use abundant and widely distributed sources of fuel, shut down easily, require no fissionable materials, operate in a continuous mode to meet demand, and produce manageable radioactive waste. A science-based approach to fusion offers the fastest 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

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[a] Excludes $1,555,128 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003.

[b] Excludes $5,837,000 which was transferred to the SBIR program and $350,000 which was transferred to the STTR program.

[c] Excludes $1,615,228 for a rescission in accordance with the Consolidated Appropriations Resolution, FY 2003.

materials coatings, the efficient destruction of chemical and radioactive wastes, and more efficient space propulsion.

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 FES program supports the following goals:

Energy Strategic Goal
General Goal 4, Energy Security: Enhance energy security by developing technologies that foster a diverse supply of affordable and environmentally sound energy, improving energy efficiency, providing for reliable delivery of energy, exploring advanced technologies that make a fundamental change in our mix of energy options, and guarding against energy emergencies.

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, to advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences, and to provide world-class research facilities for the Nation's science enterprise.

The FES program has one program goal which contributes to General Goals 4 and 5 in the "goal cascade":

Program Goal 04.24.00.00/05.24.00.00: Bring the power of the Stars to Earth — Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels a star.

Contribution to Program Goal 04.24.00.00 (Energy Security)
The Fusion Energy Sciences program contributes to this goal through participation in ITER, an experiment to demonstrate the sustained burning of fusion fuel. The next frontier in fusion science is a sustained, burning (or self-heated) plasma. 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 endorsed this strategy in December 2002 (and more recently, in November 2003). Based in part on these recommendations, plus an Office of Science assessment of the cost estimate for the construction of ITER, the President decided in January 2003 that the U.S. should join the ITER negotiations. This proposed international collaboration will test the scientific and technical feasibility of fusion power. In FY 2003, DOE began leading U.S. participation in the negotiations and supporting technical activities preparing the project for construction beginning in 2006.

Contribution to Program Goal 05.24.00.00 (World-Class Scientific Research Capacity)

The Fusion Energy Sciences 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) focusing on non-neutral plasma physics and high energy density physics; 6) developing the cutting edge technologies that enable fusion facilities to achieve their scientific goals; and 7) advancing the science base for innovative materials.

These activities require operation of a set of unique and diversified experimental facilities, ranging from smaller-scale university devices to larger national facilities that require extensive collaboration. These facilities provide scientists with the means to test and extend theoretical understanding and computer models—leading ultimately to an improved predictive capability for fusion science.

The following indicators establish specific long term (10 years) goals in Scientific Advancement that the FES program is committed to and progress can be measured against.

1. **Predictive Capability for Burning Plasmas:** Develop 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.
2. **Configuration Optimization:** Demonstrate enhanced fundamental understanding of magnetic confinement and improved basis for future burning plasma experiments through research on magnetic confinement configuration optimization.
3. **Inertial Fusion Energy and High Energy Density Physics**: Develop the fundamental understanding and predictability of high energy density plasmas.

Annual Performance Results and Targets

FY 2000 Results	FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Targets	FY 2005 Targets
Program Goal 04.24.00.00/05.24.00.00 (Energy Security/World-Class Scientific Research Capacity)					
Facility Operations					
	Kept deviations in weeks of operation for each major facility within 10 percent of the approved plan. [met goal]	Kept deviations in weeks of operation for each major facility within 10 percent of the scheduled weeks. [met goal]	Kept deviations in weeks of operation for DIII-D and Alcator C-Mod each major facility within 10 percent of the approved plan. NSTX did not meet the target because of a coil joint failure. [Did not meet 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 percent 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 percent 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 percent 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%.	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%.
			Completed the National Compact Stellarator Experiment (NCSX) Conceptual Design and began Preliminary Design. [met goal]		

Means and Strategies

The Fusion 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 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 self-sustained plasma reaction in a burning plasma physics experiment. The proposed international burning plasma experiment called ITER is the focal point of burning plasma fusion research around the world, and the Administration has decided to join the negotiations to conduct this experiment. In light of this decision, many elements of the fusion program that are broadly applicable to burning plasmas will now be 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. The U.S. funding commitment to ITER will increase significantly in the future as the project moves to construction and eventually to science operations.

Scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad, and conduct comparative studies to supplement the scientific understanding they can obtain 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). These collaborations provide a valuable link with the 80 percent 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) that 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 Atomic Energy Implementing Agreements on tokamaks. In FY 2004, the United States began participating in the ITER Transitional Arrangements activities preparing the project for construction beginning in 2006.

All research projects undergo regular peer review and merit evaluation based on SC-wide procedures set down in 10 CFR 605 for the extramural grant program, and under a similar modified process for the laboratory programs and scientific user facilities. All new projects are selected by peer review and merit evaluation. FES formally peer reviews their scientific user facilities to assess the scientific output, user satisfaction, and the overall cost-effectiveness of each facility’s operations, and their ability to deliver the most advanced scientific capability to its user 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; user 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 construction of scientific facilities. In FES, construction of major research facilities has generally been on time and within budget. User facilities have as a goal to be operated and maintained so they operate more than 90%, 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) 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 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 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 Budget Request and has taken or will take the necessary steps to continue to improve performance.

In the PART review, OMB gave the Fusion Energy Sciences (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. Although FES is establishing 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, and this committee has met and prepared its report, FESAC has not yet met to receive the report. Once the COV issues a report, FES will develop an action plan to respond to the findings and recommendations within 30 days. The assessment found that FES has developed a limited number of adequate performance measures. However, OMB noted concerns regarding the collection and reporting of performance data. To address these concerns, FES will work with its Advisory Committee to develop research milestones for the long-term performance goals, will include the long term research goals in grant solicitations, will work to improve performance reporting by grantees and contractors, and will work with the CFO to improve FES sections of the Department's performance documents. The Administration strongly supports efforts to explore possible U.S. participation in ITER. OMB found that the FES budget is 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. FES will engage its advisory committee to prepare a top-to-bottom scientific prioritization for U.S. fusion and will then develop a strategic plan, based upon that input, by September 2005.

Funding by General and Program Goal

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Goal 4, Energy Security					
Program Goal 04.24.00.00, Advance Plasma Science, Fusion Science, and Fusion Technology					
Facility Operations: ITER	0	3,000[a]	7,000[b]	+4,000	+133.3%
General Goal 5, World-Class Scientific Research Capacity					
Program Goal 05.24.00.00, Advance Plasma Science, Fusion Science, and Fusion Technology					
Science	136,198	150,660	150,815	+155	+0.1%
Facility Operations: Non-ITER	66,198	81,532	78,495	-3,037	-3.7%
Technology	38,299	27,363	27,800	+437	+1.6%
Total, Program Goal 05.24.00.00, Advance Plasma Science, Fusion Science, and Fusion Technology	240,695	259,555	257,110	-2,445	-0.9%
Total, General Goal 4 and 5 (Fusion Energy Sciences)	240,695	262,555	264,110	+1,555	+0.6%
Use of Prior Year Balances	0	-529	0	+529	+100.0%
Total, Fusion Energy Sciences	240,695	262,026	264,110	+2,084	+0.8%

Overview

Fusion science is a subfield of plasma science that deals primarily with studying the fundamental processes taking place in plasmas where the temperature and density approach the conditions needed to allow the nuclei of two low-mass elements, like hydrogen isotopes, to join together, or fuse. When these nuclei fuse, a large amount of energy is released. There are two leading methods of confining the fusion plasma—magnetic, where strong magnetic fields constrain the charged plasma particles, and inertial, where laser or particle beams compress and heat the plasma during very short pulses. Most of the world's fusion energy research effort, the U.S. included, is focused on the magnetic approach. But NNSA's supports a robust program in inertial fusion for stockpile stewardship but also provides a base for Fusion Energy Science work in this area. Thus FES depends on NNSA for the physics of the target-driver interaction.

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[a] Reflects $3,000,000 in direct funding for ITER preparations. An additional $5,000,000 for ITER supporting activities is reflected within goal 5, bringing the total Fusion program resources in preparation for ITER to $8,000,000 in FY 2004.

[b] Reflects $7,000,000 in direct funding for ITER preparations. An additional $31,000,000 for ITER supporting activities is reflected within goal 5, bringing the total Fusion program resources in preparation for ITER to $38,000,000 in FY 2005.

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 outward to the plasma edge and to the material walls as a result of electromagnetic turbulence in the plasma (chaos, turbulence, and transport),
- the stability of the magnetic configuration and its variation in time as the plasma pressure, density, turbulence level, and population of high energy fusion products change (stability, reconnection, and dynamo),
- the role of the colder plasma at the plasma edge and its interaction with both material walls and the hot plasma core (sheaths and boundary layers),
- the interaction of electrons and ions in the plasma with high-power electromagnetic waves injected into the plasma for plasma heating, current drive and control (wave-particle interaction), and
- the development of reliable and economical superconducting magnets, plasma heating and fueling systems, vacuum chamber, and heat extraction systems and materials that can perform satisfactorily in an environment of fusion plasmas and high energy neutrons.

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 Theory and Modeling, as well as General Plasma Science;
- Configuration Optimization, that includes experiments on advanced tokamaks, magnetic alternates, and inertial fusion concepts, as well as facility operations and technology; and
- Materials, that includes fusion specific materials science closely coupled to the 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 the Fusion Energy Sciences (FES) program governance is the funding, management, and oversight of the program. FES has established an open process for obtaining scientific input for major decisions, such as planning, funding, evaluating and, where necessary, terminating facilities, projects, and research efforts. There are also mechanisms in place for building fusion community consensus and orchestrating international collaborations that are fully integrated with the domestic program. FES is likewise active in promoting effective outreach to and communication with related scientific and technical communities, industrial and government stakeholders, and the public.

Advisory and Consultative Activities

The Department of Energy uses a variety of external advisory entities to provide input that is used in making informed decisions on programmatic priorities and allocation of resources. The FESAC is a standing committee that provides independent advice to the Director of the Office of Science on complex scientific and technological issues that arise in the planning, implementation, and management of the fusion energy sciences program. The Committee members are drawn from universities, national laboratories, and private firms involved in fusion research 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 containing its advice and recommendations to the Department.

During FY 2001 and 2002, the Department undertook a multi-step process to plan the future directions of the FES program. In October 2000, the FESAC was charged to address the scientific issues of burning plasma physics. In its September 2001 report "Review of Burning Plasma Physics" (DOE/SC-0041), FESAC stated that "*Now*" is the time to take steps leading to the expeditious construction of its finding that a burning plasma experiment would bring enormous scientific benefits and technical rewards not only to the fusion program, but to several other fields as well. FESAC also found that the present scientific understanding and technical expertise were sufficient to allow such an experiment, no matter how challenging, to succeed with a high degree of confidence.

In the summer of 2002, at a two-week workshop involving a large part of the fusion research community, a statement about the need for burning plasma research received unanimous support of the attendees. In addition, a uniform technical assessment of the three leading proposals for a burning plasma experiment was developed.

With these steps in hand, FESAC that had been charged in February 2002 to recommend a strategy for burning plasma experiments, issued its report, "A Burning Plasma Program Strategy to Advance Fusion Energy" (DOE/SC-0060) in September 2002. The report states that the world effort to develop fusion is at a threshold of a new state in its research: the investigation of burning plasmas. This investigation, at the frontier of the physics of complex systems, would be a huge step in establishing the potential of magnetic fusion to contribute to the world's energy security. The report then outlines a consistent, aggressive strategy, taking advantage of international efforts, to develop the science and technology of plasmas.

These three steps fit together with the recommendation from the NRC following its review of burning plasmas, Burning Plasma: Bringing a Star to Earth", September 2003, in which NRC recommends that the United States participate in ITER, a burning plasma experiment and one of the three approaches assessed technically during the summer workshop in 2002.

A variety of other committees and groups provide input to program planning. Ad hoc activities by fusion researchers, such as the 2002 Snowmass meeting, provide a forum for community debate and formation of consensus. The President's Committee of Advisors on Science and Technology (PCAST) has also examined the fusion program on several occasions, as has the Secretary of Energy Advisory Board. As noted, the National Research Council, who's 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 formed primarily from researchers from outside the host facility, including non-U.S. members. They review proposals for research to be carried out on the facility and assess support requirements, and, in conjunction with host research committees, provide peer recommendations regarding priority assignments of facility time. Because of the extensive involvement of researchers from outside the 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 programs for their balance, relevance, and standing in the broader scientific community.

Universities and most industries submit grant proposals to receive funding from FES for their proposed work. 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 field work proposals for funding of both new and ongoing activities. These are subject to peer review according to procedures that are patterned after those given in 10 CFR Part 605 that govern the SC grant program. For the major facilities that FES funds, these extensive reviews are conducted as part of a contract or cooperative agreement renewal, with nominal five-year renewal dates. External peer reviews of laboratory programs are carried out on a periodic basis.

Another review mechanism 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. The CoV should not only report on process, but on how this process impacts the substance of the program quality, and perceived gaps in the overall research portfolio supported by the program under review. The CoVs should be answering questions such as: Are the best people and proposals being funded, and if not, why not?; Are the right reviewers being chosen?; Are the common variety of approaches to merit review (e.g., mail, panel, etc.) and competition being used in an appropriate manner?; Are poorly-rated proposals funded, and if so, why? The first CoV review will address the theory and computation program, reporting its result to the Department by March 2004.

Planning and Priority Setting

The FESAC carries out an invaluable role in the fusion program by identifying critical scientific issues and providing advice on medium- and long-term goals to address these issues.

The National Research Council (NRC), in its report on the Department's strategy for addressing the science of a burning plasma, recommended that a new effort be made to integrate the U.S. participation in the ITER project into the U.S. domestic program. The NRC report stated that this integration should be defined through a prioritized balancing of the content, scope, and level of the U.S. activities in fusion. The fusion community and FESAC were ready to act on this recommendation, and so the FESAC has been charged to assist the Department and the community in establishing priorities for the fusion program. The FESAC panel that will address this charge will 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 priority order in which those campaigns will be pursued. FESAC's report on this activity is scheduled to be completed in July 2004.

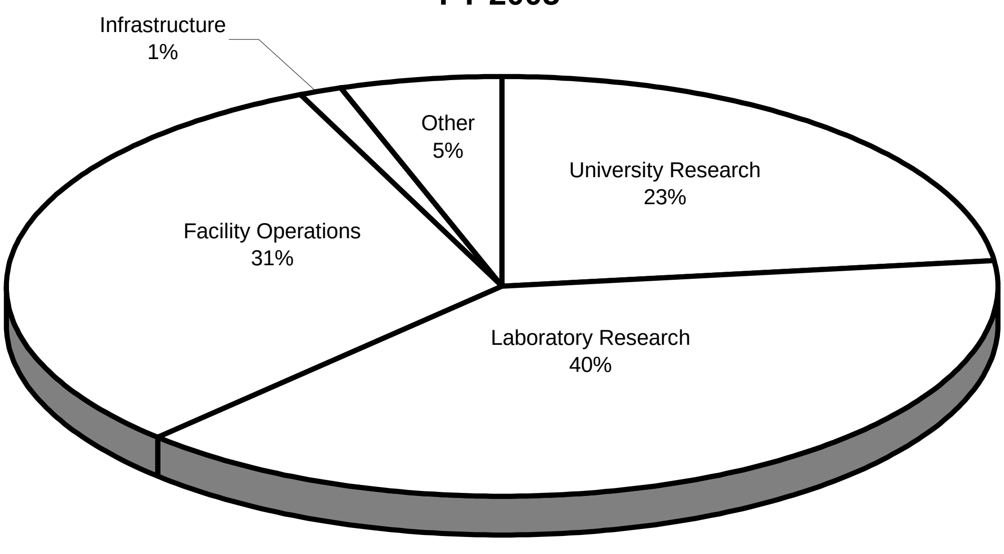
A variety of sources of information and advice, as noted above under the heading "Advisory Activities," are integrated with peer reviews of research proposals and when combined with high-level program reviews and assessments provide the basis for prioritizing program directions and allocations of funding.

How We Spend Our Budget

The FES budget has three components: Science, Facility Operations, and Technology. 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). 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 undergoes periodic scrutiny by the FESAC. The following chart illustrates the allocation of funding to the major program elements.

Fusion Energy Sciences Budget Allocation
FY 2005



Research

The DOE fusion energy sciences program involves over 1,100 researchers and students at more than 70 U.S. academic, federal, and private sector institutions. The program funds research activities at 67 academic and private sector institutions located in 30 states and at 11 DOE and Federal laboratories in 8 states. The three major facilities are operated by the hosting institutions, but are configured with national research teams made up of local scientists and engineers, and researchers from other institutions and universities, as well as foreign collaborators.

- **University Research**

  University researchers continue to be a critically important component of the fusion research program and are responsible for training graduate students. University research is carried out on the full range of scientific and technical topics of importance to fusion. University researchers are active participants on the major fusion facilities and one of the major facilities is sited at a university (Alcator C-Mod at MIT). In addition, there are 16 smaller research and technology facilities located at universities, including a basic plasma user science facility at UCLA that is jointly funded by DOE and NSF. There are 5 universities with significant groups of theorists and modelers. About 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 peers review proposals submitted in response to announcements of opportunity and funding is competitively awarded according to the guidelines published in 10 CFR Part 605. Support for basic plasma physics is carried out through the NSF/DOE Partnership in Basic Plasma Science and Engineering.

- **National Laboratory and Private Sector Research**

  The Fusion Energy Sciences program supports national laboratory-based fusion research groups at the Princeton Plasma Physics Laboratory, Oak Ridge National Laboratory, Sandia National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Idaho National Engineering and Environmental Laboratory, Argonne National Laboratory, and Los Alamos National Laboratory. In addition, one of the major research facilities is located at and operated by General Atomics in San Diego, California. The laboratory programs are driven by the needs of the Department, and research and development carried out there is tailored to take specific advantage of the facilities and broadly based capabilities found at the laboratories.

  Laboratories submit field work proposals for continuation of ongoing or new work. Selected parts of proposals for continuing work are reviewed on a periodic basis, and proposals for new work are peer reviewed. FES program managers review laboratory performance on a yearly basis to examine the quality of their research and to identify needed changes, corrective actions, or redirection of effort.

Significant Program Shifts

The budget requested for FY 2005 is slightly above the FY 2004 Appropriation. The FY 2005 budget continues the redirection of the fusion program to prepare for participation in the ITER program, while also supporting many of the program priorities recommended by the Fusion Energy Sciences Advisory Committee and supported by the Secretary of Energy Advisory Board and the National Research Council (NRC).

The principal program shifts comport with the President's decision to join the ITER negotiations to build a burning plasma experimental facility. Longer range technology activities will have been phased out in FY 2004 while engineering and technology R&D activities that directly support existing and near term experiments as well as preparations for the construction of the burning plasma device will be increased. The three major fusion research facilities will be operated for 14 weeks each, 56 percent of the maximum possible single-shift operation, to advance our understanding of the key physics issues governing toroidal fusion concepts, thereby contributing to future experiments on ITER.

The FY 2005 budget will also support the continuation of the Scientific Discovery through Advanced Computing (SciDAC) program, which is being focused on burning plasma physics and ITER.

A summary of program resources to be applied to ITER in FY 2005, as well as the corresponding level for FY 2004, is shown in the following table. For the DIII-D and Alcator C-Mod research programs, the fraction of research in support of ITER needs is increased in FY 2005 despite a reduction in total weeks of facility operation. Also, Plasma Technology research in support of ITER is significantly increased in FY 2005 relative to FY 2004 when specific ITER R&D needs began to be identified by the interim ITER project team.

Fusion Program Resources in Preparation for ITER

(dollars in thousands)

	FY 2004	FY 2005
DIII-D Experimental Program	$3,000	$10,000
Alcator C-Mod Experimental Program	1,000	5,000
Fusion Plasma Theory & Computation	1,000	3,000
ITER Preparations	3,000	7,000
Plasma Technology	~ 0	13,000
Total	$8,000	$38,000

ITER negotiations are continuing in FY 2004. A comprehensive process to prepare an international agreement covering all aspects of ITER construction, operation and decommissioning is in place. This includes input on all topics by experts from each negotiating Party, discussion by representatives of each Party and resolution of differences by the negotiators. The negotiating process is aiming at a negotiated agreement in early 2004 for subsequent consideration and approval within the Parties' governmental systems. In addition, representatives of the Parties are addressing critical decisions on siting, sharing of costs and assignment of management personnel. During FY 2004 a U.S. ITER Project Office will be selected to manage the preparations in FY 2004 and FY 2005 for ITER construction starting in FY 2006.

The FY 2005 budget request is consistent with the expected cost and schedule baseline for the design and fabrication of the National Compact Stellarator Experiment (NCSX), a joint ORNL/PPPL advanced stellarator experiment at the Princeton Plasma Physics Laboratory, that is now expected to begin operation in late FY 2008/early FY 2009.

Finally, the Inertial Fusion Energy research program will be focused on the science issues of non-neutral plasmas and high energy density physics research.

Awards

- Nine fusion researchers were elected Fellows of the American Physical Society in 2002.

- A recent PhD recipient from the University of Texas won the 2003 Marshall N. Rosenbluth Outstanding Doctoral Thesis Award for his first principles theoretical analysis of a plasma thruster that models the helicon plasma source, single-pass radio frequency heating, and particle and momentum balance.
- A fusion materials scientist was elected fellow of the American Society of Materials “for outstanding contributions to our understanding of the effects of radiation on the properties of materials, and the development of new, advanced materials for service in the challenging environment of fusion reactors.
- A PPPL Nobel Prize winning scientist has been elected a Fellow of the American Association for the Advancement of Science (AAAS).
- A recent graduate of Princeton University who did his thesis research at PPPL, was named an APS Congressional Science Fellowship winner.
- A PPPL engineer was named a Fellow of the American Society of Mechanical Engineers.

Scientific Discovery through Advanced Computing (SciDAC)

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all Office of Science mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit 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 made progress 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. There have been significant advances in the simulation of mode conversion 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.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes funds to operate and make use of major fusion scientific user facilities. The Department’s three major fusion physics facilities are: the DIII-D Tokamak at General Atomics in San Diego, California; the Alcator C-Mod Tokamak at the Massachusetts Institute of Technology; and the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory. These three facilities are each unique in the world’s fusion program and offer opportunities to address specific fusion science issues that will contribute to the expanding knowledge base of fusion. Taken together, these facilities represent a nearly $1,000,000,000 capital investment by the U.S. Government, in current year dollars.

The funding requested will provide research time for about 465 scientists in universities, federally sponsored laboratories, and industry, and will leverage both federally and internationally sponsored research, consistent with a strategy for enhancing the U.S. National science investment.

The total number of weeks of operation at all of the major fusion facilities is shown in the following table.

	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
Maximum weeks	75	75	75	75	75
Planned weeks	44	34	31	54	42
Weeks operated as % of planned weeks	100%	94%	81%	TBD	TBD

In addition to the operation of the major fusion facilities, a Major Item of Equipment project, the NCSX project at PPPL, is supported in the fusion program. Milestones for this project are shown in the following table.

FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
		Complete the NCSX Conceptual Design and begin the Preliminary Design.	Complete final design of NCSX and begin 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 C-Mod Lower Hybrid Upgrade Project		

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 2003, the FES program supported 384 graduate students and post-doctoral investigators. Of these, approximately 50 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.

	FY 2001	FY 2002	FY 2003	FY 2004, est.	FY 2005, est.
# University Grants	186	186	189	195	195
# Permanent PhD's [a]	741	731	745	775	775
# Postdocs	99	99	100	105	105
# Grad Students	266	279	284	295	295
# PhD's awarded	49	53	40	42	42

[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 2003	FY 2004	FY 2005	$ Change	% Change
Science					
Tokamak Experimental Research	47,050	49,519	48,406	-1,113	-2.2%
Alternative Concept Experimental Research	52,423	54,122	55,279	+1,157	+2.1%
Theory	24,478	25,228	25,340	+112	+0.4%
SciDAC	3,256	3,320	3,300	-20	-0.6%
General Plasma Science	8,991	11,725	11,700	-25	-0.2%
SBIR/STTR	0	6,746	6,790	+44	+0.7%
Total, Science	136,198	150,660	150,815	+155	+0.1%

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. In addition, the Science subprogram supports exploratory research to combine the favorable features of and the knowledge gained from magnetic and inertial confinement, steady-state and pulsed approaches, in new, innovative fusion approaches. There has been great progress in plasma science during the past three decades, in both magnetic and inertial confinement, and today the world is at the threshold of a major advance in fusion power development--the study of burning plasmas, in which the self-heating from fusion reactions dominates the plasma behavior.

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.

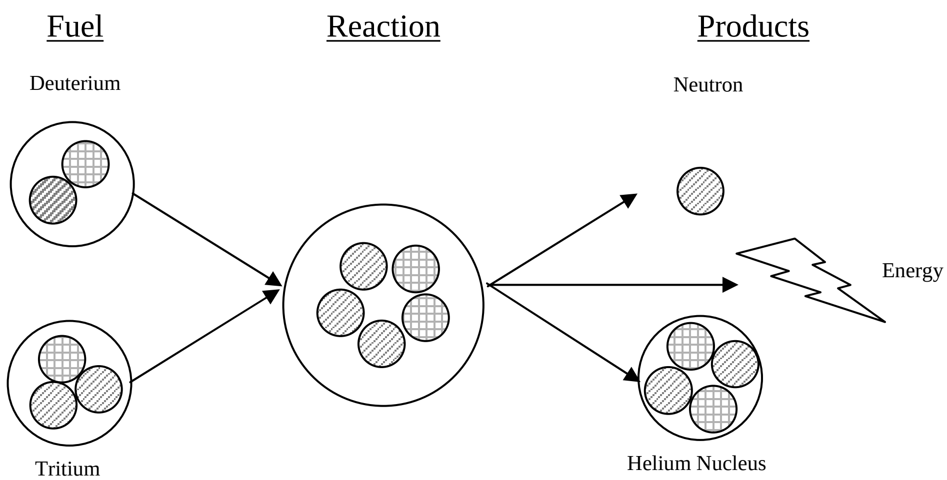
Supporting Information

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 the understanding of plasmas through an integrated program of experiments, theory, and simulation as outlined in the ***Integrated Program Planning Activity for the Fusion Energy Sciences Program*** prepared for FES and reviewed by the Fusion Energy Sciences Advisory Committee. This integrated research program will focus on well-defined plasma scientific issues including 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, and to benefit from ignition experiments on the NNSA-sponsored National Ignition Facility (NIF).

An additional objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma science. Two activities, an NSF/DOE partnership in plasma physics and engineering, and Junior Faculty development grants for members of university plasma physics faculties, will continue to contribute to this objective. A new “Centers of Excellence in Fusion Science” program will also foster fundamental understanding and connections to related sciences.

Plasma science includes not only plasma physics but also physical phenomena in a much wider class of ionized matter, in which atomic, molecular, radiative 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 where the peak temperatures are greater than 100 million degrees Celsius and densities 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 producing 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.

Science Accomplishments

Research funded by the Fusion Energy Sciences program in FY 2003 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.

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.

Turbulent transport is the dominant mechanism for energy and particle transport in high temperature tokamak plasmas. Understanding turbulent transport is one of the great challenges of plasma science and is essential to be able to optimize a burning plasma experiment.

- For the first time, a scientific code (GYRO) developed as part of the SciDAC program has been able to correctly predict the transport of heat in the core of a turbulent plasma. The code results were compared to experimental results from the DIII-D tokamak and found to predict the correct level of transport throughout the core of the plasma. This result is a big step in understanding turbulence and transport in tokamak plasmas.
- As our understanding of transport has evolved, we have discovered techniques for reducing energy transport. Internal transport barriers have been observed on both the DIII-D tokamak and the Alcator C-Mod tokamak. A key issue in tokamaks is reducing energy transport without reducing particle transport to the point where density and impurities accumulate in the plasma. Recent experiments with Internal Thermal Barriers (ITB's) generated by off-axis radio frequency (RF) heating on C-Mod have confirmed the ability to control the density peaking, and avoid impurity accumulation, through the application of simultaneous on-axis RF heating. Modeling of these discharges with the GS2 transport code has revealed that a small-scale instability (the Trapped Electron Mode), stimulated by the increased temperature gradients which result from the on-axis heating, appear to be primarily responsible for the enhanced diffusive particle transport, which controls the density peaking and the impurity confinement.

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.

- In a tokamak, a fast-growing instability can lead to a complete loss of magnetic confinement and a rapid transport of the plasma energy to the vacuum vessel walls. A new set of coils, controlled by a high-speed computer system, were installed inside the DIII-D vacuum vessel to stabilize the plasma at pressures that would otherwise be unstable. This active feed-back control system allowed DIII-D to operate with plasma pressures up to 40% higher than the conventional limits.

- One of the less severe but still significant instabilities in the tokamak arises from resistive diffusion of the plasma current so that it collects in clumps that form "magnetic islands" inside the plasma. These islands limit the energy content of the plasma by providing radial short circuits for heat flow across the island. Modern theory work has characterized a new form of these instabilities called Neoclassical Tearing Modes (NTMs), which are driven by a local deficit in plasma's bootstrap current, forming NTM islands. The drive for the NTM instabilities increases as the plasma pressure (or plasma density and temperature) increases. The growth of NTM islands can be arrested by providing localized current drive by microwaves. Experiments in DIII-D demonstrated the validity of the theory and the ability to stabilize these NTMs. In these experiments, conducted in several stages, radially-localized off-axis current was driven by high power microwaves, completely suppressing different modes of the NTM stability. After the islands were completely suppressed, it was possible to increase the plasma pressure with additional beam heating power.

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.

- Recent measurements on the Alcator C-Mod tokamak with the phase contrast imaging diagnostic show intermediate wavelength mode converted waves in the core of the plasma. Detailed modeling with the TORIC code has shown that these intermediate wavelength mode converted waves are in fact Ion Cyclotron Waves. This is the first definitive observation of these waves in a tokamak. The ion cyclotron wave propagates toward the low magnetic field region and may have favorable properties for plasma flow drive. Plasma flows are known to have a stabilizing effect on plasma turbulence.

- Electromagnetic wave current drive and/or profile modification are essential elements of all planned advanced, high-performance operating scenarios for ITER. Recent experiments on the DIII-D tokamak at General Atomics have demonstrated stationary plasma performance that projects to longer pulse length and/or higher gain operation in ITER than the present baseline scenario. The results from these experiments, that use a small amount of Ohmic heating transformer flux to support the plasma current and match ITER plasma shape, indicate that the ITER pulse length may be extended to about one hour duration (up from the 400 second baseline case) with full fusion power of about 500 MW. Alternatively, higher fusion power could be achieved for shorter pulses.

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.

- In High confinement discharges, an undesirable phenomenon is the formation of Edge Localized Modes (ELMs) that eject pulses of particles and energy to plasma facing components and may cause melting or erosion. Previous experiments in DIII-D discovered a new mode of operation with two radial regions of improved heat insulation (transport barriers). Recent experiments in DIII-D involve exhaust of plasma fuel particles and impurities through these barriers without generating ELMs at the plasma edge. The plasma edge in this new mode of operation is 'quiescent' with the absence of ELMs. Additional experiments and analysis during the past year showed that the quiescent double barrier mode in DIII-D resulted in high performance and could be sustained for 3.8 seconds. The conclusion is that this mode can lead to steady-state operation using external current drive. The DIII-D team worked with the ASDEX-Upgrade team in Germany to extend the DIII-D results to

ASDEX-UG, achieving quiescent plasmas (without ELMs) and further strengthening the conclusions reached in DIII-D.

- Experiments in DIII-D have revealed an alternate technique for controlling ELMs in DIII-D using 'chaotic' like magnetic fields in the plasma edge. An international team of scientists used a set of new internal coils to break the smooth magnetic surfaces at the narrow plasma edge into a 'chaotic' configuration. This chaotic edge configuration eliminated Edge Localized Modes (ELMs) that impart large transient heat loads to the plasma chamber walls and limit plasma performance.
- During the past year, NSTX scientists measured and analyzed the heat flux on the plasma facing components during high power operation. In high confinement mode operation, the dispersion of the heat flux on the divertor plates increased by a factor of three as the plasma triangularity was increased. Geometric effects accounted for less than a factor of two in the increase in the heat flux dispersion. This is a favorable result as increased triangularity is often needed to achieve high performance operation, and greater dispersion of the heat flux reduces peak heat loads on the divertor plates.

Configuration Optimization

Since the inception of this program element in 1997, significant progress has been made in many areas, such as transport in plasmas undergoing Taylor relaxation, the generation of magnetic helicity and its injection into toroidal plasma systems (including tokamaks), stability and generation of exoteric plasma configurations, and shear flow stabilization of plasmas.

- Self organization of plasma flows occurs in many of the important plasmas being studied for fusion, and plays an important role in the dynamics of these plasmas, for better or for worse. The approach to self organization in plasmas 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, has 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.
- 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. Injecting magnetic helicity into a tokamak, for example, is a candidate for non-inductive start-up and producing electrical currents in tokamak, that are among the most important issues in tokamaks. To that end, a major milestone was demonstrated in the past year in a small, university-scale experiment at the University of Washington. In this experiment, magnetic helicity was generated using a coaxial plasma gun and was injected into a spherical tokamak, resulting in a 30% increase in the toroidal current in the spherical tokamak. The physics underlying the generation of magnetic helicity is further elucidated by another university-scale experiment at Caltech, in which the processes leading to flux amplification are captured photographically and analyzed for the first time. In yet another small university-scale experiment at the University of California in Davis, small balls of magnetic helicity have been accelerated to 200 km/s in the past year, and are being studied as a candidate for refueling tokamaks.
- When magnetic helicity is captured in a toroidal form in a simple vacuum vessel (simply connected) instead of a toroidal chamber (doubly connected), 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. A fundamental issue in spheromak research is its sustainment, as magnetic helicity decays due to resistive dissipative processes. In the past year, an important milestone in spheromak research has been demonstrated at the Sustained Spheromak Physics Experiment (SSPX) at the LLNL. In this experiment, for the first time, short pulses of magnetic helicity were injected sequentially into a spheromak, and were successfully retained by the spheromak. Injection of helicity into a spheromak usually opens up the flux surfaces, causing sudden loss of energy confinement. Through better theoretical understanding gained from using modern diagnostics and computational modeling, researchers at LLNL learned to time the helicity injection properly to avoid significant loss of energy confinement. The overall energy confinement was improved by a factor of four, and the plasma temperature was raised from 1.4 million degrees Celsius to 2.6 million degrees Celsius.

- A potentially cost effective way to heat a plasma to fusion temperatures is to compress a magnetized plasma using a material wall, called a liner, that may be solid, liquid, or gaseous. The plasma science question that underpins the approach is the ability of extremely high magnetic field in providing thermal insulation of the material liner so that heat is not lost too rapidly to the liner during the compression of the plasma. Significant progress has been made during the past year in preparing for the feasibility experiment. A cylindrical, solid aluminum liner, 30 cm long and 10 cm in diameter, has been compressed electromagnetically achieving 13 times radial compression with velocities ~ 4 km/s. High density field reversed configurations suitable as magnetized plasmas for the compression experiment have been generated with a density of 3×10^{16} ions/cc, a temperature of 3.3 million degrees Celsius and sustainment time of 10–20 microseconds.
- In the past year, in yet another small-scale university experiment at the University of Washington, the stabilization of a magnetized plasma by a velocity shear in the plasma flow has been demonstrated. In this experiment, the growth rate of the magnetohydrodynamic instabilities was reduced by more than a factor of 700 in a long (0.5 m) Z-pinch plasma configuration.

Inertial Fusion Energy and 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, that 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 holhraum 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 have positive electrical charge and repel each other. This electrostatic repulsion creates difficulties in focusing them to achieve high energy density. One approach is to neutralize the ions electrically by passing them through a plasma, allowing the electrons in the plasma to recombine with the ions, thus converting the ions to neutral particles. The neutral particles can then be focused by arranging their ballistic trajectories to converge. This focusing mechanism was demonstrated experimentally in the Neutralized Transport Experiment (NTX) at the LBNL, in which an ion beam of approximately 10 cm in diameter was focused down to a spot of less than a few millimeters for the first time in the past year. 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. The experiment has used beam currents up to 0.2 amperes, that is high compared to other particle accelerators, such as those used in high energy physics.

- An exciting new scientific development in recent years in the area of inertial fusion and high energy density physics is the use of petawatt (a thousand-trillion-watt) lasers to heat an already dense solid. For fusion, the concept is to use such a laser to heat and ignite a fusionable capsule that is pre-compressed by another laser, the main compression laser. 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, have obtained the first experimental data that will throw the first light on the transport of these relativistic electrons in the material.

Specific FY 2005 goals leading toward the long-term performance measures for Fusion Energy Sciences are:

Tokamaks

- Develop a comprehensive experimental database of tokamak stability, transport, particle interaction, and edge effects that will be used to validate predictive models for burning plasmas.

  Obtain experimental data from DIII-D, C-MOD, and NSTX on the control of current profiles by different electromagnetic waves injected into the plasma (high power Electron cyclotron waves in DIII-D, lower hybrid waves in C-MOD, fast waves in NSTX) in order to improve plasma performance and extend pulse length. Compare these results with data from international tokamaks and theoretical predictions.

Alternates

- Assess the value of alternative magnetic confinement configurations to enhance the fundamental understanding of magnetic confinement and improve the basis for future burning plasma experiments.

  For the leading magnetic alternate concept, the spherical torus, complete a preliminary determination of its attractiveness for fusion applications, assessing stability, turbulence and transport, non-inductive current drive, scrape-off layer fluxes, and integration of high plasma pressure and high confinement efficiency for several energy replacement times.

High Energy Density Physics/IFE

- Assess the new physical phenomena that result from using high energy beams and lasers to explore extreme states of matter.

  A roadmap for an interagency high energy density program will be developed jointly with NSF and NNSA, using workshops and symposia to obtain input from the research community.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Tokamak Experimental Research	**47,050**	**49,519**	**48,406**

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 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 have increased their efforts on joint experiments with other major facilities in Europe and Japan in support of ITER-relevant physics issues.

Both DIII-D and Alcator C-Mod will focus on using their flexible plasma shaping and dynamic control capabilities to attain good confinement and stability by controlling the distribution of current in the plasma with electromagnetic wave current drive and the interface between the plasma edge and the material walls of the confinement vessel by means of a "magnetic divertor." Achieving high performance regimes for longer pulse duration, approaching the steady state, will require simultaneous advances in all of the scientific issues listed above.

▪ **DIII-D Research**	**24,420**	**25,538**	**24,926**

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 a 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—energy transport, stability, plasma-wave interactions, and boundary physics, and various thrust areas that integrate across topical areas to support the goal of achieving a burning plasma. The level of effort for most physics research topics in FY 2005 decreases from FY 2004, but a larger fraction of effort will support burning plasma physics, specifically for ITER. 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 ("wind tunnel") techniques.

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. In particular, the experimental program will aim at accomplishing the following related research goal in FY 2005: 1) demonstrate the technical benefits of operating plasmas with a normalized beta (a measure of plasma pressure) value above the "standard" value, made possible by feedback control of new internal wall stabilization coils installed in FY 2003. The initial experiments in FY 2003 with these coils were promising, leading to the planning of experiments in FY 2004. These will be further expanded in 2005. 2) Extend the "Negative Central Shear" mode of operation to higher performance and long pulse plasmas using the 6 MW Ion Cyclotron Radio Frequency (ICRF) system, and the 6 MW Electron Cyclotron Heating (ECH) system. The refurbishment and commissioning of the ICRF system, that was built about 4 years ago, started in FY 2003, and it will be available for these experiments in FY 2005. 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 AT.

	FY 2003	FY 2004	FY 2005
▪ **Alcator C-Mod Research**..	**7,123**	**8,458**	**8,500**

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 a fusion plasma. In FY 2005, 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 ("wind tunnel") 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 beam enabled diagnostics will shed light on the physics of temperature and density profile pedestals, 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 2005. The new lower hybrid (microwave) current drive

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

system will be in operation, and experiments will continue using it for control of the current density profile.

	FY 2003	FY 2004	FY 2005
▪ **International Collaborations**...	**4,696**	**4,862**	**4,900**

In addition to their work on domestic experiments, scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad, 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 conducted outside the U.S.

International collaboration will continue on these unique facilities abroad. In FY 2005, an expansion on joint International Tokamak Physics Activity (ITPA) with Japan, Europe, and Russia will enhance collaboration on physics issues related to tokamak burning plasmas. In FY 2005, 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 cited in the Science Subprogram description.

	FY 2003	FY 2004	FY 2005
▪ **Experimental Plasma Research (Tokamaks)**........................	**7,009**	**6,570**	**6,500**

Funding provided in this category, for FY 2005, will continue to support research on innovative tokamak experiments at universities and the development of diagnostic instruments.

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 a 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.

Support of the development of unique measurement capabilities (diagnostic systems) that provide an understanding of the plasma behavior in fusion research devices will continue at a number of institutions. This research provides the necessary information for analysis codes and theoretical interpretation. Some key areas of diagnostic research include the development of: (1) techniques to measure the cause of energy and particle loss from the core to the edge of magnetically confined plasmas, including techniques aimed at understanding how barriers to heat loss can be formed in plasmas; (2) methods to measure the production, movement, and loss/retention of the particles that are needed to ignite and sustain a burning plasma; and (3) new approaches that are required to measure plasma parameters in alternate magnetic configurations, which add unique constraints due to magnetic field configuration and strength, and limited lines of sight into the plasma. The requested funding level in FY 2005 supports research that will enhance our understanding of critical plasma phenomena and the means of affecting these phenomena to improve energy and

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

particle confinement in tokamaks and innovative confinement machines. The funding will also support development of diagnostic systems related to the processes associated with burning plasmas, on U.S. and foreign facilities. Currently supported programs will be peer reviewed prior to awarding FY 2005 funds.

	FY 2003	FY 2004	FY 2005
▪ **Other**	**3,802**	**4,091**	**3,580**

Funding for educational activities in FY 2005 will support research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, and outreach efforts related to fusion science and enabling R&D.

	FY 2003	FY 2004	FY 2005
Alternative Concept Experimental Research	**52,423**	**54,122**	**55,279**

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 scientific user facility. The Madison Symmetric Torus (MST) is at an intermediate stage of development between a small-scale experiment and a major facility.

	FY 2003	FY 2004	FY 2005
▪ **NSTX Research**	**13,761**	**16,251**	**16,300**

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 self-driven current fraction exist simultaneously in the presence of a nearby conducting wall bounding the plasma. If these predictions are verified in detail, it would indicate that spherical 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, as are all high beta plasmas, is uniquely characterized by high velocity fast ions and with a large radius of gyration relative to plasma size that could potentially lead to new plasma behaviors of interest. In FY 2005, funding will allow the NSTX national team to carry out research in the areas of high-pressure stability, short wavelength turbulence, wave-particle interactions, boundary physics, and integrated operating scenarios. Several new diagnostics and control upgrades will become operational in FY 2005. Using these new diagnostics and control system enhancements, NSTX team members plan to produce and characterize plasmas near theoretically predicted limits. They will also measure short wavelength turbulence in the plasma core in a range of plasma conditions and explore its relationship to electron thermal transport. Building on experiments carried out in FY 2004, they will demonstrate full non-inductive current drive using combinations of radio frequency waves, neutral beam injection, and pressure driven

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

currents. Further, NSTX researchers plan to characterize heat and particle fluxes in the plasma edge and explore techniques for handling the high fluxes that are produced in high performance plasmas. Finally, they will begin to explore integrated scenarios to achieve high plasma pressure and good energy confinement efficiency for pulse lengths much longer than the energy replacement time. Comparison of all these experimental results with theory will contribute to the scientific understanding of these effects needed to make a preliminary assessment of the attractiveness of the spherical torus concept in late 2006.

	FY 2003	FY 2004	FY 2005
▪ **Experimental Plasma Research (Alternatives)**	**16,910**	**18,049**	**18,100**

With the emphasis in developing the fundamental understanding of the plasma science that underpins innovative fusion concepts, this research element is a broad-based research activity, conducted in twenty five 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 meritoriously high performance is maintained.

Other current projects in the balance of the magnetic alternate program include fundamental investigations into concepts such as, advanced stellarator configurations, advanced spherical torus, the levitated dipole, field-reversed configurations (FRC), spheromaks, and magnetized target fusion.

As examples of the research being pursued in these experiments:

- Research in advanced stellarators, such as the Helically Symmetric Torus at 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 target by FY05 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

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

conventional Magnetic Fusion Energy (MFE), but using drivers considerably less powerful and cheaper than Inertial Fusion Energy (IFE). The main experimental objectives by FY 2005 are to produce magnetized plasma with three times the density and to begin exploring the problem of translating 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.

- **Inertial Fusion Energy/High Energy Density Physics**......... **12,753** **13,877** **13,900**

  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 (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. The research activities in IFE will be redirected to encompass the emphases of a national roadmap in High Energy Density Physics currently being developed by an interagency task force jointly by NSF, DOE, NASA and NIST, following the recommendations of the two NRC reports "Frontiers in High Energy Density Physics" and "Connecting Quarks to the Cosmos." Most high energy density conditions are produced through the use of high power lasers, ion beams, or convergence of high density plasma jets. The impact of heavy ion beams with a metallic holhraum 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) which 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. The beam science program will become part of a more broadly based high energy density science program. This high energy density plasma physics program is a new and exciting area that we will begin to fund in FY 2005. This will require modifications to the existing IFE program, but offers attractive research opportunities in the future. Another exciting development in HEDP in recent years is the science of ultra-intense ultra-fast lasers and its applications to create states of high energy densities. A phenomenon receiving world-wide scientific attention is fast ignition, in which a petawatt laser is used to heat and possibly ignite a fusionable capsule that has been compressed by another slower laser. We are beginning to explore the physics of thermal transport under these conditions.

- **Madison Symmetrical Torus**.. **5,189** **5,174** **6,200**

  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,

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

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 and FY 2004 will enable in FY 2005 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 2005 will be to measure the improved confinement and sustainment in MST.

	FY 2003	FY 2004	FY 2005
▪ **National Compact Stellarator Experiment (NCSX)**	**3,810**	**771**	**779**

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 and ORNL are the participants in NCSX Research that maintains U.S. contact with major stellarator experiments in Germany, Japan and Spain. The over-all objective of this work is to keep planning for NCSX research abreast of developments in stellarator research both domestically and internationally, during the fabrication phase of NCSX.

	FY 2003	FY 2004	FY 2005
Theory	**24,478**	**25,228**	**25,340**

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 a multidisciplinary teams while those at universities generally support smaller, innovative experiments or work on more fundamental problems in plasma physics.

The theory program is composed of 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.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
SciDAC	**3,256**	**3,320**	**3,300**

An important element is the FES portion of the Office of Science's Scientific Discovery through Advanced Computing (SciDAC) program. Major scientific challenges exist in many areas of plasma and fusion science that can best be addressed through advances in scientific supercomputing. In FY 2004, the FES SciDAC projects are being re-competed. The selected projects will be focused on providing a fundamental understanding of plasma science issues important to a burning plasma, and laying the groundwork for the fusion simulation project. The new projects will continue to involve collaborations among physicists, applied mathematicians and computer scientists.

In FY 2005, the computation program will continue to emphasize advanced computing and will make use of rapid developments in computer hardware to attack complex problems involving a large range of scales in time and space, 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 computers in the past, but advancements in computation are allowing a new look at problems that once seemed almost intractable. The objective of the advanced computing activities, including the SciDAC program, is to promote the use of modern computer languages and advanced computing techniques to bring about a qualitative improvement in the development of models of plasma behavior. This will ensure that advanced modeling tools are available to support the preparations for a burning plasma experiment, a set of innovative national experiments, and fruitful collaboration on major international facilities.

General Plasma Science	**8,991**	**11,725**	**11,700**

The general plasma science program is directed toward basic plasma science and engineering research. This research strengthens the fundamental underpinnings of the discipline of plasma physics that makes contributions in many basic and applied physics areas. Principal investigators at universities, laboratories and private industry carry out the research. A critically important element is the education of plasma physicists. Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Junior Faculty in Plasma Physics Development program and the basic and applied plasma physics program at DOE laboratories. In FY 2005, the program will continue to fund proposals that have been peer reviewed. Funding will also continue for the *"Centers of Excellence in Fusion Science"* program that was started in FY 2004, supporting one or two centers. Basic plasma physics user facilities will be supported at both universities and laboratories, cost sharing with NSF where appropriate. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases. The Office of Fusion Energy Sciences will continue to share the cost of funding the multi-institutional plasma physics frontier science center funded by NSF in FY 2003. In FY 2004 and FY 2005, the Department is planning to spend just over $2,100,000 for the work being done at these centers.

SBIR/STTR	**0**	**6,746**	**6,790**

FY 2003 excludes $5,837,000 and $350,000 that was transferred to SBIR and STTR programs, respectively. The FY 2004 and FY 2005 amounts are the estimated requirements for the continuation of these programs.

Total, Science	**136,198**	**150,660**	**150,815**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Tokamak Experimental Research	
▪ The DIII-D decrease reflects the decrease in research efforts that accompanies the reduction in experimental operations from 18 weeks to 14 weeks.	-612
▪ The Alcator C-Mod research effort is essentially the same in FY 2005 as in FY 2004. The level of scientific analysis is maintained despite the reduction in experimental operations from 18 weeks to 14 weeks.	+42
▪ Funding for International Collaboration is increased to support mutually beneficial work on unique international facilities.	+38
▪ The Experimental Plasma Research (Tokamaks) funding is reduced slightly to support higher priority research efforts elsewhere in the program.	-70
▪ The funding in the "Other" category reflects the completion of an Intergovernmental Personnel Act assignment and a shift in funding for higher priority activities in other parts of the program.	-511
Total, Tokamak Experimental Research	**-1,113**
Alternate Concept Experimental Research	
▪ A small increase in NSTX research funding will support increased analysis of experimental data.	+49
▪ The small increase in funding for Experimental Plasma Research (ALT) will be used to partially fund the increased effort directed at understanding the physics of moving metal walls in stabilizing plasmas.	+51
▪ The small increase in IFE funding will provide a slight increase in effort as the program shifts emphasis to High Energy Density Physics research.	+23
▪ The increased MST Research funding will allow the experiment to initiate systematic research on the merits of various techniques in current drives and heating in the MST's reversed field pinch plasma in FY 2005, supported with the appropriate diagnostics, as recommended by competitive peer review.	+1,026
▪ Funding for NCSX research is increased slightly to provide additional support in preparation for operation.	+8
Total, Alternative Concept Experimental Research	**+1,157**
Theory	
▪ Funding for Theory is increased to support additional students.	+112
SciDAC	
▪ Funding is decreased to support higher priority research elsewhere in the program.	-20
General Plasma Science	
▪ Funding is decreased to support higher priority research elsewhere in the program.	-25

	FY 2005 vs. FY 2004 ($000)
SBIR/STTR	
▪ Support for SBIR/STTR is provided at the mandated level.	+44
Total Funding Change, Science	**+155**

Facility Operations

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Facility Operations					
DIII-D	27,474	30,427	29,074	-1,353	-4.4%
Alcator C-Mod	12,039	13,764	13,000	-764	-5.6%
NSTX	16,367	18,427	17,300	-1,127	-6.1%
NCSX	7,897	15,921	15,921	0	0.0%
ITER	0	3,000	7,000	+4,000	+133.3%
GPP/GPE/Other	2,421	2,993	3,200	+207	+6.9%
Total, Facility Operations	66,198	84,532	85,495	+963	+1.1%

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 users. In addition, fabrication of new projects and upgrades of major fusion facilities will be accomplished in accordance with highest standards and with minimum deviation from approved cost and schedule baselines.

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 sub-program provides for the construction of new facilities such as NCSX, and for participation in ITER.

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 user facilities enable U.S. scientists from universities, laboratories, and industry, as well as visiting foreign scientists, to conduct world-class research funded in the Science and Technology subprograms. The facilities consist of magnetic plasma confinement devices, plasma heating and current drive systems, diagnostics and instrumentation, experimental areas, computing and computer networking facilities, and other auxiliary systems. The Facility Operations subprogram provides funds for operating and maintenance personnel, electric power, expendable supplies, replacement parts, system modifications and facility enhancements. In FY 2005, funding is requested to operate the major fusion facilities for 14 weeks.

Funding is also provided for the continuation of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment project at PPPL. In FY 2005, the project will be in its third year, following the FY 2003 project start, and FY 2004 funding will support the final design activities and initial hardware procurements.

Funding is also provided for ITER transitional activities, in which U.S. scientists and engineers will be involved in various technical activities that support both ITER negotiations for a construction project as well as preparations for eventual project construction. These activities will be managed from a U.S. ITER Project Office, to be selected in FY 2004, in preparation for ITER construction starting in FY 2006.

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 third of four years to support the move of ORNL fusion personnel and facilities to a new location at ORNL.

Facility Operations Accomplishments

In FY 2003, 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:

- Princeton Plasma Physics Laboratory (PPPL) has awarded contracts, for $600,000 each, to two industrial teams for manufacturing development of the National Compact Stellarator Experiment (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 is to develop the manufacturing processes for the forms through fabrication of full-scale prototypes. The project plans to award a follow-on contract for the production order to one of these teams next year.

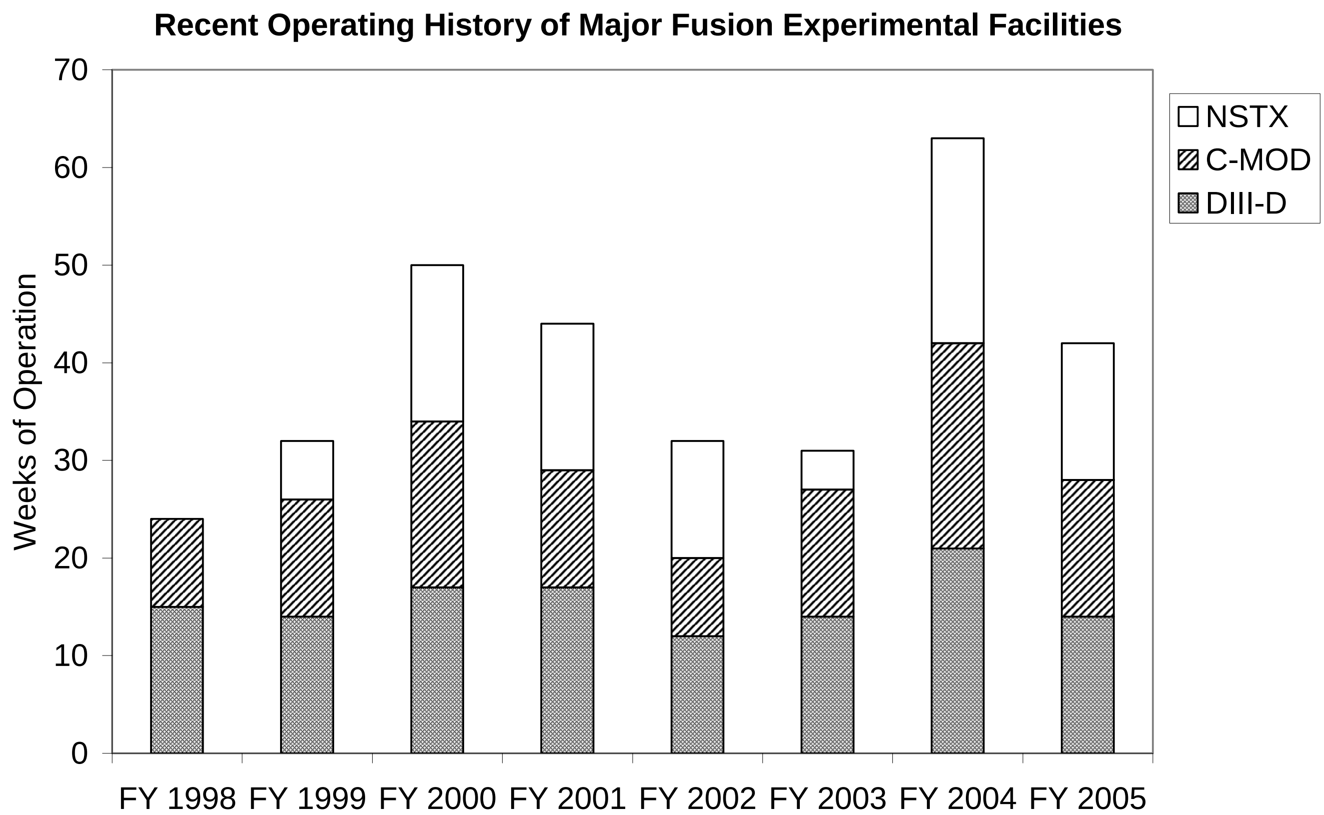
  In addition, PPPL has awarded contracts, for $400,000 each, to two industrial suppliers for manufacturing development of the NCSX vacuum vessel. The vacuum vessel is a highly shaped structure with stringent requirements on vacuum quality and magnetic permeability. The purpose of these contracts is to 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 plans to award a follow-on contract for the production order to one of these suppliers next year.

The table and chart below summarizes the longer-term history of operation of the major fusion facilities.

Weeks of Fusion Facility Operation

(Weeks of Operations)

	FY 2003 Results	FY 2004 Target	FY 2005 Target
DIII-D	14	18	14
Alcator C-Mod............	13	18	14
NSTX	4	18	14
Total...........................	31	54	42



The specific FY 2005 goal leading toward the long-term performance measures for Fusion Energy Sciences is:

NCSX Fabrication

- Award, through a competitive process, production contracts for the following major NCSX systems: Modular Coil Winding Forms and Conductor, and Vacuum Vessel. Complete winding of the first modular coil.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
DIII-D..	**27,474**	**30,427**	**29,074**

Provide support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. In FY 2005, these funds support 14 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 sequentially upgrading the oldest gyrotrons used in the electron cyclotron heating system to provide a uniform 10 second pulse length capability.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Alcator C-Mod	**12,039**	**13,764**	**13,000**

Provide support for operation, maintenance, and improvement of the Alcator C-Mod facility and its auxiliary systems. In FY 2005, these funds support 14 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)	**16,367**	**18,427**	**17,300**

Provide support for operation, maintenance, and minor upgrades, such as error field coils and antenna upgrades. In FY 2005, these funds support 14 weeks of single shift plasma operation to carry out the research described in the Science subprogram.

National Compact Stellarator Experiment (NCSX)	**7,897**	**15,921**	**15,921**

Funding in the amount of $15,921,000 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 total estimated cost (TEC) of NCSX is in the range of $87,000,000-$89,000,000, with completion expected to be in the late FY 2008/early FY 2009 time frame. After the preliminary design is completed at the end of CY 2003, the cost and schedule baseline for this project will be established in early CY 2004.

ITER	**0**	**3,000**	**7,000**

Funding in the amount of $7,000,000 is provided to continue with ITER transitional activities such as safety, licensing, project management, preparation of final specifications and system integration. U.S. personnel will participate in these activities in preparation for eventual project construction. In addition, preparations will be made to qualify U.S. vendors to supply hardware and components for the project when the need arises.

General Plant Projects/General Purpose Equipment/Other	**2,421**	**2,993**	**3,200**

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	**66,198**	**84,532**	**85,495**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
DIII-D	
▪ Funding is reduced to support higher priority activities such as ITER preparation. The number of weeks of operation, 14, is a decrease of 4 weeks from the FY 2004 planned operation.	-1,353
Alcator C-Mod	
▪ Funding is reduced to support higher priority activities such as ITER preparation. The number of weeks of operation, 14, is a decrease of 4 weeks from the FY 2004 planned operation.	-764
NSTX	
▪ Funding is reduced to support higher priority activities such as ITER preparation. The number of weeks of operation, 14, is a decrease of 4 weeks from the FY 2004 planned operation.	-1,127
ITER	
▪ Funding for direct ITER support is increased to $7M to support additional U.S. preparation for ITER construction, primarily for sending additional U.S. personnel to the interim ITER team, for broader qualification of potential U.S. suppliers of hardware, for expanded R&D preparations, and expanded project preparations in the United States.	+4,000
GPP/GPE/Other	
▪ Funding is increased to provide necessary improvements in the PPPL infrastructure and to move ORNL fusion personnel and facilities to a new location at ORNL.	+207
Total Funding Change, Facility Operations	**+963**

Technology

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Technology					
Engineering Research	30,558	19,763	20,421	+658	+3.3%
Materials Research	7,741	7,600	7,379	-221	-2.9%
Total, Technology	38,299	27,363	27,800	+437	+1.6%

Description

The mission of the Technology 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 technology 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 Technology 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 advances in fusion technology 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 technology R&D for magnetic fusion systems as well as international collaborations that support the mission and objectives of the Fusion Energy Sciences 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 burning plasma experiments, especially ITER. Technology 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 United States 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 of 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 to fusion.

The Materials Research element focuses on the key science issues of materials for practical and environmentally attractive uses in fusion research and future facilities. This element continues to strengthen its modeling and theory activities, which makes it more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded by the Office of Basic Energy Sciences and other government-sponsored programs, as well as more capable of contributing to broader materials research in niche areas of materials science. Through a variety of cost-shared international collaborations, this element conducts irradiation testing of candidate fusion materials in the simulated fusion environments of fission reactors to provide data for validating and guiding the development of models for the effects of neutron bombardment on the microstructural evolution, damage accumulation, and property changes of fusion materials. This collaborative work supports both nearer-term fusion devices, such as burning plasma experiments, as well as other future fusion experimental facilities. In addition, such activities support the long-term goal of developing experimentally validated predictive and analytical tools that can lead the way to nanoscale design of advanced fusion materials with superior performance and lifetime.

Management of the diverse and distributed collection of technology R&D activities continues to be accomplished through a Virtual Laboratory for Technology, with community-based coordination and communication of plans, progress, and results.

Technology Accomplishments

A number of technological advances were made in FY 2003. Examples include:

- Los Alamos National Laboratory (LANL) completed all characterization and stabilization activities of the Tritium Systems Test Assembly (TSTA) Facility and as per the Memorandum of Agreement signed by the Office of Science, Office of Environmental Management (EM), and the Office of Defense Programs in the National Nuclear Security Administration, overall management and financial responsibilities were transferred to EM on August 1. EM will now be responsible for conducting the surveillance and maintenance and eventually, the decontamination and decommissioning.

  The TSTA Facility was built to develop and demonstrate the deuterium-tritium fuel cycle technology for next step fusion devices as well as conduct tritium testing of different fusion components and systems. TSTA successfully and safely demonstrated the capability of processing over 1 kilogram of tritium per day which is approximately one tenth the rate of the ITER Tritium Plant. The data base from its operation was critical to the design of the ITER Tritium Plant.

- The Oak Ridge National Laboratory has completed the installation and testing of the Joint European Torus (JET) high power prototype antenna. This new antenna should enhance the heating of the plasma during experiments. The JET antenna was designed, fabricated and tested on schedule. As planned, the results of this collaborative program were used by JET scientists to design their production antenna.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Engineering Research	**30,558**	**19,763**	**20,421**
▪ **Plasma Technology**	**13,517**	**13,635**	**17,840**

Engineering research efforts will continue on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for use and testing in ITER. Nearer-term experiment support efforts will be oriented toward plasma facing components and plasma heating and fueling technologies. Additional funds and redirected effort will be provided for technology R&D supporting U.S. responsibilities for ITER procurement packages. Fabrication started in FY 2004 of a 110 gigahertz, 1.5 megawatt industrial prototype gyrotron microwave generator that will be the most powerful of its kind for electron cyclotron heating of plasmas. Completion of the prototype and the beginning of testing will be accomplished in FY 2005. Testing will also begin in FY 2005 of a high speed, compact vertical pellet injector system relevant to the fueling requirements of burning plasma experiments. Based on the experimental research and initial designs during FY 2004 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 design of a lithium module for future deployment in NSTX will be initiated in FY 2005. During FY 2005, studies will continue in the Plasma Interactive Surface Component Experimental Station (PISCES) at the University of California at San Diego, and the Tritium Plasma Experiment at INEEL, of tungsten-carbon-beryllium mixed materials layer formation and redeposition with attached hydrogen isotopes, and results will be applied to evaluate tritium accumulation in ITER plasma facing components. Following initiation in FY 2004 of full-scale tritium operations in the Safety and Tritium Applied Research (STAR) facility at INEEL, preliminary results will be obtained in FY 2005 from material science experiments in STAR performed 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 ITER nuclear and safety design and analysis, as well as for research on safety, power extraction and tritium technologies for blanket concepts that will be tested in. Funds will be provided to continue superconducting magnet research, 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.

▪ **Fusion Technology**	**11,023**	**3,038**	**0**

Following close out of Fusion Technology efforts in FY 2004 in order to focus on research relevant to ITER, no activities are planned for FY 2005**.**

▪ **Advanced Design**	**6,018**	**3,090**	**2,581**

Funding for this effort will 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.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Materials Research	**7,741**	**7,600**	**7,379**

Materials Research remains a key element in establishing the scientific foundations for safe and environmentally attractive uses of fusion. Through a wide variety of modeling and experimental activities aimed at the science of materials behavior in fusion environments, research on candidate materials for the structural elements of fusion chambers will continue. Priorities for this work are based on the innovative approaches to evaluating materials and improved models of materials behavior that were adopted from recommendations of earlier FESAC reviews. Building on successes during FY 2004 in the first phase of a cost-shared collaborative program with Japan for irradiation testing of fusion materials in a U.S. fission reactor (High Flux Isotope Reactor), which provides key data to evaluate the effects of neutron bombardment on the microstructural evolution, damage accumulation, and property changes of fusion materials that could be used in next step devices, preliminary investigations will be completed in FY 2005 of nanocomposited ferritic steels with alloy compositions and fabrication techniques designed through nanoscience methods to operate at high temperatures without significant deformation by creep mechanisms. Investigations during FY 2005 will focus on thermodynamics, interface structure, irradiation stability, and helium trapping efficiency of the nanometer sized yttrium-titanium based oxide dispersoids in nano-composited ferritic alloys. In addition, an assessment will be made during FY 2005 of the effects of helium additions on the low temperature radiation embrittlement of ferritic steels.

	FY 2003	FY 2004	FY 2005
Total, Technology	**38,299**	**27,363**	**27,800**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Engineering Research	
Plasma Technology	
▪ Additional funds will be provided for ITER nuclear and safety design and analysis for research on power handling and tritium technology concepts that will be tested in ITER for extracting heat from burning plasmas and for producing sufficient amounts of tritium to achieve self-sufficiency and for technology R&D supporting U.S. responsibilities for ITER procurement packages.	+4,205
Fusion Technology	
▪ Fusion Technology, which generally consists of longer range technology activities, will be closed out in FY 2004 and no activities are planned in FY 2005. This action will provide additional resources for technology development that enables existing and near term facilities like ITER to achieve their full performance capability.	-3,038

	FY 2005 vs. FY 2004 ($000)
Advanced Design	
▪ Advanced Design funding is decreased due to the closeout of the next-step option.	-509
Total, Engineering Research	**+658**
Materials Research	
▪ Funding for research on vanadium alloys is reduced due to closeout of tasks that did not yield promising results.	-221
Total Funding Change, Technology	**+437**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Plant Projects	1,300	1,415	1,643	+228	+16.1%
Capital Equipment	12,448	20,206	19,998	-208	-1.0%
Total, Capital Operating Expenses	13,748	21,621	21,641	+20	+0.1%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2003	FY 2004	FY 2005	Accept-ance Date
Alcator C-Mod LH Modification	5,180	4,471	709	0	0	FY 2003
NCSX	87,000-89,000[a]	0	7,897	15,921	15,921	FY 2008-FY 2009
Total, Major Items of Equipment		4,471	8,606	15,921	15,921	

[a] The preliminary TEC increased from $69,000,000 to $73,500,000 with completion in FY 2007, based on the completed conceptual design activities that demonstrated more contingency funds were needed for fabricating the highest risk components. However, because of a delayed start (April 2003) of the project attributable to delayed FY 2003 Congressional appropriations, more detailed information on the design and cost of NCSX components/systems, recommendations from three different review committees and revised funding profile, the NCSX TEC is now expected to be in the range of $87,000,000-$89,000,000 with completion expected to be in the late FY 2008/early FY 2009 time frame. After preliminary design is completed at the end of CY 2003, the cost and schedule baseline for the NCSX project will be established in early CY 2004. The NCSX MIE project will be completed when first plasma is attained during cryogenic operation.

Safeguards and Security

Funding Profile by Subprogram

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Safeguards and Security					
Protective Forces	27,951	27,003	0	27,003	32,353
Security Systems	9,319	4,664	+809[a]	5,473	7,836
Information Security	5,266	970	+1,671[a]	2,641	2,794
Cyber Security	13,593	11,551	+2,066[ab]	13,617	15,823
Personnel Security	4,397	2,369	+2,615[a]	4,984	5,439
Material Control and Accountability	2,076	2,060	+478[a]	2,538	2,521
Program Management	4,275	3,270	+2,802[a]	6,072	6,549
Subtotal, Safeguards and Security	66,877	51,887	+10,441	62,328	73,315
Less Security Charge for Reimbursable Work	-5,605	-4,383	-1,215[a]	-5,598	-5,605
Total, Safeguards and Security	61,272[c]	47,504	+9,226	56,730	67,710

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.

[a] Includes $9,506,000 for the transfer in FY 2005 of the Pacific Northwest Site Office safeguards and security activities from the Office of Environmental Management, as follows: Security Systems ($809,000); Information Security ($1,671,000); Cyber Security ($2,346,000); Personnel Security ($2,615,000); Material Control and Accountability ($478,000); Program Management ($2,802,000); and Less Security Charge for Reimbursable Work ($-1,215,000).

[b] Excludes $280,274 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003.

[c] Excludes $286,748 rescinded in accordance with the Consolidated Appropriations Resolution, FY 2003. Includes $4,342,749 for the Emergency Wartime Supplemental Appropriations for FY 2003, $3,607,000 for the transfer of safeguards and security activities from Science Program Direction in FY 2004 and $9,494,000 for the transfer of the Pacific Northwest Site Office safeguards and security activities from the Office of Environmental Management in FY 2005.

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 (ISSM) strategy encompasses a graded approach that enables each facility to design its security protection program to meet the facility-specific threat scenario.

The following is a brief description of the types of activities performed:

Protective Forces

The Protective Forces activity provides for security guards or security police officers and equipment, training and maintenance needed to effectively carry out the protection tasks during normal and increased or emergency security conditions (SECON). This request is adequate for up to 60 days of heightened security at the SECON 2 level.

Security Systems

The Security Systems activity provides for equipment to protect vital security interests and government property per the local threat. Equipment and hardware include fences, barriers, lighting, sensors, entry control devices, etc.

Information Security

The Information Security activity ensures that materials and documents that may contain classified or “Official Use Only” (OUO) information are accurately and consistently identified; properly reviewed for content; appropriately marked and protected from unauthorized disclosure; and ultimately destroyed in an appropriate manner.

Cyber Security

The Cyber Security activity ensures that 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-site 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 2003	FY 2004	FY 2005
Ames Laboratory	**395**	**409**	**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. The increased funding for FY 2005 is primarily for cyber security. Reimbursable work is included in the numbers above; the amount for FY 2005 is $26,000.

Argonne National Laboratory	**7,680**	**7,651**	**9,784**

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. An increase in funding for FY 2005 will enable continued expansion of access control systems and improve the reliability of surveillance systems, cyber security, and foreign visit processing. Enhancements to the physical security systems will help reduce some of the reliance on protective force coverage. Increase also supports requirements of the revised Design Basis Threat (DBT). Reimbursable work is included in the numbers above; the amount for FY 2005 is $388,000.

Brookhaven National Laboratory	**10,929**	**10,756**	**11,342**

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 2005 is associated primarily with the cyber security risk management and self-assessment programs, and projected maintenance of elevated SECON levels. Reimbursable work is included in the numbers above; the amount for FY 2005 is $806,000.

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		
Fermi National Accelerator Laboratory	**2,805**	**2,837**	**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	**4,649**	**4,689**	**5,165**

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 increased funding for FY 2005 is primarily for projected maintenance of elevated SECON levels and enhanced cyber security. Reimbursable work is included in the numbers above; the amount for FY 2005 is $830,000.

Oak Ridge Institute for Science and Education	**1,250**	**1,254**	**1,410**

The Oak Ridge Institute for Science and Education (ORISE) Safeguards and Security program provides physical protection/protective force services by employing unarmed security officers. The facilities are designated as property protection areas for the purpose of protecting government owned assets. In addition to the government owned facilities and personal property, ORISE possesses small quantities of nuclear materials that must be protected. The increased funding for FY 2005 is primarily for enhanced cyber security and program management needs. Reimbursable work is included in the numbers above; the amount for FY 2005 is $319,000.

Oak Ridge National Laboratory	**9,433**	**6,894**	**8,713**

The Oak Ridge National Laboratory (ORNL) Safeguards and Security program includes security systems, information security, cyber security, personnel security, material control and accountability, and program management. Program planning functions at the Laboratory provide for short- and long-range strategic planning, and 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; for conducting recurring programmatic self-assessments; and for identifying, tracking, and obtaining closure on findings or deficiencies noted during inspections, surveys, or assessments of safeguards and security programs. The funding increase is primarily for cyber security to support monitoring and response for intrusions, malicious code and vulnerabilities; and for program management to provide training/professional development and to improve vulnerability assessments and radiological/toxicological sabotage assessments. Reimbursable work is included in the numbers above; the amount for FY 2005 is $1,945,000.

Oak Ridge Operations Office	**11,593**	**11,688**	**15,872**

The Oak Ridge Operations Office Safeguards and Security program provides for contractor protective forces for the Oak Ridge National Laboratory. This includes protection of a Category I special nuclear material facility, Building 3019 ($11,060,000), 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 ($454,000). The FY 2005

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

increase is for protective force requirements associated with projected maintenance of elevated SECON levels and requirements of the revised DBT.

Office of Scientific and Technical Information...............	**265**	**60**	**590**

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. Its safeguards and security funding priorities are to meet requirements of the revised DBT, for protective forces, security systems designed to protect information, and enhanced cyber security in FY 2005. The majority of the increase in FY 2005 is needed to implement the revised DBT. It will provide a main entrance security policy officer (1.5 Full Time Equivalent) at OSTI ($150,000) and the installation of badge readers, cameras, updated video surveillance, and vehicle barriers at OSTI ($180,000). In addition, it will provide additional funds needed to implement required cyber security enhancements ($200,000) to protect against intrusions and ensure reliability, integrity and confidentiality of the networks.

Pacific Northwest National Laboratory ……………...	**10,716**	**10,721**	**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. As part of the organizational restructuring of PNNL from an Environmental Management (EM) Site to an SC Site, a Pacific Northwest Site Office (PNSO) is being established. Funding for protective force operations remains the responsibility of EM. Projected increase for FY 2005 is primarily focused on personnel security. Reimbursable work is included in the numbers above; the amount for FY 2005 is $1,222,000.

Princeton Plasma Physics Laboratory	**3,489**	**1,855**	**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. The FY 2005 increase is for protective force requirements associated with projected maintenance of elevated SECON levels. Reimbursable work is included in the numbers above; the amount for FY 2005 is $54,000.

Stanford Linear Accelerator Center................................	**2,211**	**2,207**	**2,341**

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 2005 increase is for protective force requirements associated with projected maintenance of elevated SECON levels. Reimbursable work is included in the numbers above; the amount for FY 2005 is $15,000.

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		
Thomas Jefferson National Accelerator Facility	**1,132**	**972**	**1,174**

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 FY 2005 increase is for cyber security and protective force requirements associated with projected maintenance of elevated SECON levels.

	FY 2003	FY 2004	FY 2005
All Other	**330**	**335**	**337**

This funding provides for program management needs for SC and for the Presidential E-Gov initiative of SAFECOM.

	FY 2003	FY 2004	FY 2005
Subtotal, Safeguards and Security	**66,877**	**62,328**	**73,315**
Less Security Charge for Reimbursable Work	**-5,605**	**-5,598**	**-5,605**
Total, Safeguards and Security	**61,272**	**56,730**	**67,710**

Detailed Funding Schedule

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Ames Laboratory					
Protective Forces	143	143	157	+14	+9.8%
Security Systems	33	24	34	+10	+41.7%
Cyber Security	141	148	227	+79	+53.4%
Personnel Security	39	42	35	-7	-16.7%
Material Control and Accountability	7	7	8	+1	+14.3%
Program Management	32	45	44	-1	-2.2%
Total, Ames Laboratory	395	409	505	+96	+23.5%
Argonne National Laboratory					
Protective Forces	3,197	3,209	2,700	-509	-15.9%
Security Systems	422	455	2,155	+1,700	+373.6%
Information Security	299	211	294	+83	+39.3%
Cyber Security	1,775	1,744	2,012	+268	+15.4%
Personnel Security	960	904	1,067	+163	+18.0%
Material Control and Accountability	688	796	940	+144	+18.1%
Program Management	339	332	616	+284	+85.5%
Total, Argonne National Laboratory	7,680	7,651	9,784	+2,133	+27.9%
Brookhaven National Laboratory					
Protective Forces	6,706	6,146	6,739	+593	+9.6%
Security Systems	881	577	658	+81	+14.0%

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
Information Security	121	131	116	-15	-11.5%
Cyber Security	2,247	2,270	2,664	+394	+17.4%
Personnel Security	53	49	29	-20	-40.8%
Material Control and Accountability	320	742	522	-220	-29.6%
Program Management	601	841	614	-227	-27.0%
Total, Brookhaven National Laboratory	10,929	10,756	11,342	+586	+5.4%
Fermi National Accelerator Laboratory					
Protective Forces	1,538	1,700	1,656	-44	-2.6%
Security Systems	456	246	320	+74	+30.1%
Cyber Security	640	780	910	+130	+16.7%
Material Control and Accountability	69	49	70	+21	+42.9%
Program Management	102	62	111	+49	+79.0%
Total, Fermi National Accelerator Laboratory	2,805	2,837	3,067	+230	+8.1%
Lawrence Berkeley National Laboratory					
Protective Forces	1,430	1,392	1,578	+186	+13.4%
Security Systems	860	942	790	-152	-16.1%
Cyber Security	1,915	1,955	2,339	+384	+19.6%
Personnel Security	11	11	9	-2	-18.2%
Material Control and Accountability	19	38	14	-24	-63.2%
Program Management	414	351	435	+84	+23.9%
Total, Lawrence Berkeley National Laboratory	4,649	4,689	5,165	+476	+10.2%
Oak Ridge Institute for Science and Education					
Protective Forces	279	288	297	+9	+3.1%
Security Systems	94	100	71	-29	-29.0%
Information Security	123	139	108	-31	-22.3%
Cyber Security	374	420	541	+121	+28.8%
Personnel Security	107	108	112	+4	+3.7%
Program Management	273	199	281	+82	+41.2%
Total, Oak Ridge Institute for Science and Education	1,250	1,254	1,410	+156	+12.4%
Oak Ridge National Laboratory					
Security Systems	3,676	1,865	2,466	+601	+32.2%
Information Security	378	392	411	+19	+4.8%
Cyber Security	2,580	1,978	2,657	+679	+34.3%
Personnel Security	1,087	972	1,095	+123	+12.7%
Material Control and Accountability	486	428	458	+30	+7.0%
Program Management	1,226	1,259	1,626	+367	+29.2%
Total, Oak Ridge National Laboratory	9,433	6,894	8,713	+1,819	+26.4%

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Oak Ridge Operations Office					
Protective Forces	11,097	11,174	15,418	+4,244	+38.0%
Security Systems	63	134	68	-66	-49.3%
Information Security	129	97	99	+2	+2.1%
Personnel Security	304	283	287	+4	+1.4%
Total, Oak Ridge Operations Office	11,593	11,688	15,872	+4,184	+35.8%
Office of Scientific and Technical Information					
Protective Forces	0	25	175	+150	+600.0%
Security Systems	90	35	215	+180	+514.3%
Cyber Security	175	0	200	+200	N/A
Total, Office of Scientific and Technical Information	265	60	590	+530	+883.3%
Pacific Northwest National Laboratory					
Security Systems	879	809	886	+77	+9.5%
Information Security	4,216	1,671	1,766	+95	+5.7%
Cyber Security	2,290	2,346	2,404	+58	+2.5%
Personnel Security	1,836	2,615	2,805	+190	+7.3%
Material Control and Accountability	487	478	509	+31	+6.5%
Program Management	1,008	2,802	2,700	-102	-3.6%
Total, Pacific Northwest National Laboratory	10,716	10,721	11,070	+349	+3.3%
Princeton Plasma Physics Laboratory					
Protective Forces	1,209	905	1,260	+355	+39.2%
Security Systems	1,633	113	33	-80	-70.8%
Cyber Security	490	775	612	-163	-21.0%
Program Management	157	62	40	-22	-35.5%
Total, Princeton Plasma Physics Laboratory	3,489	1,855	1,945	+90	+4.9%
Stanford Linear Accelerator Center					
Protective Forces	1,781	1,606	1,829	+223	+13.9%
Security Systems	26	0	0	0	0.0%
Cyber Security	404	601	512	-89	-14.8%
Total, Stanford Linear Accelerator Center	2,211	2,207	2,341	+134	+6.1%
Thomas Jefferson National Accelerator Facility					
Protective Forces	571	415	544	+129	+31.1%
Security Systems	206	173	140	-33	-19.1%
Cyber Security	270	308	453	+145	+47.1%

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Program Management	85	76	37	-39	-51.3%
Total, Thomas Jefferson National Accelerator Facility	1,132	972	1,174	+202	+20.8%
All Other					
Cyber Security	292	292	292	0	0.0%
Program Management	38	43	45	+2	+4.7%
Total, All Other	330	335	337	+2	+0.6%
Subtotal, Safeguards and Security	66,877	62,328	73,315	+10,987	+17.6%
Less Security Charge for Reimbursable Work	-5,605	-5,598	-5,605	-7	-0.1%
Total, Safeguards and Security	61,272	56,730	67,710	+10,980	+19.3%

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Ames Laboratory	
The increased funding is primarily in cyber security. Increases are also provided in the areas of protective forces and security systems with minor adjustments in the other elements.	+96
Argonne National Laboratory	
Increases mainly are associated with security systems requirements, cyber security, personnel security needs, and for program management. These increases will: enable continued expansion of access control systems, network monitoring and security for wireless connections; improve the reliability of surveillance systems to help meet the revised DBT requirements; support revisions to vulnerability assessments in support of revised DBT; and support full implementation of a compliant foreign visits and assignments program.	+2,133
Brookhaven National Laboratory	
The increase is associated primarily with the cyber security risk management and self-assessment programs, and projected maintenance of elevated SECON levels. Adjustments to other elements are made to reflect the latest priorities.	+586
Fermi National Accelerator Laboratory	
Limited funding increases are being applied to the security systems and cyber security activities.	+230

	FY 2005 vs. FY 2004 ($000)
Lawrence Berkeley National Laboratory	
The increased funding is primarily for cyber security. Also, projected maintenance of elevated SECON levels result in increased protective force funding.	+476
Oak Ridge Institute for Science and Education	
The increased funding is primarily for cyber security. The enhancements are needed to address identified vulnerabilities to sensitive information.	+156
Oak Ridge National Laboratory	
The funding increase is primarily for security systems to replace limited critical system components or equipment as necessary and to meet the revised DBT requirements; cyber security to support monitoring and response for intrusions, malicious code and vulnerabilities; and for program management to provide training/professional development and to improve vulnerability assessments and radiological/toxicological sabotage assessments..	+1,819
Oak Ridge Operations Office	
The funding increase is primarily for protective force requirements associated with Building 3019 and the Spallation Neutron Source facility. Consideration is also given to projected maintenance of elevated SECON levels and to meet requirements of the DBT.	+4,184
Office of Scientific and Technical Information	
The funding increase is reflected in cyber security for required enhancements primarily for classified archived data and in security systems and protective forces for requirements of the revised DBT.	+530
Pacific Northwest National Laboratory	
Increases are associated primarily with cyber security, information security and personnel security. The increases will enable continued self-assessment activities, full implementation of ISSM, protection of national security and nonproliferation classified information and provide adequate support for the Foreign Visits and Assignments program.	+349
Princeton Plasma Physics Laboratory	
The increase is for protective force requirements associated with projected maintenance of elevated SECON levels, partially offset by reductions to the other elements.	+90

	FY 2005 vs. FY 2004 ($000)
Stanford Linear Accelerator Center	
The increase is for protective force requirements associated with projected maintenance of elevated SECON levels, partially offset by a reduction in cyber security.	+134
Thomas Jefferson National Accelerator Facility	
The increase is for the cyber security program and protective force requirements associated with projected maintenance of elevated SECON levels. Adjustments to the other elements are made to reflect the latest priorities	+202
All Other	
Minor adjustment for program management needs	+2
Subtotal Funding Change, Safeguards and Security	+10,987
Less Security Charge for Reimbursable Work	-7
Total Funding Change, Safeguards and Security	**+10,980**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
General Plant Projects	1,600	0	0	0	0.0%
Capital Equipment	1,297	102	104	+2	+2.0%
Total, Capital Operating Expenses	2,897	102	104	+2	+2.0%

Science Program Direction

Funding Profile by Subprogram

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Science Program Direction					
Program Direction	61,508	58,217	+8,354[a]	66,571	65,927
Field Operations	75,917	80,102	+5,908[b]	86,010	89,341
Office of Scientific and Technical Information	0	7,714	-7,714[c]	0	0
Energy Research Analysis	0	1,020	-1,020[d]	0	0
Subtotal, Science Program Direction	137,425	147,053	+5,528	152,581	155,268
Less Use of Prior Year Balances	0	-358	0	-358	0
Total, Science Program Direction	137,425[e]	146,695	+5,528	152,223	155,268

[a] Excludes $327,050 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003. Includes $1,013,000 for the alignment of program planning and analysis activities and $7,668,000 for the alignment of Office of Scientific and Technical Information (OSTI) activities to headquarters.

[b] Excludes $484,076 for a rescission in accordance with the Consolidated Appropriations Act, 2004 and $944,000 for a transfer in FY 2005 to Nuclear Energy (NE) of 7 FTEs at Oak Ridge Operations Office (ORO) associated with Uranium management activities. Includes $6,236,000 (adjusted for rescission) for the transfer in FY 2005 of 46 FTEs from the Office of Environmental Management (EM) to the Office of Science (SC) for the establishment of the Pacific Northwest Site Office (PNSO) and $1,100,000 for the transfer in FY 2005 of 10 FTEs from the National Nuclear Security Administration (NNSA) to SC for site office activities previously under Oakland Operations Office (OAK).

[c] Excludes $46,000 for a rescission in accordance with the Consolidated Appropriations Act, 2004 and $7,668,000 for the alignment of OSTI activities to headquarters.

[d] Excludes $7,000 for a rescission in accordance with the Consolidated Appropriations Act, 2004 and $1,013,000 for the alignment of program planning and analysis activities to headquarters.

[e] Excludes $881,185 rescinded in accordance with the Consolidated Appropriations Resolution, FY 2003, $820,000 for distribution of a general reduction, $3,607,000 for the transfer in FY 2004 of safeguards and security activities to Science Safeguards and Security and $911,000 for a transfer in FY 2005 to NE of 7 FTEs at ORO associated with Uranium management activities. Includes $5,942,000 for the transfer in FY 2005 of 46 FTEs from EM to SC for the establishment of PNSO and $1,050,000 for the transfer in FY 2005 of 10 FTEs from NNSA to SC for site office activities previously under OAK.

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Staffing (FTEs)					
Headquarters (FTEs)	356	284	+72	356	356
Field Operations (FTEs)	658	609	+49	658	658
Office of Scientific and Technical Information (FTEs)	0	72	-72	0	0
Total, FTEs	1,014	965	+49	1,014	1,014

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 and science-related research disciplines, diversely supported through research programs, projects, and facilities under the Office of Science's (SC) 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 directing, administering, and supporting the broad spectrum of SC scientific disciplines. This subprogram also includes program planning and analysis activities which provide 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 the scientific and technical information of the Department of Energy (DOE) for use by the DOE, the scientific community, academia, U.S. industry, and the public to expand the knowledge base of science and technology. The Field Operations subprogram is the centralized funding source for the Federal workforce within the field complex responsible for providing best-in-class business, administrative, and specialized technical support across the entire SC enterprise and to other DOE programs.

Overview

Significant Program Shifts

- Both OSTI and program planning and analysis activities are reflected in the Program Direction subprogram because of their organizational reference and relevance to other SC Headquarters offices.
- SC is proposing a restructuring and reengineering project, OneSC, and anticipates that this effort will result in functional consolidations, process reengineering and elimination of skills imbalances throughout the SC complex. Full implementation of this realignment is expected to begin in FY 2004. Functions targeted for workforce reductions will also be identified. This project reflects the

changes envisioned by the President's Management Agenda (PMA) and directly supports the PMA objective to manage government programs more economically and effectively.

- Beginning in FY 2003, the Berkeley Site Office (BSO) and Stanford Site Office (SSO) began identifying the impact of the closure of the Oakland Operations Office (OAK) as a result of the organizational restructuring of the National Nuclear Safety Administration (NNSA). The closure of OAK significantly impacts all support areas required by the BSO and SSO. In response, NNSA and SC have agreed to, and DOE and the Office of Management and Budget (OMB) have approved, the transfer of ten FTEs and associated funding from OAK to BSO/SSO in FY 2005. SC has determined that the Chicago (CH) Operations Office will be the primary service center for the BSO and SSO organizations.
- In response to the functional transfer within the Richland Operations Office from the Office of Environmental Management (EM), in support of the Pacific Northwest National Laboratory, SC has established a Pacific Northwest Site Office (PNSO). EM and SC have agreed to, and DOE and OMB have approved, the transfer of 46 FTEs and associated funding for the new PNSO. SC has determined that the Oak Ridge (OR) Operations Office will be the primary service center for the PNSO.
- SC has also agreed to, and DOE has approved, the functional transfer of seven FTEs and associated funding supporting uranium management activities from the OR Operations Office to Nuclear Energy, Science and Technology (NE).

Program Direction

Funding Schedule by Category

(dollars in thousands, whole FTEs)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Headquarters					
Salaries and Benefits	39,711	41,841	44,009	+2,168	+5.2%
Travel	1,201	1,644	1,645	+1	+0.1%
Support Services	12,072	13,710	11,627	-2,083	-15.2%
Other Related Expenses	8,524	9,376	8,646	-730	-7.8%
Total, Headquarters	61,508	66,571	65,927	-644	-1.0%
Full Time Equivalents	356	356	356	0	0.0%

Mission

The Program Direction subprogram funds all of the SC Federal staff in Headquarters responsible for directing, administering, and supporting the broad spectrum of scientific disciplines. These disciplines include High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, and Advanced Scientific Computing Research programs. Additionally, this subprogram supports management, human resources, policy, technical, and administrative support staff responsible for budget and finance; general administration; grants and contracts; information technology; policy review and coordination; infrastructure management; construction management; safeguards and security; and environment, safety and health. Funding for OSTI is also provided within this subprogram activity. OSTI is responsible for sharing the agency's R&D knowledge and fulfills this responsibility through leading-edge e-government information systems. 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 homeland defense. By supporting its Federal workforce (to include travel, contractual services, Working Capital Fund (WCF), and other related expenses), SC is able to successfully administer major Federal science programs, projects and facilities across the nation in a safe, secure, and efficient manner.

Detailed Justification

(dollars in thousands)

	FY 2003	FY 2004	FY 2005
Salaries and Benefits	**39,711**	**41,841**	**44,009**

This funds 356 FTEs in Headquarters pending completion of the OneSC Project. The FY 2005 salary request includes the proposed January 2005 1.5 percent increase in personnel compensation.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Travel	**1,201**	**1,644**	**1,645**

Travel includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with Federal travel regulations. The FY 2005 request incorporates a non-pay Gross Domestic Product (GDP) inflation factor of 1.3 percent.

Support Services	**12,072**	**13,710**	**11,627**

Provides funding for general administrative services and technical expertise provided as part of day-to-day operations, including mailroom operations; travel management; environment, safety and health (ES&H) support; security and cyber security support; and administration of the Small Business Innovation Research (SBIR) program.

Funding also supports program planning and analysis activities in the following areas: (1) current curriculum of *Original and Collaborative Research Projects*, which includes benchmarking, planning studies, research management theory, the development and validation of performance metrics, options theory, and datamining/statistical analysis tools, (2) support of *Case Studies* to demonstrate and document the societal impact (outcomes) of SC research in key fields/subfields critical to DOE missions and National needs, and (3) E. O. Lawrence Award ceremony and other high profile projects.

Capital Equipment funding is included for computer hardware (i.e., purchase of servers, routers and backup storage space) to support electronic information exchange efforts through E-Government Information Systems.

The $2,083,000 decrease in FY 2005 is the net result of the following: program planning and analysis activities (+$18,000); incorporates a non-pay GDP inflation rate of 1.3 percent for support service contract requirements (+$37,000); the development of integrated business applications and enhancement of leading-edge technologies in support of research and improved business processes ($+267,000); and the implementation of the e-Government Corporate R&D Portfolio Management, Tracking and Reporting Environment (ePME) to automate receipt and review of laboratory proposals ($-2,405,000).

Other Related Expenses	**8,524**	**9,376**	**8,646**

Provides funds for a variety of tools, goods, and services that support the Federal workforce, including acquisitions made through the WCF, computer and office equipment, publications, training, etc.

The $730,000 decrease in FY 2005 is the net result of several items: support for IM projects including ePME and maintenance of e-government information systems (+$78,000); projected increase in the WCF (+$223,000); and realignment of resources previously reserved for the OneSC Project to other critical needs within the SC Program Direction budget (-$1,031,000).

Total, Program Direction	**61,508**	**66,571**	**65,927**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Salaries and Benefits	
■ Supports 356 FTEs and factors 1.5 percent pay adjustment in personnel compensation. This includes FTEs and funding for OSTI.	+2,168
Travel	
■ Supports Federal employees and incorporates non-pay inflation rate of 1.3 percent.	+1
Support Services	
■ Increase in program planning and analysis activities that support SC programs through the development of management tools, analysis of policy direction set by the Administration and Congress, development and integration of SC strategic plans and research portfolios, evaluation of programs and performance, and facilitation of SC collaborations with other Federal agencies and major stakeholders.	+18
■ Increase incorporates non-pay inflation rate of 1.3 percent for support service contract activity requirements in the areas of ES&H, safeguards and security; mail room and travel management; and SBIR	+37
■ Supports development of integrated business applications; development and implementation of ePME; development and enhancement of leading-edge technology in support of research and improved business processes; and alignment of OSTI activities to headquarters. Decrease partially offset by use of uncosted balances.	-2,138
Total, Support Services	-2,083
Other Related Expenses	
■ Supports SC Headquarters IT infrastructure requirements and maintenance of e-government information systems including technical management of ePME; and alignment of OSTI activities to headquarters.	+78
■ Funds activities and projected increase in the WCF	+223
■ Decrease related to the ramp-down of the OneSC Project	-1,031
Total, Other Related Expenses	-730
Total Funding Change, Program Direction	**-644**

Support Services by Category

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Technical Support					
Test and Evaluation	988	1,060	1,168	+108	+10.2%
Management Support					
Automated Data Processing	8,421	9,930	7,695	-2,235	-22.5%
Reports and Analyses Management and General Administrative Services	2,663	2,720	2,764	+44	+1.6%
Total, Management Support	11,084	12,650	10,459	-2,191	-17.3%
Total, Support Services	12,072	13,710	11,627	-2,083	-15.2%

Other Related Expenses by Category

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Other Related Expenses					
Communications, Utilities, Misc.	350	350	350	0	0.0%
Working Capital Fund	4,100	4,338	4,561	+223	+5.1%
Other Services	4,074	4,688	3,735	-953	-20.3%
Total, Other Related Expenses	8,524	9,376	8,646	-730	-7.8%

Field Operations

Funding Schedule by Category

(dollars in thousands, whole FTEs)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	30,221	30,695	32,401	+1,706	+5.6%
Travel	431	542	550	+8	+1.5%
Support Services	510	2,307	2,592	+285	+12.4%
Other Related Expenses	639	3,910	3,664	-246	-6.3%
Total, Chicago Operations Office	31,801	37,454	39,207	+1,753	+4.7%
Full Time Equivalents	302	302	302	0	0.0%
Oak Ridge Operations Office					
Salaries and Benefits	33,217	34,193	35,634	+1,441	+4.2%
Travel	590	521	533	+12	+2.3%
Support Services	3,259	7,203	7,320	+117	+1.6%
Other Related Expenses	7,050	6,639	6,647	8	+0.1%
Total, Oak Ridge Operations Office	44,116	48,556	50,134	+1,578	+3.2%
Full Time Equivalents	356	356	356	0	0.0%
Total Field Operations					
Salaries and Benefits	63,438	64,888	68,035	+3,147	+4.8%
Travel	1,021	1,063	1,083	+20	+1.9%
Support Services	3,769	9,510	9,912	+402	+4.2%
Other Related Expenses	7,689	10,549	10,311	-238	-2.3%
Total, Field Operations	75,917	86,010	89,341	+3,331	+3.9%
Full Time Equivalents	658	658	658	0	0.0%

Mission

The Field Operations subprogram is the centralized funding source for the SC Field Federal workforce responsible for the management and administrative functions at the Chicago (CH) and Oak Ridge (OR) Operations Offices supporting SC laboratories and facilities. These include Ames, Argonne, Brookhaven. Fermi, Lawrence Berkeley National Laboratories, Oak Ridge National Laboratory, Princeton Plasma Physics Laboratory, Thomas Jefferson National Accelerator Facility, Stanford Linear Accelerator Center, and Spallation Neutron Source.

This subprogram supports the Federal workforce that is responsible for SC and other DOE programmatic missions performed in support of science and technology, energy research, and environmental management. Workforce operations include financial stewardship, personnel management, contract and procurement acquisition, labor relations, security, legal counsel, public and congressional liaison, intellectual property and patent management, environmental compliance, safety and health management, infrastructure operations maintenance, and information systems development and support.

In addition, this subprogram provides funding for the fixed requirements associated with rent, utilities, and telecommunications. Other requirements such as IT maintenance, administrative support, mail services, document classification, personnel security clearances, emergency management, printing and reproduction, travel, certification training, vehicle acquisition and maintenance, equipment, classified/unclassified data handling, records management, health care services, 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 (CHRIS) 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 2003	FY 2004	FY 2005
Salaries and Benefits..	**63,438**	**64,888**	**68,035**

Supports 658 FTEs within the SC Field complex and includes the proposed January 2005 1.5 percent increase in personnel compensation.

Travel	**1,021**	**1,063**	**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, and permanent change of station relocation, etc. The FY 2005 request incorporates the non-pay GDP inflation factor of 1.3 percent.

Support Services..	**3,769**	**9,510**	**9,912**

The Field uses a variety of administrative and technical assistance services that are critical to their success in meeting local customer needs. The services provided support IT routine computer maintenance, specific improvements, operating systems upgrades, cyber security, network monitoring, firewalls, and disaster recovery tools. Other areas include staffing 24-hour emergency and communications centers, processing/distributing mail, travel management centers, contract close-out activities, copy centers, directives coordination, filing and retrieving records, etc. Requirements in FY 2003 appear artificially low because some of the requirements funded in FY 2003 came from prior year uncosted balances to avoid involuntary reductions in force (IRIFs) in FY 2003. The $402,000 increase incorporates the non-pay GDP inflation factor of 1.3 percent for support service contract requirements (+$152,000) and requirements redistributed from Other Related Expenses to the correct category (i.e. Support Services) based on FY 2002 actuals (+$250,000).

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Other Related Expenses	**7,689**	**10,549**	**10,311**

Funds day-to-day requirements associated with operating a viable office, including fixed costs associated with occupying office space, utilities, telecommunications and other costs of doing business, e.g., postage, printing and reproduction, copier leases, site-wide health care units, records storage assessments, office equipment/furniture, building maintenance, etc. Employee training and development and the supplies and furnishings used by the Federal staff are also included. Requirements in FY 2003 appear artificially low because some of the requirements were funded in FY 2003 from prior year uncosted balances to avoid IRIFs in FY 2003. The $238,000 decrease incorporates the non-pay GDP inflation factor of 1.3 percent for support service contract requirements (+$158,000), redistributed requirements to support services (-$196,000) and a projected decrease in WCF support (-$200,000).

Total, Field Operations	**75,917**	**86,010**	**89,341**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Salaries and Benefits	
■ Supports 658 FTEs within the SC Field complex and factors 1.5 percent pay adjustment in personnel compensation. Includes transfers from EM and NNSA in support of PNSO, BSO and SSO	+3,147
Travel	
■ Supports Federal employees and incorporates the non-pay GDP inflation factor........	+20
Support Services	
■ Increase incorporates the non-pay GDP inflation factor of 1.3 percent for support service activities (contract closeout, mail/travel management, etc.)	+152
■ Increase represents redistribution of requirements from Other Related Expenses	+250
Total, Support Services	+402
Other Related Expenses	
■ Increase incorporates the non-pay GDP inflation factor of 1.3 percent in support of day-to-day activities such as building services and maintenance, janitorial, other supplies and materials, and systems support; i.e., the Financial Service Center processes	+158

	FY 2005 vs. FY 2004 ($000)
■ Decrease redistributes requirements to support services category	-196
■ Decrease projected within WCF in the Field Complex based on historical trend	-200
Total, Other Related Expenses	-238
Total Funding Change, Field Operations	+3,331

Support Services by Category

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Management Support					
Automated Data Processing	2,649	4,188	4,452	+264	+6.3%
Reports and Analyses Management and General Administrative Services	1,120	5,322	5,460	+138	+2.6%
Total, Support Services	3,769	9,510	9,912	+402	+4.2%

Other Related Expenses by Category

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Other Related Expenses					
Printing and Reproduction	36	250	254	+4	+1.6%
Communications, Utilities, Misc.	3,842	4,545	4,675	+130	+2.9%
Working Capital Fund	453	500	300	-200	-40.0%
Other Services	3,358	5,254	5,082	-172	-3.3%
Total, Other Related Expenses	7,689	10,549	10,311	-238	-2.3%

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Capital Equipment	150	150	150	0	0.0%

Workforce Development for Teachers and Scientists

Funding Profile by Subprogram

(dollars in thousands)

	FY 2003 Comparable Appropriation	FY 2004 Original Appropriation	FY 2004 Adjustments	FY 2004 Comparable Appropriation	FY 2005 Request
Workforce Development for Teachers and Scientists					
Undergraduate Internships..........	3,614	3,768	-38[a]	3,730	3,650
Graduate/Faculty Fellowships..................................	903	1,900	0	1,900	3,110
Pre-College Activities	875	802	0	802	900
Subtotal, Workforce Development for Teachers and Scientists.............	5,392	6,470	-38	6,432	7,660
Less Use of Prior Year Balances.	0	-74	0	-74	0
Total, Workforce Development for Teachers and Scientists..................	5,392[b]	6,396	-38	6,358	7,660

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 program is to provide a continuum of opportunities to the Nation's students and teachers of science, technology, engineering and mathematics (STEM).

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 will implement in the coming years.

The Workforce Development for Teachers and Scientists program supports three science, technology and workforce development subprograms: 1) Undergraduate Internships, for a broad base of undergraduate students planning to enter STEM careers, including teaching; 2) Graduate/Faculty Fellowships for STEM students, teachers, and faculty; and 3) Pre-College Activities for middle and high school students,

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[a] Excludes $37,736 for a rescission in accordance with the Consolidated Appropriations Act, 2004, as reported in conference report H.Rpt. 108-401, dated November 25, 2003.

[b] Excludes $35,277 for a rescission in accordance with Consolidated Appropriations Resolution, FY 2003.

the principle effort being the National Science Bowl. Each subprogram targets a different group of students and teachers to attract as broad a range of participants to the programs and to expand the pipeline of students who will enter the STEM workforce. In this fashion, the subprograms use our National Laboratories to meet the Department's own, 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

- In FY 2005, the Laboratory Science Teacher Professional Development activity will run at five or more DOE National Laboratories with about 90 participating STEM teachers, in response to the national need for science teachers who have strong content knowledge in the classes they teach. The 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, each teacher could enter the classroom as a genuine effective representative 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.
- A new Faculty Sabbatical activity, proposed in FY 2005, is aimed at providing sabbatical opportunities to 12 faculty members from minority serving institutions (MSIs) to facilitate the entry of their faculty into the research funding mainstream. This proposed 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 complete a research project that is formally documented in a paper or presentation.

Supporting Information

As documented by a July 2001 DOE's Inspector General, the Department faces a critical and immediate shortage of scientific and technical staff sufficient to meet its mission requirements. Further, unless current trends are reversed the Department could, within less than five years, face a 40 percent shortage in these job function areas. The Office of Workforce Development is addressing this shortfall by managing its current programs, and initiating target programs, that align with the mission of SC and the Laboratories.

Our programs provide a grade school through post-grad school set of opportunities that are unified under the common belief that Department of Energy (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 National Science Foundation, 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 2003	FY 2004	FY 2005	$ Change	% Change
Undergraduate Internships					
Science Undergraduate Laboratory Internship	2,503	2,615	2,650	+35	+1.3%
Community College Institute of Science and Technology	601	605	560	-45	-7.4%
Pre-Service Teachers	510	510	440	-70	-13.7%
Total, Undergraduate Internships	3,614	3,730	3,650	-80	-2.1%

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, their investigative expertise, and inspire commitments to careers in science and 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.

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" 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.

Accomplishments

- Workforce Development has fully implemented an innovative, interactive Internet system for all Office of Science national workforce development programs, to receive and process hundreds of student and teacher/faculty applications for summer, fall, and spring semester research appointments at participating DOE laboratories. The 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.
- This system enhances communication with the participants regarding their internships, contains pre- and post-surveys that quantify student knowledge, performance and improvement, allows SC to measure program effectiveness, track students in their academic and career path, and be a hosting site for publishing student papers, abstracts and all activity guidelines. This system also provides valuable data on the quality of experiences and provides various metrics for outside evaluators to access the impact of the program.
- Through special recruitment efforts, the Science Undergraduate Laboratory Internship (SULI) has attracted a diverse group of students using the electronic application. Over 20 percent of those submitting applications were from under-represented groups. Approximately 40 percent of the applicants were females, and more than 25 percent were from low-income families. In the summers of 2000 through 2003, about 500 appointments were made each year 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 third edition was published in 2003, with 15 full-length papers and 488 abstracts. In 2003, more than 95% 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 program has revised its *Undergraduate Internships Program Guidebook*. The guidebook is an invaluable tool for both students and laboratory research mentors as it describes the responsibilities, requirements, and outcomes that are to be accomplished to have a successful internship. Contained therein are formats and instructions for the written requirements, including scientific abstract, research paper, oral presentation, and poster; and instructions for an education module for the Pre-Service Teachers.
- The DOE Community College Institute of Science and Technology (CCI) is open to students from all community colleges. In the summer of 2003, 81 community college students attended a 10-week mentor-intensive scientific research experience at several DOE National Laboratories. Almost 60

percent of the participating students came from underrepresented groups in STEM disciplines; many were "non-traditional" students. Grades of abstracts for these students were statistically equal to those from the 4 year program.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Science Undergraduate Laboratory Internship	**2,503**	**2,615**	**2,650**

The Science Undergraduate Laboratory Internship (SULI) supports a diverse group of students at our National Laboratories in individually mentored research experiences. Through these unique and highly focused experiences these students will comprise a repository of talent to help the DOE meet its science mission goals. The paradigms of the activity are: 1) students apply on a competitive basis and are matched with mentors working in the students' fields of interest; 2) students spend an intensive 10-16 weeks working under the individual mentorship of resident scientists; 3) students must each produce an abstract and formal research report; 4) students attend seminars that broaden their view of career options and help them understand how to become members of the scientific community; and 5) activity goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal 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 American Association for the Advancement of Science (AAAS) and the abstracts of their presentations are posted on the AAAS web site. The National Science Foundation (NSF) began a collaboration with this activity as of FY 2001 to offer students in its undergraduate student programs access to individually mentored research internships that they would otherwise not have. The 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 2003, 25 students participated in the Spring semester program, 336 students participated in the summer, and 19 students in the fall semester program. An estimated 370 students in FY 2004 and 360 students in FY 2005 will participate in the Science Undergraduate Laboratory Internship.

Community College Institute of Science and Technology	**601**	**605**	**560**

The Community College Institute (CCI) of Science and Technology was originally a collaborative effort between DOE and its National Laboratories with the American Association of Community Colleges and specified member institutions. Through a recent Memorandum of Understanding with the NSF, undergraduate students in NSF programs (e.g., Lewis Stokes Alliance for Minority Participation and Advanced Technology Education program) are also participating in this activity and in FY 2002 the CCI was made available to students from all community colleges. This allows students in NSF-funded programs access to advanced laboratories, which would otherwise be unavailable to them, to perform research that will advance their STEM careers. 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 Institute provides a ten-week

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

mentored research internship at a DOE National Laboratory for highly motivated community college students. The paradigms of the activity are: 1) students apply on a competitive basis and are matched with mentors working in the students' field of interest; 2) students spend an intensive 10 weeks working under the individual mentorship of resident scientists; 3) students must each produce an abstract and formal research report; 4) students attend professional enrichment activities, workshops and seminars that broaden their view of career options, help them understand how to become members of the scientific community, and enhance their communication and other professional skills; and 5) activity goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was created to publish selected full research papers and all abstracts of students in this activity. The National Science Foundation entered into a collaboration with the Office of Science on this activity in FY 2001. This allows NSF's undergraduate programs to include a community college internship in the opportunities they provide to students. In FY 2003, 81 students directly participated in this internship. A similar number is expected in FY 2004 and in FY 2005 there will be approximately 73 students. The decrease in the number of students in the Undergraduate Research Internships subprogram is because additional funding was provided to: (a) Faculty and Students Teams, (b) Albert Einstein Distinguished Educator Fellowship and (c) US First Robotics [per FY 2004 Appropriations language].

Pre-Service Teachers	**510**	**510**	**440**

The Pre-Service Teachers activity is for students who are preparing for a teaching career in a STEM discipline. This effort is aimed at addressing the national need to improve content knowledge of STEM teachers prior to entering the teaching workforce. The paradigms of the activity are: 1) students apply on a competitive basis and are matched with mentors working the student's field of interest; 2) students spend an intensive 10 weeks working under the mentorship of master teachers and laboratory scientists to help maximize the building of content, knowledge, and skills through the research experience; 3) students must produce an abstract and an educational module related to their research and may also produce a research paper or poster or oral presentation; 4) students attend professional enrichment activities, workshops and seminars that help students apply what they learn to their academic program and the classroom, and also to help them understand how to become members of the scientific community, and enhance their communication and other professional skills; and 5) activity goals and outcomes are measured based on students' abstracts, education modules, surveys and outside evaluation. In FY 2003, 65 students are participating in this program. Approximately 80 students in FY 2004 and 68 students in FY 2005 are expected to participate in the Pre-Service Teachers activity. The decrease in the number of students in the Undergraduate Research Internships subprogram is because additional funding was provided to: (a) Faculty and Students Teams, (b) Albert Einstein Distinguished Educator Fellowship and (c) US First Robotics [per FY 2004 Appropriations language].

Total, Undergraduate Internships	**3,614**	**3,730**	**3,650**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Science Undergraduate Laboratory Internship	
▪ This increase allows Science Undergraduate Laboratory Internship (SULI) students to attend the American Association for the Advancement of Science national meeting. The number of students in SULI decreases by 10 from 370 in FY 2004	+35
Community College Institute of Science and Technology	
▪ The number of students in the Community College Institute of Science and Technology decreases by 7 from 80 in FY 2004	-45
Pre-Service Teachers	
▪ The number of students participating in the Pre-Service Teachers activity decreases by 12 from 80 in FY 2004.	-70
Total Funding Change, Undergraduate Internships	**-80**

Graduate/Faculty Fellowships

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Graduate/Faculty Fellowships					
Laboratory Science Teacher Professional Development	60	1,000	1,500	+500	+50.0%
Faculty and Student Teams	180	210	320	+110	+52.4%
Albert Einstein Distinguished Educator Fellowship	588	600	700	+100	+16.7%
Energy Related Laboratory Equipment	75	90	90	+0	0.0%
Faculty Sabbatical Fellowship	0	0	500	+500	--
Total, Graduate/Faculty Fellowships	903	1,900	3,110	+1,210	+63.7%

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, their investigative expertise and to enhance the research capabilities at academic institutions.

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 program addresses the Administration's goal of a "qualified teacher in every classroom." The program provides K-14 classroom teachers long-term, mentor-intensive professional development through scientific research opportunities at the National Laboratories. The program will improve: teachers' content knowledge; student achievement in science, technology, engineering and mathematics (STEM); and numbers of students pursuing STEM careers. 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; support to connect students via classroom activities to ongoing national laboratory research; support for continuing communication and collaboration with other participant teachers and laboratory scientists; subject enhancement trips to the laboratory; and support to present their experiences at professional conferences and in publications.

The Faculty and Student Teams (FaST) program provides research opportunities at a National Laboratory to faculty and undergraduate students from colleges and universities with limited prior research capabilities as well as institutions serving populations, women, and minorities underrepresented in the fields of science, technology, engineering, and mathematics. These opportunities are also extended to faculty from NSF funded institutions.

The Faculty Sabbatical Fellowship program is an extension of the successful Faculty and Student Teams program. It provides a research fellowship where a faculty member may 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 (signed into law in November 1994). The law gives DOE responsibility for administering the activity of distinguished educator fellowships for elementary and secondary school mathematics and science teachers.

The "Energy Related Laboratory Equipment" (ERLE) activity was established by the Department of Energy (DOE) to grant available excess equipment to institutions of higher education for energy-related research.

Accomplishments

- An innovative, interactive Internet system has been developed and implemented for all Office of Science national workforce development programs to receive and process hundreds of student and teacher/faculty applications for summer, fall, and spring semester research appointments at participating DOE laboratories. The automated system is virtually paperless and provides an excellent example of how the Internet can be used to streamline the operation of the Department's research participation programs. The on-line application system is linked with an SC laboratory central processing center called Education Link.
- This system enhances communication with the participants regarding their internships, contains pre- and post-surveys that quantify student knowledge, performance and improvement, allows SC to measure program effectiveness and track students in their academic and career path, and 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 National Science Foundation, and the National Institute of Standards and Technology contributed funds to place seven additional Einstein Fellows in those agencies.
- Five Office of Science laboratories – Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory and Pacific

Northwest National Laboratory directly provided support for 12 Faculty and Student Teams. In collaboration with the National Science Foundation, this number was leveraged to support a total of 23 teams in FY 2003. Faculty and students from colleges and universities with limited prior research capabilities and those institutions serving populations, women, and minorities underrepresented in the fields of science, engineering, and technology were part of a research team at a National Laboratory. Over a ten week summer visit to the laboratory, the faculty were introduced to new and advanced scientific techniques that will help them prepare their students for careers in science, engineering, computer sciences and technology and their own professional development.

Detailed Justification

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Laboratory Science Teacher Professional Development	**60**	**1,000**	**1,500**

The *National Commission on Mathematics and Science Teaching* and numerous other studies indicate that professional staff development is one of the most effective ways of improving the achievement of K-14 students. The National Laboratories can play a significant role in providing carefully designed *mentor-intensive training for science and math teachers* that will allow them to more effectively teach, *attract their students' interests to science, mathematics and technology careers,* and improve student achievement. The paradigms of the pilot "*Laboratory Science Teacher Professional Development*" activity are: 1) Teachers apply on a competitive basis and are matched with mentors working in their subject fields of instruction; 2) *approximately 60 teachers per year in FY 2004 and 90 in FY 2005 will spend an intensive 4 to 8 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*; 3) follow-on support is considered critical. Master teachers and other teacher participants receive an $800/week stipend, travel and housing expenses. All teachers completing the initial immersion experience will be provided monetary support, which consists of approximately $3,000 to *purchase materials and scientific equipment,* to help them transfer their research experience to their classroom. Follow-on support also will include: returning to the laboratory in the first year for *additional training sessions* of approximately 1 week; and *long-term support* in following years through communication with other participants and laboratory scientists, more *return trips* to the National Laboratory, and support to *present their experience at teaching conferences and publications*; and 4) *outside evaluation* of program effectiveness including visits to participant teachers' schools and long term impact of the program on student achievement. Success of this research experience relies on two elements: 1) proper placement of each participant to match their professional developmental needs and, 2) the follow-on interaction between the teachers and the National Laboratories. In FY 2004, the program will be initiated at five or more National Laboratories.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005
Faculty and Student Teams	**180**	**210**	**320**

Faculty and Student Teams (FaST) activities at the Department of Energy, Office of Science Laboratories are being conducted in collaboration with the National Science Foundation. Faculty from colleges and universities with limited prior research capabilities and those institutions serving women, minorities, and other populations underrepresented in the fields of science, engineering, and technology are encouraged to take advantage of the FaST opportunity to prepare students for careers in science, engineering, computer sciences and technology and for their own professional development. The first year (FY 2001) of this program there was one Faculty and Student Team. In collaboration with National Science Foundation, there were 6 teams in FY 2002 and 23 teams in FY 2003. This 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	**588**	**600**	**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.

Energy Related Laboratory Equipment	**75**	**90**	**90**

The "Energy Related Laboratory Equipment" (ERLE) grant activity was established by the Department of Energy (DOE) 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 disapprove the applications. The equipment is free; however, the receiving institution pays all shipping costs.

Faculty Sabbatical Fellowship	**0**	**0**	**500**

In FY 2005, the Faculty Sabbatical Fellowship activity will provide sabbatical research opportunities for 12 faculty members from minority serving institutions 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. The Faculty Sabbatical activity is designed for each minority serving institution (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 the Office of Science and other granting institutions. Each faculty member would receive

	(dollars in thousands)	
FY 2003	FY 2004	FY 2005

half of their sabbatical support from their home institutions. Since their salaries are comparatively low, this insufficient level of monetary support prevents them from an extended stay at a National Laboratory. This sabbatical would match each faculty member's home institution contribution, bringing the sabbatical salary level 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.

	FY 2003	FY 2004	FY 2005
Total, Graduate/Faculty Fellowships	**903**	**1,900**	**3,110**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
Laboratory Science Teacher Professional Development	
▪ This allows an evaluation of results for the Laboratory Science Teacher Professional Development activity and supports 30 additional teachers in FY 2005.	+500
Faculty and Student Teams	
▪ This allows an increase of four additional Faculty and Student Teams, compared to 16 in FY 2004, to participate in a 10 week mentored research experience at a DOE National Laboratory.	+110
Albert Einstein Distinguished Educator Fellowship	
▪ Increase the number of Einstein Fellowships from 12 to 13 and increase their stipends by 10% per Fellow to remain in step with rapidly rising costs of living in the Washington D.C. area.	+100
Faculty Sabbatical Fellowship	
▪ Initiate the Faculty Sabbatical pilot for 12 faculty members from minority serving institutions (MSIs). For faculty from MSIs to effectively compete for and receive research grants, they must be well trained in their science and fully adept in not only understanding where the cutting edge science is, but also how to actually apply for and receive grants. Typically MSIs do not have the infrastructure or the experienced faculty to enter and succeed in this highly competitive arena. This full sabbatical experience would allow faculty from these under-represented	

	FY 2005 vs. FY 2004 ($000)
institutions to become fully engaged in their respective fields of research and access to the support structure of the National Laboratories, which will provide them with the expertise and experience to apply for and receive federally and non-federally funded research grants	+500
Total Funding Change, Graduate/Faculty Fellowships	**+1,210**

Pre-College Activities

Funding Schedule by Activity

(dollars in thousands)

	FY 2003	FY 2004	FY 2005	$ Change	% Change
Pre-College Activities					
National Science Bowl	725	702	750	+48	+6.8%
Middle School Science Bowl	150	100	150	+50	+50.0%
Total, Pre-College Activities	875	802	900	+98	+12.2%

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.

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®" activity 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 about 68 regional events and where each regional 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. The emphasis at this grade level will be on discovery and hands-on activities such as designing, building and racing model solar cars. Students also answer questions in the life and physical sciences and mathematics.

Accomplishments

- Two additional regional competitions were held in FY 2003 in conjunction with DOE's National Science Bowl®. More than 12,000 high school students participated in the 67 regional science bowl events.
- A pilot Middle School Science Bowl was added in FY 2002, bringing eight teams to Washington, DC for the National event. In 2003, the activity was expanded to 16 regional sites, including some Jr. Solar Sprint sites. The National Event is hosted by the National Renewable Energy Laboratory in Golden, Colorado. The event has two main activities: 1) a science and mathematics academic question and answer forum; and 2) a hands-on activity sponsored by General Motors, where each team designs, builds and races a scale-model solar car and teachers are provided a day-long seminar in Hydrogen fuel cells and the Hydrogen economy.
- Saturday morning science seminars were expanded 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 to include a wide variety of academic awards to the top 18 teams and a Civility Award sponsored by IBM.
- In FY 2003, the Hydrogen Fuel Cell Model Car Challenge was added to National Science Bowl. Ten of the 67 teams took part in designing, building and racing their cars. Awards were presented to the top teams in this event.
- To accommodate the additional activities and events, an additional day was added in FY 2003.

Detailed Justification

(dollars in thousands)

	FY 2003	FY 2004	FY 2005
National Science Bowl..	**725**	**702**	**750**

SC will manage and support the National Science Bowl® for high school students from across the country for DOE. Since its inception, more than 90,000 high school students have participated in this event. The National Science Bowl® is a prestigious academic event among teams of high school students who: answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth and general science; participate in various hands-on science activities; and attend seminars on contemporary issues in science. In 1991, DOE developed the National Science Bowl® to encourage high school students from across the Nation to excel in mathematics and science and to pursue careers in those fields. The National Science Bowl® provides the students and teachers a forum to receive national recognition for their talent and hard work. An entire day of Saturday seminars in the latest scientific topics and the hydrogen fuel cell challenge has recently been added to the National Science Bowl® weekend. Selected teams build and race hydrogen fuel cell cars. 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 nationals are all primarily volunteer programs where several thousand people dedicate a few weeks of there time to organize and judge educational events and be involved with bright, enthusiast middle and high school students.

(dollars in thousands)

	FY 2003	FY 2004	FY 2005

In FY 2005, an additional $48,000 will allow 68 teams (an additional 2 regional sites over the FY 2004 level) to participate. Without this funding, these additional students will not participate in these events, activities and seminars.

	FY 2003	FY 2004	FY 2005
Middle School Science Bowl	**150**	**100**	**150**

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 science, life science, physical science, mathematics, and general science. The model alternative energy car competition challenges students to design, build, and race alternative energy model 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 2005, an additional $50,000 will allow 24 teams (an additional 4 regional sites over the FY 2004 level) to attend and participate in the National event. Without this additional funding, these middle school students will not have this opportunity to compete in the regional events.

	FY 2003	FY 2004	FY 2005
Total, Pre-College Activities	**875**	**802**	**900**

Explanation of Funding Changes

	FY 2005 vs. FY 2004 ($000)
National Science Bowl	
▪ This is to increase the number of National Science Bowl teams by 2 and to also provide a whole day of scientific seminars and workshops for the students. DOE provides all funding for the teams to attend the National finals.	+48
Middle School Science Bowl	
▪ This is to increase the number of participating Middle School Science Bowl teams to 24 from 20. DOE provides all funding for the teams to attend the National finals.	+50
Total Funding Change, Pre-College Activities	**+98**