Science

Science

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

[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).

[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 6^{th} 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%

	(dollars in thousands)				
	FY 2003	FY 2004	FY 2005	$ Change	% Change
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 2^{nd} 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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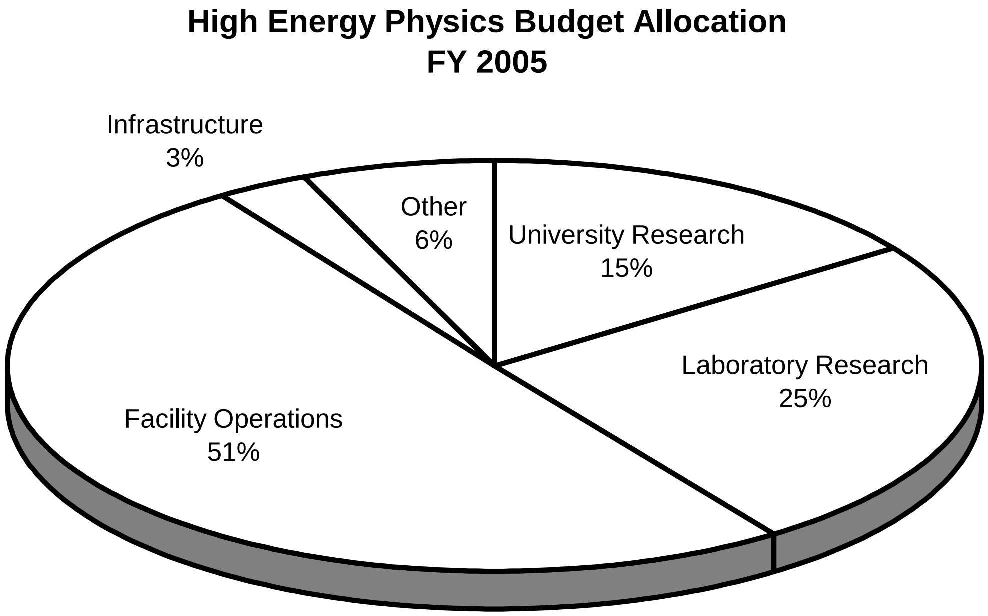
[*] A U.S. Linear Collider Steering Group has been formed, comprised of eminent scientists in the field, to coordinate U.S. efforts toward a linear collider. This group is working closely with the recently formed International Linear Collider Steering Committee to develop an international strategy and formally organize an international R&D collaboration (See detailed justification for Advanced Technology R&D below).



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.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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.

▪ **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.

Facilities	**307,771**	**317,265**	**338,044**

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

▪ **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 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 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.

	FY 2003	FY 2004	FY 2005
▪ **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 (4th quarter FY 2005), but for each a small amount of work is intimately tied to the late stages of the CERN schedule. This is primarily work directly related to the final assembly, testing, and installation of the full detectors, as well as purchase of computing hardware for data acquisition. Under the current schedule, this work will occur in 2006 and 2007, changing the final project completion date. The increased costs arising from the delay are modest and will be contained within the projects contingency allowances. The result of these changes is a stretch out of the planned U.S. contributions to the LHC detectors by two years. The FY 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)

	Department of Energy			National Science Foundation[a]
Fiscal Year	Accelerator	Detector	Total	(Detector)
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

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[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

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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.

	(dollars in thousands)		
	FY 2003	FY 2004	FY 2005

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.

[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

[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 x 10^{26} cm^{-2} s^{-1} for heavy ions. [Met Goal]	Initiated first round of experiments with collisions with other ions to compare to results of gold-gold collisions. [Met Goal]	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]	Upgraded the RHIC cryogenics system by replacing turbine oil skids and removing seal gas compressor, eliminating a single point failure. [Met Goal]		
		Met the cost and schedule milestones for the PHENIX Muon Arm Instrumentation (Major Item of Equipment) within 10% of baseline estimates. [Met Goal]			

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

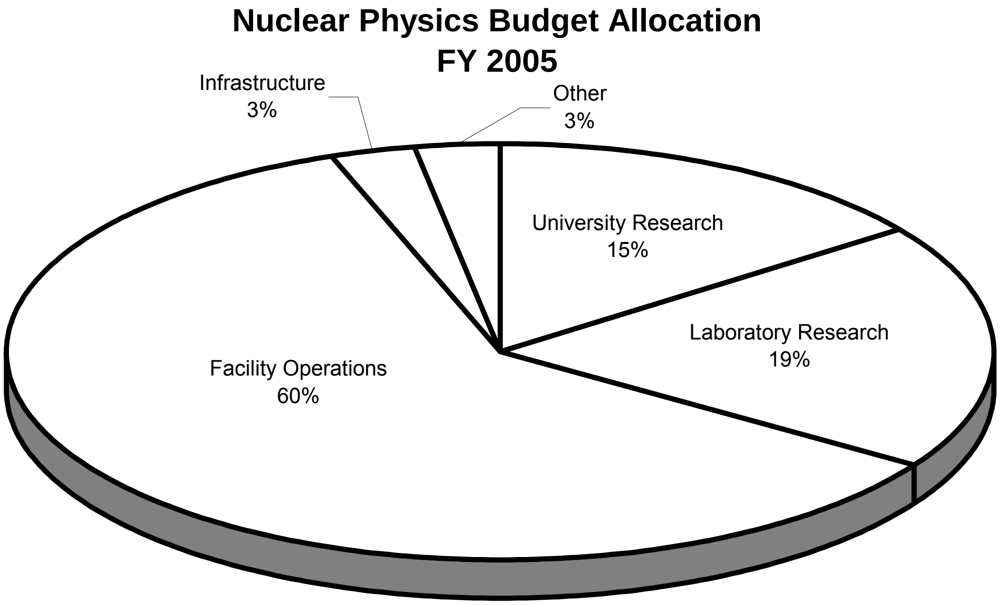
One of the most important activities of NSAC is the development of long-range plans that serve as a framework for the coordinated advancement of the field for the coming decade. These plans are undertaken every 5-6 years to review the scientific opportunities in the field, perform retrospective assessments 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.

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		
▪ **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.

▪ **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.

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.

• **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.

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		

RHIC Operations

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

	FY 2003	FY 2004	FY 2005
• **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.

	FY 2003	FY 2004	FY 2005
▪ **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:

	FY 2003	FY 2004	FY 2005
	(dollars in thousands)		

- 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.

• **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.

▪ **Other Operations**	**300**	**150**	**150**

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

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.

▪ **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.