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 the purchase of not to exceed [58] *25* passenger motor vehicles for replacement only, [$3,186,352,000] *$3,159,890,000*, to remain available until expended. *(Energy and Water Development Appropriations Act, 2001, as enacted by section 1(a)(2) of P.L. 106-377.)*

[For an additional amount for "Science", $1,000,000, to remain available until expended, for high temperature superconducting research and development at Boston College.] *(Division A, Miscellaneous Appropriations Act, 2001, as enacted by section 1(a)(4) of P.L. 106-554.)*

Office of Science

FY 2002 Executive Budget Summary

The Office of Science (SC) requests $3,159,890,000 for Fiscal Year 2002 in the "Science" appropriation, an increase of $4,436,000 over FY 2001, to invest in thousands of individual research projects at hundreds of research facilities across the Nation, primarily at DOE's national laboratories and the Nation's research universities. Within the "Energy Supply" appropriation, SC requests $8,970,000 for Technical Information Management. The SC FY 2002 request will support: continuing construction of the Spallation Neutron Source to recapture world leadership in neutron science; understanding nanoscale (1,000 times smaller that a human hair) assemblies of materials; bringing the Genomes to Life for DOE mission applications; finding the Higgs boson (thought key to understanding mass); creating computational tools for scientific discovery; providing the Nation with state-of-the-art, scientific facilities; and contributing to the supply of the next generation of scientific and technological workers.

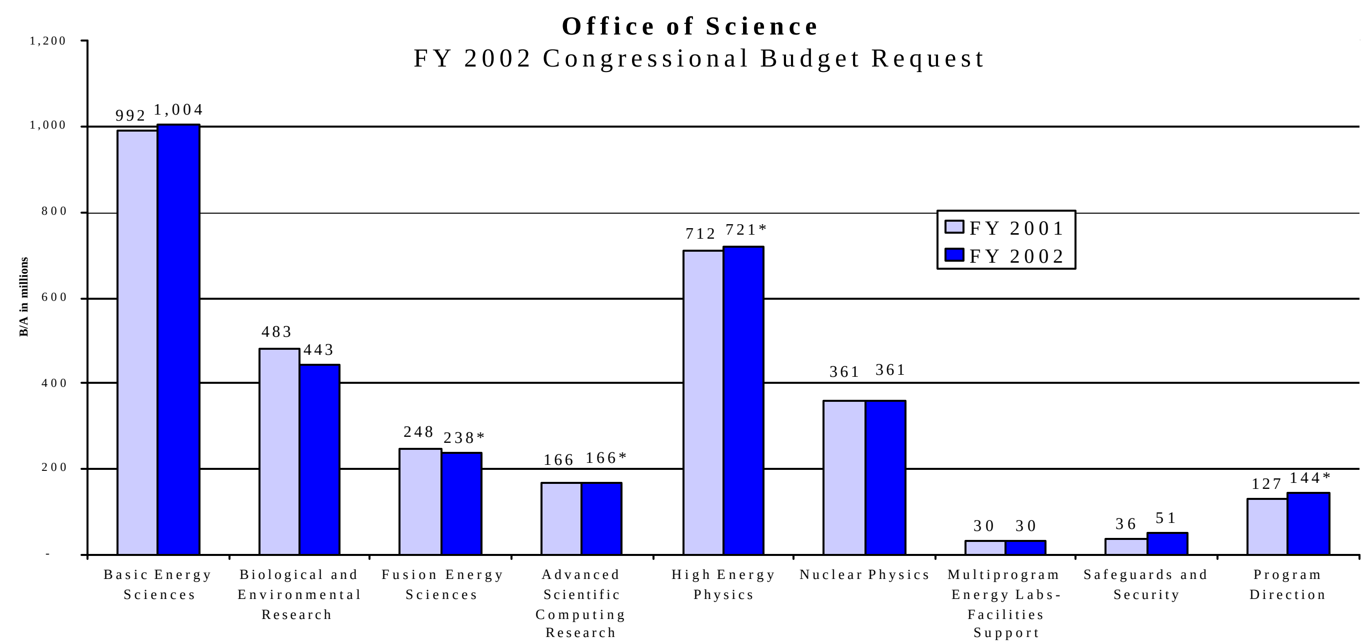
"How is this remarkable economic machine to be maintained, and how can we better ensure that its benefits reach the greatest number of people?

Certainly, we must foster an environment in which continued advances in technology are encouraged and welcomed. …(we) must push forward to expand our knowledge in science and engineering."

- Alan Greenspan, June 10, 1999

Balanced National Research Portfolio:

Knowledge drives the Information Technology Age, and the U.S. Department of Energy's Office of Science programs are one of the Nation's most prominent sources of new knowledge in the physical sciences, computation, mathematics, environmental and energy research, and other vital scientific areas. Our investments in research and forefront scientific facilities help to maintain the U.S. leadership position in many key scientific disciplines. This enables U.S.



*A Pending Budget Amendment transferring $10M to Fusion Energy Sciences from Advanced Scientific Computing Research, High Energy Physics, Energy Research Analyses and Science Program Direction will be submitted shortly.

Figure 1

researchers to move quickly to capitalize on scientific developments worldwide. These investments rely on talented people, stable resources, and the commitment of knowledgeable management. A key decision is how best to sustain the major advances in scientific knowledge that have enabled economic growth and advanced our national security.

Scientific knowledge, economists agree, leads to technological improvements that increase the quality of life for all Americans, ensure economic security, and advance national security. This scientific knowledge is generated through investments that span research fields and academic disciplines to make the most of the synergies between scientific disciplines.

Investments in Office of Science research programs - which comprise one of the most diverse research portfolios in the Federal Government - are an essential part of a balanced national research portfolio that will maintain our gains in knowledge creation and produce new intellectual capital.

The Department of Energy is a Science Agency

Top Five Government Research Organizations for*:

Physical Sciences	Mathematics & Computing	Engineering	Life Sciences	Environmental Sciences**
1. Energy (1,732)	1. Energy (739)	1. DOD (2,169)	1. HHS (13,523)	1. NASA (1,015)
2. NASA (959)	2. DOD (673)	2. NASA (1,964)	2. USDA (1,313)	2. NSF (522)
3. NSF (558)	3. NSF (409)	3. Energy (1,038)	3. DOD (609)	3. Interior (371)
4. DOD (382)	4. HHS (147)	4. NSF (482)	4. NSF (435)	4. DOD (352)
5. HHS (233)	5. Commerce (81)	5. Trans. (300)	5. Energy (313)	5. Commerce (313)

** Numbers are FY 2000 Dollars in Millions - Source: NSF*
*** DOE is Sixth in Environmental Sciences with $306 million in FY 2000*

The Office of Science is the dominant supporter of the physical sciences (i.e. physics, chemistry, etc.) in the U.S. and plays a major role in supporting other scientific fields, including life sciences, mathematics, computation, engineering and environmental research. In addition, SC has been a principle supporter of graduate students and postdoctoral researchers in their early careers, and is the steward of a vast network of major scientific facilities that are essential to the vitality of the U.S. research community.

Past investments in SC programs continue to pay off handsomely for the U.S. taxpayer. Researchers funded by these programs have resolved some of the major questions of our time including basic research that is helping us to understand the origins and fate of the universe and changes in our global climate. In addition, major advances in medical diagnostic tools, microelectronics, advanced materials, nanoscience, computation, lasers, and other scientific innovations supported by Office of Science programs continue to improve the lives of millions of Americans and have added greatly to our store of knowledge.

For example, publication of a complete draft of the Human Genome sequence in February 2001 was the culmination of work initiated in 1986 by the Biological and Environmental Research program in the Office of Science. This blueprint for humanity holds the promise of curing major diseases and understanding the aging process, while it continues to teach us about our origins and our potential. Fundamental discoveries in catalytic phenomena, supported by the Office of Science have provided detailed insights into the relationship between structure and chemical reactivity, which have improved major, energy-intensive industrial processes.

Advances in one field of science can often have unexpected impacts on other, seemingly unrelated fields. For example, breakthroughs in the physical sciences have often enabled rapid advances in medical and life sciences, communications and information technology.

Companies developing new medicines often depend on computer-based modeling and theoretical advances in chemistry and physics supported by the Office of Science.

"Medical advances may seem like wizardry. But pull back the curtain, and sitting at the lever is a high-energy physicist, a combinational chemist or an engineer."

Harold Varmus, Nobel Laureate and Director of the National Institutes of Health

X-ray crystallography is an excellent example of the interdependence of scientific disciplines at the forefront of medical research. A grant from NIH may fund a research team that includes biologists, but may also include a materials scientist or solid-state physicist, an optics expert, a computational scientist or a biochemist. The work of such a team relies upon the availability of a high intensity light source, a neutron source or a state of the art nuclear magnetic resonance imaging machine. All of these instruments, powerful probes of organic and inorganic materials, were the result of research in the physical sciences and the Office of Science pioneered their development and use. In fact, the Office of Science develops, constructs, and operates nearly all of the light sources and all of the neutron sources available in the U.S..

This growing interdependence between the sciences is evident at SC's scientific user facilities. For example, only 100 (6% of users) of the researchers at SC's synchrotron light sources in 1990 were from the life sciences. Today, there are more than 2,400 life science researchers (40% of users) at these facilities.

Tens of thousands of the leading research scientists in the U.S. – representing virtually every scientific discipline – depend on the major scientific instruments found only at SC laboratories and user facilities. All of SC's scientific user facilities receive more high quality proposals for research than can be accommodated and the demand for new or upgraded facilities remains pervasive.

In FY 2002, sustained investments in research sponsored by the Office of Science will support the work of thousands of university researchers and the scientists at DOE's national laboratories. The knowledge base will be expanded and scientific breakthroughs will be generated in nanoscience, physics beyond the Standard Model, terascale computing, fusion and plasma physics, functional genomics, proteomics (the study of the composition and functions of an organism's proteins), climate change, and a host of other scientific research areas that are important to DOE missions and to the Nation's prosperity.

The Office of Science has a long-standing and critical role in ensuring the flow of young scientists, engineers and technicians into the U.S. research enterprise. Unique research experiences at national laboratories are often a stepping stone to successful careers in science.

World-class research facilities attract many young researchers who conduct a single experiment or choose to spend their careers at an Office of Science laboratory. Expanding efforts to attract the best and brightest our Nation has to offer, while promoting diversity in the scientific workforce, is a major goal of the Office of Science. To accomplish this

"Although U.S. fourth graders did relatively well in both math and science, by twelfth grade… U.S. students were among the very worst in the world, and in some areas, such as physics, were last. This evidence indicates that our schools are not preparing our students adequately for today's knowledge-based, technologically rich society or to become future scientists and engineers."

President George W. Bush – FY 2002 Budget Blueprint goal, the Office of Science formed a partnership with the National Science Foundation to leverage our investment and the unique capabilities of the national labs in training U.S. science educators and students.

Performance Evaluation:

The Government Performance and Results Act (GPRA) calls for accountability from all Federal programs. The Office of Science has always relied upon external peer review, independent construction management review, and regular program reviews, to ensure the excellence and relevance of our research portfolio. These effective evaluation tools will continue.

In addition, the Office of Science has embraced the recommendations of the National Academy's Committee on Science and Engineering in Public Policy (COSEPUP) report "*Science, Technology and the Federal Government: National Goals for a New Era*" that calls for the U.S. to maintain a leadership position in key areas of science and to be "among the world leaders" in all areas of research. This enables the U.S to quickly absorb and build upon breakthroughs in science worldwide. Therefore, the Office of Science will evaluate its programs for scientific excellence, relevance to DOE mission areas, scientific leadership and management excellence. This will be accomplished through a variety of mechanisms, that may include: external review by peers, review of prizes and awards to SC's researches, citation analysis, and a characterization of the significance and impact of the research as recognized at international conferences and Advisory Committee evaluations.

SC is widely recognized for its world-class research and for the construction and operation of major scientific facilities. Demand for these facilities has steadily increased and calls for new or improved facilities greatly exceed budgetary resources. To ensure that the proper balance is maintained between laboratory research and facility operations, and between new and existing facilities, the Office of Science relies upon the advice of external Advisory Committees, on feedback from the facility User Groups, and on the results of the merit review process.

Critical to ensuring the excellence, relevance and leadership of SC's research is the human and physical infrastructure that enables world-class science. The Office of Science will continue to evaluate the health and utility of its laboratory infrastructure through on-site institutional reviews, program reviews, and through merit evaluation. A continuing supply of talented researchers in critical subfields will be ensured through fellowships, support of graduate students within research grants, and through student use of research facilities.

Specific performance goals that will be tracked throughout SC include:

- At least 80% of all new research projects supported by SC will be peer reviewed and competitively selected, and will undergo regular peer review merit evaluation. In FY 2000, 96% of new research projects supported by SC were peer reviewed and competitively selected.
- Upgrades and construction of scientific user facilities will stay within 10%, on average, of cost and schedule milestones. In FY 2000, construction of scientific facilities were kept within 10%, on average, of cost and schedule milestones.
- The SC scientific user facilities will be operated and maintained so that unscheduled operational downtime will be kept to less than 10%, on average, of total scheduled operating time. In FY 2000, SC

scientific user facilities operated, on average, 96% of the scheduled time.

- The Office of Science will ensure the safety and health of the workforce and members of the public and the protection of the environment in all SC program activities.

A History of Success:

The Office of Science has developed a list of the "Top 100" contributions to science from the basic research programs of the Department of Energy. These contributions are available on our website at www.sc.doe.gov.

Each year, many of the principal investigators funded by the Office of Science win major prizes and awards sponsored by professional societies, industry, academia, and governments worldwide. In addition, many are elected to membership in such prestigious organizations as the National Academy of Sciences, the National Academy of Engineering, and to fellowship in the major professional societies.

The long history of scientific contributions from the Office of Science continues in FY 2000 and FY 2001 with discoveries such as the following.

- Office of Science investments in high energy and nuclear physics continue to move us closer to a complete picture of the fundamental particles and interactions that dictate the nature of matter and energy and explain a myriad of natural and man-made phenomena.
- A newly developed class of nanostructured materials have been developed that can selectively filter molecules by their size and chemical identity. This achievement involved creating self-organizing precursors, controlling the pore size, and employing a novel evaporation process that promotes self-assembly. As a result, we may one day wear "breathing" fabrics that block hazardous chemicals while admitting benign species like oxygen.
- Quantum dots – nanometer-size particles in which electrons are confined in a relatively small volume – have recently been shown to emit light at multiple wavelengths, blinking on and off on a time-scale of seconds. This remarkable behavior, attributed to luminescence from different electronic states, may one day lead to nano-scale computers and/or portable analytical instrumentation.
- Combining state-of-the-art ultrafast laser systems with evolutionary computer algorithms has led to an important new source of ultrafast, coherent soft x-rays for studies of materials properties and chemical physics.
- Office of Science investments in plasma physics and fusion energy sciences continue to expand our understanding of how to generate, control and harness the energy of high energy, high density plasmas here on earth.
- In 1990, computers were able to model only fragments of separation agents such as simple ether. With advances in computation power, and through targeted investments by the Office of Science's Advanced Scientific Computing Research Program, researchers are now able to model real-world separation agents – advancing DOE's remediation efforts and basic research.
- Completion of the draft map of the human genome was made possible by DOE's Biological and Environmental Research Program initiative, sequencing technologies and the combined efforts of NIH and the national labs.

Program Priorities for FY 2002:

Advances in computation have changed the lives of millions of Americans. They have also changed the ways in which scientific research is conducted today and will evolve throughout the new century.

The **Advanced Scientific Computing Research** (ASCR) program's mission, which is primarily carried out by the Mathematical, Information, and Computational Sciences (MICS) subprogram, is to discover, develop, and deploy the computational and networking tools that enable scientific researchers to analyze, model, simulate, and predict complex physical, chemical, and biological phenomena important to the Department of Energy.
In FY 2002, ASCR will continue to invest in research that advances the next generation of high performance computing and communications tools that are critical to the Department's scientific missions.

The MICS subprogram will support research in applied mathematics, computer science, electronic collaboratory tools and network research. Competitively selected partnerships will continue to work toward discovering, developing, and deploying key enabling technologies for scientific research. These partnerships, called Integrated Software Infrastructure Centers, play a critical role in providing the software infrastructure that will be used by the Scientific Discovery through Advanced Computing (SciDAC) applications teams. Other MICS investments include fundamental research in networking and collaboratory tools, partnerships with key scientific disciplines, and advanced network testbeds for electronic collaboration tools.

In FY 2002 the Laboratory Technology Research subprogram will continue to support basic research at SC labs that will advance innovative energy applications.

In FY 2000, a Federally-chartered advisory committee was established for the ASCR program that is charged with providing advice on: promising future directions for advanced scientific computing research; strategies to couple advanced scientific computing research to other disciplines; and the relationship of the DOE program to other Federal investments in information technology research. This advisory committee will play a key role in evaluating future planning efforts.

The **Basic Energy Sciences** (BES) program is a principal sponsor of fundamental research for the Nation in the areas of materials sciences and engineering, chemistry, geosciences, and bioscience as it relates to energy. This research underpins the DOE missions in energy, environment, and national security; advances energy related basic science on a broad front; and provides unique user facilities for the scientific community.

For FY 2002, a very high priority is the continuation of construction of the Spallation Neutron Source (SNS) to provide the next-generation, short-pulse spallation neutron source for neutron scattering. The project, which is to be completed in June 2006, is on schedule and within budget.

Enhancing U.S. research in neutron science, in preparation for the commissioning of the SNS, is also a program priority. A common finding among BES Advisory Committee studies has been the importance of establishing a large and well-trained user community by the time the SNS is fully operational in the 2008-2010 timeframe. To this end, funding will be provided for teams of scientists to participate in the development of neutron scattering instruments and for support for the neutron science/scattering programs at the host institutions of the BES facilities. Additional operations funds will be provided to HFIR and

IPNS to ensure that these facilities are available to the scientific community.

In the areas of nanoscale science, engineering, and technology (NSET) research, BES will continue the new research directions initiated in FY 2001 and will explore concepts and designs for Nanoscale Science Research Centers (NSRCs). NSRCs will be user facilities similar in concept to the existing BES major scientific user facilities and collaborative research centers. They will provide unique, state-of-the-art nanofabrication and characterization tools to the scientific community. NSRCs will enable research programs of a scope, complexity, and disciplinary breadth not possible through the support of individual investigators or small groups. Significant partnerships with regional academic institutions and with state governments are anticipated.

The response of the scientific community to the FY 2001 NSET initiative has been strong. University researchers submitted 745 pre-applications, 313 of which received encouragement letters from BES inviting the submission of full proposals. The DOE Labs were restricted to four Field Work Proposals per laboratory and 46 proposals were received. Proposals were also received for pre-conceptual design of NSRCs from ANL, BNL, LBNL, ORNL, and Sandia/LANL. All proposals will undergo peer review to determine which will be funded in FY 2001.

The **Biological and Environmental Research (BER)** program develops the knowledge needed to identify, understand, anticipate, and mitigate the long-term health and environmental consequences of energy production, development, and use.

As the founder of the Human Genome Project, BER will maintain a critical role in the International Human Genome Consortium that includes the National Institutes of Health.

A redirected effort entitled, "Genomes to Life," will support research and computational tools that will lead to an understanding of complex biological systems. It will incorporate research to develop a comprehensive understanding of the Microbial Cell that will be used to engineer microbes for DOE mission applications such as environmental cleanup. In FY 2002, BER Microbial research will provide DNA sequences for four additional microbes important in bioremediation, clean energy, or global carbon cycling. BER studies of low dose radiation will lead to new standards for determining the health risks of low dose ionizing radiation and includes investments in scientific infrastructure at the laboratories.

The Atmospheric Radiation Measurement (ARM) program will improve radiative transfer models, including cloud and water vapor effects on climate, to reduce uncertainty in predicting the effect of greenhouse gases on future climates. Carbon cycle and sequestration research will help to assess current carbon sinks and to develop methods of enhancing natural processes for terrestrial and ocean sequestration of carbon. Ecological research will provide data to develop and test robust models to predict the effects of changes in climate and atmospheric composition on important ecological systems and resources.

BER will continue research in environmental bioremediation focusing on research at the Field Research Center in Oak Ridge Tennessee. The Environmental Molecular Sciences Laboratory (EMSL), a national scientific user facility provides analytical and experimental capabilities to address the complex scientific barriers to restoring our environment. The EMSL computational facility will upgrade its computing capability by leasing a high performance computer in FY 2002. This will enable the simulation of key environmental and molecular processes.

Medical Sciences Research will develop advanced technology and instrumentation to image single molecules, genes, cells, organs, and whole organisms in real time with a high degree of precision. These technological achievements have a broad impact on biomedicine, in particular the fields of cell and developmental biology and on more accurate medical diagnoses and effective treatments.

The resources of the DOE National Labs enable rapid advances in our programs in biophotonics, lasers in medicine, biological and chemical sensors, and advanced imaging instrumentation. BER and the National Institutes of Health (NIH) have developed a partnership in which the advanced technologies, instrumentation, and computational modeling capabilities developed in the DOE National Labs will be applied to specific biomedical problems of high importance in the NIH intramural program. Cooperation will facilitate rapid application of advances in the biophysical sciences to solve clinical problems of national importance.

The **Fusion Energy Sciences** (FES) program's mission is to advance plasma science, fusion science and technology. The program emphasizes the underlying basic research in plasma and fusion sciences, with the long-term goal of harnessing fusion as a viable energy source. The program centers on the following goals: understanding the physics of plasmas; identification and exploration of innovative and cost effective development paths to fusion energy; and exploration of the science and technology of energy producing plasmas, as a partner in international efforts.

In FY 2002, the program will incorporate the recommendations of reports by the National Research Council, the Secretary of Energy Advisory Board and recommendations of the Fusion Energy Science Advisory Committee. The FY 2002 FES program includes basic research in plasma science in partnership with NSF, plasma containment research, and investigation of tokamak alternatives along with continued operation of DIII-D, Alcator C-Mod, and the National Spherical Torus Experiment. Research on alternate concepts is pursued to develop a fuller understanding of the physics of magnetically confined plasma and to identify approaches that may improve the economical and environmental attractiveness of fusion.

The inertial fusion energy activity will continue exploring an alternative path for fusion energy that would capitalize on the major R&D effort in inertial confinement fusion that is carried out by NNSA for stockpile stewardship purposes. Ongoing theory and modeling efforts, aimed at developing a predictive capability for the operation of fusion experiments, will continue as will enabling technology development.

The **High Energy Physics** (HEP) program's mission is to understand energy and matter at a fundamental level by investigating the elementary particles and forces between them. Until the Large Hadron Collider (LHC) at CERN is completed in 2006, the U.S. will be the primary center of activity for experimental research in the field of high energy physics. There is the potential for exciting new discoveries, and the program needs to position itself to take advantage of these opportunities.

The HEP program will concentrate on utilization and upgrading of its facilities, including direct support for research scientists. In FY 2002, Fermilab will begin a five-year campaign to discover the Higgs particle (thought key to understanding mass) and other new particles predicted by current theories. The B-factory at SLAC will begin a three-year campaign to make important contributions toward understanding the preponderance of matter over antimatter in the universe.

A small HEP program continues at the Alternating Gradient Synchrotron (AGS). The muon g-2 experiment recently announced results that showed a higher magnetic strength for the muon than that predicted by the Standard Model. If confirmed, these findings could lead science into exciting new territory beyond the Standard Model.

Appropriately focused support for university and laboratory based physics theory and experimental research will be emphasized in FY 2002. The experimental programs are performed by university (primarily) and laboratory based scientists. These scientists construct, operate, and maintain the detectors and analyze the resulting data as well as train the new generations of scientists.

An important element of the program is successful completion of construction and major capital equipment projects. Continued participation in the LHC is a high priority as is construction of the Neutrinos at the Main Injector (NuMI) project at Fermilab and its detector, MINOS. When NuMI/MINOS is completed in 2004, it will provide a world-class facility to study neutrino properties and make definitive measurements of masses.

In partnership with NASA, the HEP program will continue two particle astrophysics projects -- the Alpha Magnetic Spectrometer (AMS) and the Gamma-Ray Large Area Space Telescope (GLAST). The experiments are expected to lead to a better understanding of dark matter, high energy gamma ray sources, and the origin of the universe.

Accelerator R&D is important to the future of the HEP program. Research continues on accelerator-related technologies aimed at reducing costs and improving performance.

The mission of the **Nuclear Physics** (NP) program is to advance our knowledge of the properties and interactions of atomic nuclei and nuclear matter in terms of the fundamental forces and particles of nature.

The NP program is the major sponsor of nuclear physics research in the U.S., providing about 85% of federal support. The program educates and enlarges the Nation's pool of technically trained workers and facilitates the transfer of knowledge and technology.

With the new Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) researchers have a unique opportunity to create and characterize the quark-gluon plasma, a phase of matter thought to have existed in the very early stage of the universe. Initial data from gold-gold collisions have yielded results that show aspects of possible plasma formation; the FY 2001- FY 2002 run will provide the first opportunity to explore this exciting new physics in depth.

New knowledge and insights on how quarks and gluons bind together to make protons and neutrons are being gained using high intensity electron beams from the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility. In FY 2002, the G0 Detector, a joint DOE-NSF project, will be completed and will provide an opportunity to map quark contributions to the structure of the nucleon.

Measurements of the solar neutrino flux by the Sudbury Neutrino Observatory (SNO), constructed by a collaboration of Canadian, British and U.S. supported scientists in a deep underground nickel mine in Ontario, Canada, will provide first results shortly on the "appearance" of oscillations of electron neutrinos into other neutrino flavors. Such evidence would confirm indications that neutrinos have mass, an observation that would force a re-evaluation of the existing Standard Model of particle physics.

The search for new super-heavy elements will continue in FY 2002, focusing on the techniques developed in the recent discovery of elements 116 and 118 at Lawrence Berkeley National Laboratory. Future studies will focus on the search for neighboring elements and will work to understand the surprising observation of enhanced stability for these very heavy elements.

In FY 2002, R&D activities will be supported for the proposed Rare Isotope Accelerator (RIA) facility. This facility would produce beams of highly unstable nuclei that can explore the limits of nuclear existence and measure reaction rates. These data are critical to computer modeling of the dynamics of supernovae explosions and other aspects of stellar evolution and to understanding the origins of elements.

The **Science Program Direction** (SCPD) budget supports three subprograms: Program Direction, Field Operations, and Science Education. Program Direction is the funding source for SC's Federal staff responsible for managing and supporting the scientific disciplines. Field Operations provides funding for the daily operations and administrative functions performed at the Chicago and Oak Ridge Operations Offices that support the departmental programs, projects, laboratories, facilities, and grants under their purview. Science Education sponsors programs designed to promote interest in science, math, engineering, and technology fields for college and university students and faculty.

In FY 2002, SC will continue to focus on strategic human capital management and planning with the goal of building and sustaining a talented and diverse workforce. SC needs to attract, recruit, and retain highly skilled employees to offset the existing and projected shortfall in the scientific and technical workforce, and to continue to manage its programs in a safe, efficient, and effective manner.

SC will also support the DOE Corporate R&D Portfolio Management Environment (PME) project, that will modernize and streamline the Department's R&D management processes. Process improvements and automation will enable electronic "cradle-to-grave" tracking of research projects, that is critical to DOE corporately sharing and reporting energy-related research across programs. In addition, SC will continue to standardize, integrate, and invest in information technology that will improve management processes and promote efficient use of resources among SC Headquarters and Field counterparts, e.g., increase remote accessibility to corporate systems, and enhance cyber security.

Beginning in FY 2002, funding for safeguards and security functions at the Oak Ridge Operations Office is included in SCPD, all part of congressional direction to align such functions with line management.

In FY 2002, the Science Education subprogram will support research experiences at our National Labs for a diverse group of competitively selected undergraduate students. In collaboration with the National Science Foundation, an effort is underway to attract a wider cross section of students to this program and a system is being created to document student career paths. In FY 2002, this partnership will be expanded.

The Office of Science also manages and supports the National Science Bowl© for high school students from across the country and provides the students and teachers a forum to receive national recognition for their talent and hard work. In FY 2000, Saturday seminars on scientific topics were added to the National Science Bowl© weekend. In FY 2002, Students participating in the National Science Bowl© will be tracked to document the long-term impact on their academic and career choices.

The **Multiprogram Energy Laboratories - Facilities Support** (MEL-FS) program's mission is to support the general purpose infrastructure of the five Office of Science multiprogram national laboratories by funding line item construction to rehabilitate, renovate and replace laboratory and offices buildings, utilities systems and other structures. This support helps enable high technology scientific research that is conducted in a reliable, cost effective and safe manner. Together, these laboratories have over 1,600 buildings (including 500 trailers) with 15.5 million gross square feet of space and an estimated replacement value of over $10 billion. The total DOE and non-DOE research program funding for these laboratories is over $3 billion a year.

In FY 2002, MEL-FS will support Project Engineering and Design Funding for the initiation of three new line item construction projects and construction funding for six ongoing line item construction projects.

The request also supports SC's landlord responsibility at the Oak Ridge Reservation and DOE facilities in the town of Oak Ridge, including Payments in Lieu of Taxes (PILT) at this and two other sites.

The **Technical Information Management** (TIM) program leads DOE's e-government initiatives for disseminating information resulting from the Department's $7.5 billion annual research and development (R&D) program. The Office of Scientific and Technical Information (OSTI) manages the TIM program that provides electronic access to worldwide energy science and technical information to DOE researchers, industry, academia, and the public.

In FY 2002, the TIM program will make 70 percent of DOE's scientific and technical literature searchable and retrievable through e-government systems such as the DOE Information Bridge (www.osti.gov/bridge), PubSCIENCE (www.osti.gov/pubscience), PrePRINT Network (www.osti.gov/preprint), and the R&D Project Summaries Database (www.osti.gov/rdprojects).

Closing:

The Office of Science plays an important role in a balanced federal science portfolio. In FY 2002, Office of Science investments in the physical sciences, major scientific user facilities, and other critical areas of basic research will advance the technically challenging mission of the Department of Energy while making major contributions to the Nation's R&D infrastructure.

Dr. James Decker
Acting Director
Office of Science

Table 1

OFFICE OF SCIENCE
FY 2002 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request	
Science				
Basic Energy Sciences	752,031	991,679	1,004,705	
Advanced Scientific Computing Research	122,338	165,750	165,750	*
Biological and Environmental Research	416,037	482,520	442,970	
Fusion Energy Sciences	238,260	248,493	238,495	*
High Energy Physics	683,050	712,001	721,100	*
Nuclear Physics	340,869	360,508	360,510	
Energy Research Analyses	950	976	1,300	*
Multiprogram Energy Laboratories-Facilities Support	29,557	30,174	30,175	
Science Program Direction	120,491	126,906	144,385	*
Small Business Innovation Research and Small Business Technology Transfer	83,962	-	-	
Subtotal	2,787,545	3,119,007	3,109,390	
Safeguards and Security				
Safeguards and Security	42,569	41,569	55,412	
Reimbursable Work	(5,266)	(5,122)	(4,912)	
Total, Safeguards and Security	37,303	36,447	50,500	
Total	2,824,848	3,155,454	3,159,890	
Energy Supply				
Technical Information Management	8,751	8,732	8,970	
Small Business Innovation Research and Small Business Technology Transfer	4,555	-	-	
Total	13,306	8,732	8,970	

* A Pending Budget Amendment transferring $10M to Fusion Energy Sciences from Advanced Scientific Computing Research, High Energy Physics, Energy Research Analyses and Science Program Direction will be submitted shortly.

Table 2

OFFICE OF SCIENCE
FY 2002 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request
Global Climate Change	112,964	119,140	120,679
High Performance Computing and Communications	113,914	175,985	176,092
Microbial Cell Research/Genomes to Life	-	9,591	19,470
Nanoscience Engineering and Technology	46,304	82,829	87,013
Partnerships for a New Generation of Vehicles	5,000	4,934	4,934
Science Education Programs	4,472	4,460	6,460

Table 3

OFFICE OF SCIENCE
FY 2002 PRESIDENT'S BUDGET REQUEST TO CONGRESS
(B/A in thousands of dollars)

Major Site Funding	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request
AMES LABORATORY			
Advanced Computational Scientific Research	1,957	1,668	1,668
Basic Energy Sciences	18,105	16,967	16,753
Biological and Environmental Research	948	652	690
Safeguards and Security	254	264	397
Science Program Direction	-	-	50
Total Laboratory	21,264	19,551	19,558
ARGONNE NATIONAL LABORATORY			
Advanced Computational Scientific Research	12,861	10,447	10,047
Basic Energy Sciences	151,026	155,902	159,149
Biological and Environmental Research	13,700	24,939	17,184
Fusion Energy Sciences	2,321	2,406	2,009
High Energy Physics	10,828	8,858	9,990
Multiprogram Energy Labs-Facilities Support	4,980	6,611	2,833
Nuclear Physics	17,912	17,782	16,568
Safeguards and Security	10,678	11,807	15,355
Science Program Direction	602	430	750
Total Laboratory	224,908	239,182	233,885
BROOKHAVEN NATIONAL LABORATORY			
Advanced Computational Scientific Research	1,847	1,566	1,266
Basic Energy Sciences	73,569	72,005	57,089
Biological and Environmental Research	21,723	16,948	18,169
Energy Research Analyses	50	-	-
High Energy Physics	38,778	26,507	32,595
Multiprogram Energy Labs-Facilities Support	6,881	6,444	6,063
Nuclear Physics	136,462	139,450	140,429
Safeguards and Security	9,585	9,428	10,986
Science Program Direction	558	420	650
Total Laboratory	289,453	272,768	267,247

	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request
FERMI NATIONAL ACCELERATOR LABORATORY			
Advanced Computational Scientific Research	59	60	60
Energy Research Analyses	-	22	-
High Energy Physics	294,627	289,507	314,878
Nuclear Physics	50	-	-
Safeguards and Security	2,294	2,490	2,765
Science Program Direction	-	50	100
Total Laboratory	297,030	292,129	317,803
IDAHO NATIONAL ENGINEERING LABORATORY			
Basic Energy Sciences	2,748	2,220	1,710
Biological and Environmental Research	1,713	1,440	1,486
Fusion Energy Sciences	1,568	2,210	2,082
Science Program Direction	-	40	100
Total Laboratory	6,029	5,910	5,378
LAWRENCE BERKELEY NATIONAL LABORATORY			
Advanced Computational Scientific Research	57,069	54,501	54,151
Basic Energy Sciences	65,048	70,760	72,586
Biological and Environmental Research	48,869	54,231	43,277
Energy Research Analyses	60	100	100
Fusion Energy Sciences	5,534	5,171	4,767
High Energy Physics	45,376	37,782	35,170
Multiprogram Energy Labs-Facilities Support	6,133	2,113	4,400
Nuclear Physics	18,060	18,213	17,899
Safeguards and Security	3,612	3,492	4,709
Science Program Direction	613	445	750
Total Laboratory	250,374	246,808	237,809
LAWRENCE LIVERMORE NATIONAL LABORATORY			
Advanced Computational Scientific Research	2,884	3,068	3,068
Basic Energy Sciences	5,966	5,316	4,628
Biological and Environmental Research	30,784	30,869	33,561
Fusion Energy Sciences	14,894	14,714	14,189
High Energy Physics	1,185	1,425	1,357
Nuclear Physics	792	732	672
Total Laboratory	56,505	56,124	57,475

	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request
LOS ALAMOS NATIONAL LABORATORY			
Advanced Computational Scientific Research	11,637	5,020	5,020
Basic Energy Sciences	23,696	22,721	22,927
Biological and Environmental Research	20,082	20,594	16,685
Fusion Energy Sciences	6,741	6,826	7,629
High Energy Physics	1,375	711	661
Nuclear Physics	10,714	9,479	9,798
Total Laboratory	74,245	65,351	62,720
NATIONAL RENEWABLE ENERGY LABORATORY			
Basic Energy Sciences	5,177	4,873	4,535
Biological and Environmental Research	99	-	-
Fusion Energy Sciences	50	-	-
Science Program Direction	-	120	100
Total Laboratory	5,326	4,993	4,635
OAK RIDGE NATIONAL LABORATORY			
Advanced Computational Scientific Research	12,016	10,563	10,223
Basic Energy Sciences	212,663	370,312	384,317
Biological and Environmental Research	30,805	36,545	39,761
Energy Research Analyses	64	-	-
Fusion Energy Sciences	18,369	16,116	16,412
High Energy Physics	536	327	307
Multiprogram Energy Labs-Facilities Support	1,101	6,627	7,620
Nuclear Physics	15,910	15,720	15,376
Safeguards and Security	8,970	9,162	15,024
Science Program Direction	642	-	-
Total Laboratory	301,076	465,372	489,040
PACIFIC NORTHWEST NATIONAL LABORATORY			
Advanced Computational Scientific Research	2,844	2,038	1,738
Basic Energy Sciences	12,072	11,846	11,398
Biological and Environmental Research	75,292	67,142	66,172
Energy Research Analyses	381	320	365
Fusion Energy Sciences	1,369	1,427	1,317
Multiprogram Energy Labs-Facilities Support	-	-	880
Science Program Direction	293	-	100
Total Laboratory	92,251	82,773	81,970

	FY 2000 Comparable Approp.	FY 2001 Comparable Approp.	FY 2002 Pres. Request
PRINCETON PLASMA PHYSICS LABORATORY			
Advanced Computational Scientific Research	38	-	-
Basic Energy Sciences	561	-	-
Fusion Energy Sciences	65,784	70,589	66,702
High Energy Physics	157	394	364
Safeguards and Security	1,680	1,735	1,829
Science Program Direction	-	110	100
Total Laboratory	68,220	72,828	68,995
SANDIA NATIONAL LABORATORY			
Advanced Computational Scientific Research	4,961	3,889	3,889
Basic Energy Sciences	23,740	22,967	22,843
Biological and Environmental Research	2,597	3,139	2,756
Energy Research Analyses	100	99	99
Fusion Energy Sciences	3,249	3,181	2,996
High Energy Physics	-	4	-
Nuclear Physics	-	4	-
Total Laboratory	34,647	33,283	32,583
STANFORD LINEAR ACCELERATOR CENTER			
Advanced Computational Scientific Research	590	234	234
Basic Energy Sciences	24,098	33,691	33,991
Biological and Environmental Research	3,060	3,489	4,300
Fusion Energy Sciences	49	-	-
High Energy Physics	152,858	158,681	164,343
Safeguards and Security	1,774	1,814	2,152
Science Program Direction	-	125	150
Total Laboratory	182,429	198,034	205,170
THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY			
Advanced Computational Scientific Research	49	-	-
Biological and Environmental Research	56	100	-
High Energy Physics	90	5	5
Nuclear Physics	72,779	73,336	73,830
Safeguards and Security	480	492	947
Science Program Direction	-	45	100
Total Laboratory	73,454	73,978	74,882

High Energy Physics

Program Mission

The mission of the High Energy Physics (HEP) program is to understand the universe at a fundamental level by investigating the elementary particles that are the basic constituents of matter and the forces between them. The mission has been consistently affirmed by the science community in long range planning efforts sponsored by the High Energy Physics Advisory Panel (HEPAP). The program supports one of the four business lines of the Department of Energy Strategic Plan: *Science*, and two goals of the Office of Science Strategic Plan: *Explore Matter and Energy* and *Provide Extraordinary Tools for Extraordinary Science*.

Unique Opportunities for World Leadership

Within the framework of a constant budget request for FY 2002, the U.S. High Energy Physics program is being realigned to take advantage of unique opportunities for history-making discoveries that have developed in the past year. The Large Electron-Positron Collider (LEP) experimental program at CERN was terminated in November 2000, leaving behind a tantalizing hint of a *Higgs boson* with a mass of about 115 GeV, well within reach of the Tevatron. The field transmitted by the Higgs boson is believed to be the source of all mass, and its discovery would be a major advance in physics. The Large Hadron Collider (LHC) now being constructed in the LEP tunnel at CERN will be a strong contender to find the Higgs, but cannot begin its active physics program before the spring of 2006. Thus the Tevatron at Fermilab, just upgraded with its new Main Injector, will have a chance to discover the Higgs before the LHC can get fully underway. With protons and antiprotons colliding head-on at an energy of nearly one trillion electron volts (1 TeV), the Tevatron will be at the world's energy frontier during this period. In order to find the Higgs in a few years, the Tevatron will need to run extensively and to increase its luminosity (and thus its data rate) as much as possible. To do this will require progressive fine-tuning of collider operations as well as further equipment upgrades to increase luminosity by a factor of ten. It will require a program of improvements to be carried out from 2002 to 2004, interleaved with intensive data runs. The data taken in 2005-2007 would then be enough to find the Higgs if its mass is less than 165 GeV. Tevatron data will also give more information about the surprisingly heavy (170 times the mass of the proton) *top quark* discovered there in 1995, and could reveal other important new particles that have been predicted by current theories (for example, *supersymmetric* particles).

At Stanford Linear Accelerator Center (SLAC), the highly successful B-factory and its BaBar detector will have the opportunity to shed light on the mysterious preponderance of matter over antimatter in the universe. Electrons colliding at several billion electron volts (GeV) will allow the study of an asymmetry known as *Charge-Parity (CP) violation* in B-mesons, which contain a heavy b-quark or its anti-particle, and have roughly five times the proton mass. CP violation was originally discovered in 1964 in an experiment at Brookhaven National Laboratory involving the much lighter K mesons, and its accommodation within the current theory has only recently been established through extremely difficult and exquisitely precise measurements at Fermilab and CERN. The big question for SLAC is whether CP violation in the B-mesons will follow theoretical predictions or will instead indicate some additional, hitherto unknown source of the phenomenon. Such a discovery would have profound implications for our understanding of the matter-dominated universe in which we live. The B-factory will need a progressive series of upgrades in order to be competitive with a similar facility now operating in Japan that has three times more design luminosity.

To fully exploit the discovery potential of the Tevatron at Fermilab and the B-factory at the SLAC along with their corresponding detectors as discussed above, these facilities must be strongly utilized and significantly upgraded in FY 2002 and beyond. Therefore, the FY 2002 budget focuses on the utilization and upgrades of these facilities to maximize the discovery potential with lower priority being given to other parts of the program. The distribution of resources as specified in this budget reflects this focused program.

Although the emphasis will be on the discovery potential at Fermilab and SLAC, there are other unique opportunities in the program.

The first results were announced in early 2001 from a precise measurement of the anomalous magnetic moment of the *muon*, one of the twelve fundamental constituents of matter. The measurement, from a dedicated experiment (called *g-2*) at Brookhaven's AGS accelerator, differs significantly from theoretical predictions. If this early result holds up after further analysis, it will be a signal of new physics beyond current theories. For example, it could mean that the supersymmetric particles mentioned above will indeed be discovered at the Tevatron. Because of the potential importance of the g-2 experiment, its running time will be extended in 2002.

A long baseline neutrino detection experiment called MINOS (the Main Injector Neutrino Oscillation Search) is currently being fabricated at Fermilab, and the NuMI project (Neutrinos at the Main Injector) will provide a dedicated beam of neutrinos for MINOS. With NuMI/MINOS, Fermilab will have the opportunity to confirm early indications of neutrino mass and to make precise mass measurements. Positive results would require that the current theory of elementary particles and interactions be modified and that a non-zero neutrino mass be incorporated into a larger, more encompassing theory.

Major Advances

The DOE HEP program has been extremely successful. Since the DOE and its predecessors began supporting more than 90% of the research in this field about 1950, our understanding of the fundamental nature of matter has deepened profoundly, generating a stream of Nobel Prizes. Cutting edge experimental research at DOE accelerator laboratories in the 1960s and 1970s revealed a deeper level in the structure of matter, and theoretical physicists developed a new theory to explain it. Neutrons and protons, the building blocks of atomic nuclei, were shown to be tightly bound systems of more basic constituents called *quarks*, all of which were discovered at DOE HEP laboratories. The last one, and the heaviest, was the top quark, found at Fermilab in 1995. DOE-supported university groups played major roles in all of these discoveries.

The strong force that binds quarks into nucleons is carried by particles called *gluons*, and they were discovered at the DESY laboratory in Germany in 1978. The carriers of a second nuclear force, the weak interaction responsible for radioactivity, are called *W* and *Z bosons*, and they were discovered at the CERN Laboratory in Switzerland in 1983. The *photon*, which carries the electromagnetic force so familiar in our everyday lives, has been known since the turn of the twentieth century.

These discoveries give us a new vision of the basic structure of matter that may be compared to the discovery of the atomic nucleus in the early twentieth century. It is encompassed within a theory known as the Standard Model, which identifies the basic constituents of matter and the fundamental forces that affect them. The theory also provides a mathematical structure to calculate properties of the particles and the ways they combine and interact with each other. The Standard Model lists twelve fundamental constituents of matter (*fermions*): six quarks and six leptons. They occur in three families, each containing two quarks and two leptons. All three families are organized in the same patterns, but the members have different masses. There is strong evidence that no more families of quarks and leptons exist.

The theory includes three of the four known basic forces: the *strong*, *electromagnetic*, and *weak* forces, and twelve force carriers (called *bosons:* eight gluons, two W's, the Z, and the photon). The fourth basic force, gravity, is not included. The quarks are subject to all four basic forces. The leptons (familiar examples are the electron and the neutrino) are subject to all of the basic forces except the strong force. Only two of the quarks—called *up* and *down*—are needed to make protons and neutrons. Thus these two quarks and just one of the leptons—the familiar electron—are sufficient to form all the stable matter that we observe on earth.

A major role in establishing the Standard Model is one of the proudest accomplishments of the DOE and its predecessor agencies. An American theoretical physicist supported by DOE took the lead in proposing that protons and neutrons must be made of smaller constituents, which he called quarks. American physicists, many of them working at DOE accelerator facilities, discovered all of the quarks and all but one of the leptons (the electron, known since 1897).

Major Questions

The Standard Model has been subjected to an array of rigorous tests for many years, and has survived all of them. It explains an amazing array of experimental data. Yet many important questions remain.

What gives elementary particles their great variety of masses; is it the Higgs boson predicted by the Standard Model? Why are there exactly three families of quarks and leptons? Are these fermions truly the fundamental constituents of matter, or are they made of still smaller particles? Do the leptons called *neutrinos* really have no mass at all? Can gravity be incorporated into the Standard Model to make a complete theory of all particles and forces? For every type of fermion, we have also created examples of its antiparticle (a kind of mirror image) but little of this *antimatter* is observed in the universe—why not? What is the *dark matter* that provides most of the mass in the universe, but emits no electromagnetic radiation? And what is the source of the recently observed acceleration in the expansion of the universe? Is there an undiscovered force or energy—the so-called *dark energy*?

Methods and Resources

Theoretical research in high-energy physics develops theories of elementary particles and forces. A theory expresses what is known in mathematical form and provides a way to calculate particle properties and processes. It also predicts new phenomena in ways that can be tested experimentally. Experimental work explores for new phenomena in promising areas and tests specific theoretical predictions. It relies principally on particle accelerators and particle storage rings, where beams of particles collide with targets or with other beams. Accelerator experiments typically require large and complex apparatus (*detectors*) built and used by large collaborations of physicists and engineers from universities and laboratories. The scientists who design and oversee these large detectors are primarily faculty and staff at many of the nation's best universities (DOE-HEP supports research groups at over 100 U.S. universities). In addition, there are university scientists supported by the NSF, participating scientists at DOE labs (principally Fermilab, SLAC, Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), and Argonne National Laboratory (ANL), and a substantial number of scientists from foreign institutions. Typically, these scientists work together in large international collaborations, involving hundreds of scientists from many institutions, to carry out a scientific program of experimentation that may take a decade to complete.

The main accelerator facilities in the United States are at two DOE laboratories: the Tevatron proton-antiproton collider at Fermilab in Illinois and the B-factory electron-positron collider at SLAC in California. DOE scientists also use the Alternating Gradient Synchrotron (AGS) proton synchrotron at BNL (operated for the DOE Nuclear Physics program), the CESR electron-positron collider at Cornell (operated by NSF), and facilities in other countries. American scientists have long used facilities at the European Organization for Nuclear Research (CERN), near Geneva, Switzerland, and those facilities will be even more important to the DOE program in the future. CERN has just shut down its LEP electron-positron collider and is building the LHC, which will begin operations in 2006. Under an international agreement established in 1997, DOE is providing substantial resources to help CERN build the collider itself and two major detectors (ATLAS and CMS). American scientists will participate strongly in research at the LHC.

Non-accelerator Experiments

It is important to note that while accelerators and accelerator- based experiments play a predominant role in the fields of high energy and nuclear physics, there are significant experiments that do not require the use of accelerators. Some of the non-accelerator experiments locate experimental apparatus on the earth's surface, others deep underground, and others in space. Non-accelerator experimentation is a growing part of the field of high-energy physics and offers many exciting opportunities for the future.

Examples include the study of neutrinos coming from the sun, the search for dark matter, and the search for extremely rare processes such as proton decay or neutrino-less double beta decay, all of which require specialized detectors deep underground. Other non-accelerator experiments are located at ground level, such as the Pierre Auger project, in which a system of detectors will cover thousands of square kilometers and study the highest energy cosmic rays; and the Supernova Cosmology Project, which discovered the accelerating universe, suggesting the existence of dark energy.

Still others take place in space. For example, the Alpha Magnetic Spectrometer (AMS) detector will be located on the International Space Station to search for anti-matter in space, and the Gamma Large Area Space Telescope (GLAST) will be placed in earth orbit to study high-energy gamma rays from "gamma ray bursters" and other astrophysical sources. This class of astrophysical phenomena is particularly interesting because it indicates that out in space there are concentrations of matter and acceleration mechanisms, and hence forces, far greater than any encountered here on earth.

Technical Requirements

High-energy physics has long supported an extensive program in technology research. This activity is a large annual investment, and it is fair to ask why is such a continuing investment necessary and given such high priority?

High-energy physics works with particle energies higher than exist anywhere but in certain stellar or cosmological environments and studies phenomenon on distance scales that are incomprehensibly small, much smaller than is required of any other science, except possibly nuclear physics. To make precision measurements of phenomenon buried in a background of noise and to search for very rare processes that may signal new physics, demands particle beams of greater intensities and detectors with both the sensitivity to see the rare events and the selectivity to pull these out of a cacophony of background noise. Thus the science demands accelerators and storage rings that operate at trillions of electron volts of energy and particle currents that can routinely burn holes in steel, and demands particle detectors that can identify one particle out of several thousand and catch particles that live less that a trillionth of a second. An unavoidable consequence is the essential need to accumulate, store, process, and transmit the increasingly large data sets produced by modern experiments. As international collaborations in high energy physics grow from the roughly 500 physicists presently working at each CERN, Fermilab, and SLAC detector to the approximately 1800 in each of the collaborations preparing detectors for the LHC, the need for data handling at widely separated data centers will become even more crucial.

The unavoidable consequence of operating in these extreme domains is the technological complexity, sophistication and size of the equipment used and the time and expense to design, build, maintain, operate, and upgrade the research apparatus. The R&D to conceive of a new accelerator or colliding beam device now requires 10 to 20 years of intensive work to bring the technology to the point of confidently proposing a new and cost effective construction, and the detectors and related computing needs have similar R&D needs. The R&D programs to sustain a forefront science program are unavoidably big, costly, and long term. Since almost none of the core technologies for these devices are marketable, particularly as systems, industry has no motivation to research, develop, or manufacture the key technical items, except as (usually expensive) special procurements. Consequently, in order to survive and to advance the science, it is essential for the universities and national laboratories engaged in high energy physics to themselves explore the scientific frontiers and cutting edge technologies that can generate the high energies, resolve the very small, make the measurements and analyze the results. Cutting edge science requires cutting technologies, and these require time and expense to produce and to make work effectively.

Benefits to Other Sciences and to Citizens

High-energy physics is profoundly connected to nuclear physics and to astrophysics and cosmology. Advances in any one of these fields often have a strong impact on another. A principal objective of nuclear physics research now is to incorporate the quark discovered by high-energy physics into the understanding of nuclear structure. High-energy physics, nuclear physics, and astrophysics detectors use many of the same techniques.

Technology that was developed in response to the demands of high-energy physics has become exceedingly useful to other fields of science, and thus has helped science to advance on a broad front. Synchrotron light sources, an outgrowth of electron accelerators and storage rings, have become invaluable tools for materials science, structural biology, chemistry, and environmental science. Accelerators are used for radiation therapy and to produce isotopes for medical imaging. In U.S. hospitals, one patient in three benefits from a diagnostic or therapeutic nuclear medicine procedure. The World Wide Web was invented by high-energy physicists to transport large bodies of data among international collaborators and is now bringing about a worldwide revolution in communications and commerce. International research collaborations in high-energy physics have set an example for other endeavors that require cooperative efforts by thousands of workers who must share facilities, data, and results, communicating among continents and managing the activities of diverse groups.

An important product of the HEP program is the set of talented people, trained in scientific methods and in state-of-the-art technologies. Many of them go into careers in high-tech industries, contributing to our country's economic strength.

Accelerator Research and Development

The Department is continuing research and development directed toward accelerator facilities that may be needed in the future. Several approaches are being investigated. One is a linear electron-positron collider, often called the Next Linear Collider (NLC), following the successful example of the SLAC Linear Collider. Work is directed toward achieving a center-of-mass energy in the TeV range (500 to 1000 GeV, expandable to 1.5 TeV. A GeV is one billion electron volts of energy.). The current NLC R&D program, led by SLAC and Fermilab, seeks to develop new technologies that would provide high performance while limiting cost. The R&D develops new technologies, applies available technologies, and uses industrial firms to expand its R&D reach on certain technologies and to engage in necessary technology transfer. A facility like the NLC may well be international, and research and development on linear colliders is also underway in other countries, primarily Germany and Japan.

Research is also underway on a storage ring that would collide muons rather than electrons. Radiation losses of energy from the beam would be less than for electrons and thus a circular machine could be used. The challenge for a muon collider is the short lifetime of the muon (two microseconds), which demands very rapid production, acceleration, and colliding of the beams. Fortunately, relativistic time dilation means a muon lives longer the faster it is moving through the laboratory. The decays of muons in a storage ring could also provide an intense source of neutrinos, and this idea is being investigated. Physicists are investigating the possibility of a storage ring that could serve as a muon collider and/or a neutrino factory.

In spite of the more complicated interactions of its “bags of quarks,” at energies well beyond the LHC, the best discovery machine may still be a high-energy hadron collider, with its broad range of physics interactions. Work is underway at several laboratories and universities toward designing magnets that could make possible an affordable hadron collider. Such a facility would have collision energy of perhaps 100 TeV, much higher than that of the LHC.

Program Goals

- Take advantage of unique opportunities for history-making discoveries.
- Advance our understanding of matter and energy at the most fundamental level, identifying the basic constituents of matter and characterizing their interactions.
- Advance our understanding of the origin and fate of the universe, from the Big Bang to the present time and beyond.
- Base programmatic decisions on the excellence of the science, the relevance to our national needs, and our ability to be among the leaders in international research in high-energy physics.

Regular peer review is used to evaluate research grants (primarily at universities). Program advisory committees advise DOE laboratories on the general direction of their accelerator research programs and review specific proposals for experiments. Overall **performance of the HEP program is measured by** the quality of scientific results as recognized by the scientific community and the productivity and utilization of research facilities.

Program Objectives

General Objectives

Theoretical research – Subject new experimental findings to thorough analysis and interpretation. Synthesize new and existing results into an overall coherent view of nature, developing new analytical structures as necessary. Identify key questions to be resolved by experiment.

Experimental research – Put our theoretical understanding of elementary particles and forces to rigorous experimental tests. Search for any new particles or interactions that may exist. Investigate astrophysical phenomena, using the knowledge and techniques of high-energy physics.

Accelerator facilities – Build new facilities in the United States as required to advance physics or take a substantial role in building facilities if the scope demands an international effort.

Preparation for future research – Progress in high-energy physics requires an ever-increasing experimental capability. Accelerator beams must increase in energy, intensity, and quality; detectors must improve in scope, resolution, and data recording rates, and in the ability to selectively identify events of interest. These preparations include modifications to existing accelerators and detectors, R&D aimed at possible new technologies, and the application of existing technologies to improve beams and detectors. Improvements are needed in the ability to store, transfer, and analyze increasing amounts of data. International collaborations must share access to these huge data sets.

Objectives for FY 2002

The main activities of the research component of the FY 2002 HEP Program are summarized below:

- Research using the Collider Detector Facility (CDF) and D-Zero at the Tevatron at Fermilab. A major upgrade of the CDF and D-Zero detectors was completed and brought into operation in FY 2001, providing significantly improved performance with the higher particle production rates available from the improved Tevatron, and improved precision in particle detection. The Tevatron is expected to operate for about 39 weeks in FY 2002, the first full year of operation after the upgrade.

  Search for the Higgs boson. The Higgs plays a key role in explaining the origin of mass.

  Study of the details of Quantum Chromodynamics (QCD), that is one basis of the Standard Model.

  A study of B-meson decays providing information complementary to that being obtained at the B-factory. The B-meson is one of only two particles, which exhibit CP violation.

  Precise measurements of masses and interactions of the W and Z bosons, that will set tighter bounds on the mass of the Standard Model Higgs boson.

- Research using the BaBar detector at the B-factory at SLAC. The B-factory is expected to operate for about 35 weeks in FY 2002.

  Study of the details of CP violation in B-meson decays. The B-meson is one of only two particles that exhibit CP violation. The B-factory was designed as the copious source of B-mesons needed for this research and has performed beyond expectations.

  Study of hadrons made only of combinations of the bottom quark and its antiquark (bottomonium spectroscopy).

Study of B-meson decays with a focus on very rare decay modes.

- Research using the AGS at BNL. The AGS is expected to operate for about 16 weeks for HEP research in FY 2002.

  Search for a very rare decay of the K meson. This experiment uses the K meson system to look for indications of physics beyond the Standard Model.

  Additional data taking for a precise measurement of the anomalous magnetic moment of the muon using the g-2 storage ring to pursue its early indications of physics beyond the Standard Model. In FY 2001, this experiment produced possible evidence for a significant deviation from the predictions of the Standard Model.

  A program of theoretical research at many of the universities and all of the major HEP laboratories.

- Other Research.

  Research at Super Kamiokande, in Japan, to study neutrino oscillations.

  Preliminary operation of the Cold Dark Matter Search (CDMS) an experiment designed to search for the dark matter, that apparently pervades the universe. CDMS is being constructed underground at a site in Minnesota.

  Operation of Phase I of the Pierre Auger experiment to study cosmic radiation at the highest energies. The Auger detector array is being constructed by an international collaboration at a site in Argentina.

  Experiments using the Cornell Electron Storage Ring, various international facilities with special capabilities, and a number of experiments, that do not use accelerators.

The main activities of the preparation-for-future-research component of the FY 2002 HEP program are summarized below:

- Continuation of the NuMI construction project at Fermilab that will provide a world-class facility to study neutrino properties and to make crucial measurements of neutrino mass.
- Continuation of U.S. participation in the LHC project at CERN. The HEP program is fabricating specific portions of the accelerator and of the two large detectors, ATLAS and CMS. It is also working to develop the computing and data management infrastructure in the United States that is the key to participation by U.S. scientists in obtaining physics results from the LHC experimental program. When the physics program begins in 2006, the LHC will be the world's energy frontier accelerator, and U.S. participation in its research program will become an integral part of the U.S. high-energy physics program.
- Technology R&D on new and improved magnets and accelerating devices, on needed improvements and enhancements of existing facilities, on possible future machine concepts, and on innovative, high risk possible new technologies. As always, the emphasis is on improved performance and reduced cost. R&D leading to improved performance of the facilities at Fermilab and SLAC is particularly important for the extraction of world-class physics results in a timely manner. While Technology R&D is sometimes focused on a particular possible future facility or facility upgrade, the results usually have wider application.
- Continued support for the fabrication of the CDMS, AMS and GLAST experiments, and R&D leading toward the SNAP project.

Funding Priorities

This program described above results in the following funding priorities which are designed to take advantage of the opportunity to discover the Higgs, search for physics beyond the Standard Model, and confirm and characterize neutrino oscillations and neutrino mass:

- Strong support for the operation and upgrades of the facilities at Fermilab – CDF, D-Zero and the Tevatron, as well as the supporting computing facilities.
- Strong support for the operation and upgrades of the BaBar detector, the linac, and B-factory at SLAC, as well as the supporting computing facilities.
- Support for accelerator R&D.
- Support for university and laboratory based physics research activities (both theory and experiment). The several experimental programs discussed above all are being performed by large collaborations of university (primarily) and laboratory based scientists. These scientists provide the effort needed to operate and maintain the detectors and to analyze the resulting data.
- Support for the continuation of the LHC fabrication activities as planned, and planning and preparation for the U.S. participation in the LHC research program.
- Continuation of the NuMI/MINOS construction project at Fermilab.
- Support for the operation of the AGS at BNL to conduct HEP experiments.

Evaluation of Objectives

The overall quality of the research in the High Energy Physics (HEP) Program will be judged excellent and relevant by external evaluation by peers, and through various forms of external recognition.

Leadership in key HEP disciplines that are critical to DOE's mission and the Nation will be measured through external review and other mechanisms.

At least 80% of all new research projects supported by HEP will be peer reviewed and competitively selected, and will undergo regular peer review merit evaluation.

Upgrades and construction of HEP scientific facilities will be managed to keep within 10 percent on average of schedule and cost milestones, including the U.S./DOE commitments to the international Large Hadron Collider project as reflected in the latest international agreement and corresponding plan.

HEP will ensure that operational downtime of the facilities it manages will be, on average, less than 10 percent of total scheduled operating days, barring unforeseen circumstances.

HEP will ensure the safety and health of the workforce and members of the public and the protection of the environment in all its program activities.

Significant Accomplishments and Program Shifts

Research and Technology

SCIENCE ACCOMPLISHMENTS

The following were accomplished in FY 2000:

The tau neutrino was discovered by the DONUT collaboration, a team of university and laboratory scientists working at Fermilab. This completed the last generation of leptons, and capped a major American achievement: the discovery of 11 of the 12 basic constituents of matter, the quarks and leptons of the Standard Model of elementary particles. (The first of the 12, the electron, had been discovered in England in 1897.) The discovery of the tau neutrino was considered by the American Institute of Physics to be one of the top three physics news stories of the year 2000.

University groups from the United States working on experiments at the LEP electron-positron collider at CERN completed their final data collection during FY 2000. Early analysis gave tantalizing indications that the Higgs boson may have been produced at LEP. Although not a definitive discovery, this finding was considered one of the top three physics news stories of the year 2000. In FY 2002, the data analysis should be well advanced. Discovery and study of the Higgs boson, believed to be the source of mass for all elementary particles (and hence, of all matter) is a major objective of the LHC.

At a 2000 conference in Osaka, Japan, physicists using the new BaBar detector at the new SLAC B-factory announced their first measurement of CP violation in the B-meson system. American physicists also participated in the BELLE experiment at the Japanese KEK laboratory, which reported similar measurements. The two results are consistent with each other, and with an earlier measurement from CDF at the Fermilab Tevatron. They are also consistent with the current Standard Model description of CP violation. More data are needed to make an incisive measurement that will confirm or refute the Standard Model. BaBar has collected much more data since the summer of 2000 and has recently announced new results which are very interesting but not conclusive. Data collection continues with high priority.

The g-2 experiment at BNL, designed to study magnetic properties of the muon, has obtained the most precise measurement of the muon anomalous magnetic moment. Preliminary results announced in 2001 do not agree with the standard model, suggesting new physics beyond the standard model. The measurement precision should improve by perhaps a factor of 2 as analysis proceeds and more data are collected. If this result is confirmed, it would be the first clear indication of new physics beyond the Standard Model.

Teams of university and laboratory scientists using the CDF and D-Zero detectors at the Fermilab Tevatron measured the mass and production properties of the top quark. This is the last and by far the heaviest of the quarks (fundamental building blocks of matter) predicted by the Standard Model. The mass of the top quark is now measured more accurately than that of any other quark. Further refinements of this result are continuing and will improve even more with data from the upcoming run of the Tevatron with the newly upgraded Main Injector.

Two physicists shared the Nobel Prize for Physics for 1999, for theoretical work that helped establish the Standard Model. One of the two was long supported by DOE as a physics professor at the University of Michigan.

A team of university and laboratory scientists working at the Fermilab Tevatron made the world's most precise measurement of the mass of the W boson, which transmits the weak interaction, one of the basic forces. This result is now considerably more precise than the best measurement from the

LEP facility at CERN. It will improve even more with data from the upcoming run of the Tevatron with the newly upgraded Main Injector.

The world's highest precision single measurement of the weak mixing angle, a fundamental parameter of the Standard Model, was made by a group of university and laboratory scientists working at the SLAC Linear Collider (SLC) with the Stanford Large Detector (SLD). The ability to longitudinally polarize the electron beams (align their spins along their flight paths) in a linear collider was the key to achieving high precision. The final result from the final data run has now been obtained.

The B meson containing a charmed quark was observed and its properties measured by the international CDF collaboration working at Fermilab. This discovery completes the observations of the predicted family of B mesons, lending support to the Standard Model.

The first convincing observation of direct CP violation in the fundamental Standard Model interaction was found in decays of K mesons by a team of university and laboratory scientists working on the KTeV experiment at the Fermilab Tevatron. Additional data is being analyzed to refine this key result and to compare it with a new measurement at CERN.

The observation of the predicted CP-violating decay of the kaon into a pair of pions and an electron-positron pair was made for the first time ever by the KTeV collaboration at Fermilab. This decay could be an indication of another fundamental asymmetry, violation of time reversal invariance. Further refinement of this result was achieved.

U.S. university groups involved in the new HERA-B experiment at the DESY machine in Germany began their first data collection run with the newly upgraded detector in FY 2000.

Observations of the gamma ray flare from Hercules X-1 as recorded at the Whipple Observatory on Mt. Hopkins in Arizona has provided data which puts a new upper limit on quantum gravity effects.

A major advance in theoretical physics was achieved when it was shown and verified that all of the known "string" theories are equivalent. This greatly reduces the number of possible theories that could describe all of the known forces including gravity (which is not described by the Standard Model). Further work toward delineating the underlying theory from which all string theories originate is continuing at a fast pace.

Theoretical studies have led to a prediction that the "missing dimensions" in string theories may, under certain circumstances, be experimentally detectable, thus suggesting a way to test the validity of this class of theories.

A SLAC 30 GeV electron beam was directed through a 1.5-meter segment of lithium plasma, creating a plasma wave that exhibited an accelerating gradient of greater than 0.5 GeV per meter. This is a record in a highly speculative program that may have a potential of eventually approaching accelerating gradients of 10's of GeV per meter.

Evidence of neutrino mass and quantum mixing of neutrino types was obtained in a U.S.-Japanese experiment with the Super-Kamiokande experiment in Japan. Further data and refinement of these results was achieved. Long-baseline neutrino beam experiments in Japan and at Fermilab are underway to verify the results.

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 when the LHC begins physics operation in FY 2006.

Facility Operations

FACILITY ACCOMPLISHMENTS

The Tevatron completed commissioning with the new Main Injector, and the two upgraded detectors (CDF and D-Zero) were brought into operation in FY 2001. FY 2002 will be a full year of operation to exploit these new capabilities.

The B-factory at SLAC was brought into full operation during the early part of FY 2000 and has achieved design luminosity. During FY 2002, the B-factory will be operated for maximum data collection on the key scientific question of understanding matter-antimatter asymmetry in the universe.

The new BaBar detector at the B-factory at SLAC became fully operational in FY 2000 and is performing very well in FY 2001, collecting data at a high rate.

The Alternating Gradient Synchrotron at BNL is operated by the Nuclear Physics program as part of the Relativistic Heavy Ion Collider (RHIC) facility but is available for use by the High Energy Physics program on an incremental cost and programmatic non-interference basis. The high precision muon magnetic moment experiment (the “g-2” experiment) at the AGS reported its first results in FY 2001, obtaining a record level of precision and indicating the possibility of new physics phenomena. In FY 2002, the AGS will be operated for the g-2 experiment and for a high priority rare kaon decay experiment.

The newly upgraded CLEO-III detector at the upgraded CESR facility at Cornell began operation in FY 2000 and is performing very well in FY 2001. DOE supports more than half the university groups using this new facility.

PROGRAM SHIFTS

Research with the CDF and D-Zero detectors at the Tevatron and the BaBar detector at the B-factory will receive greater emphasis to take advantage of the major science opportunities described above. For the same reason, a number of planned upgrades to both facilities intended to increase the luminosity and improve the machine and detectors are being given high priority. Lower priority parts of the program will be reduced.

A long range planning study of the High Energy Physics program, entitled “Planning for the Future of U.S. High Energy Physics,” was prepared in 1998 by a Subpanel of the High Energy Physics Advisory Panel (HEPAP). The Subpanel’s recommendations were considered carefully in preparing this budget.

An update of this report, entitled “HEPAP White Paper on Planning for U.S. High-Energy Physics,” has recently been prepared by HEPAP and was also used in planning this budget.

A new HEPAP Subpanel has been assembled and charged to prepare an updated long range planning report. This report is expected by the end of 2001.

DOE is establishing an exciting and expanding partnership with NASA in the area of Particle Astrophysics. The Alpha Magnetic Spectrometer (AMS) and Gamma Large Area Space Telescope (GLAST) experiments have been underway for some time. Preliminary consideration is being given to the interagency SuperNova Acceleration Probe (SNAP) experiment. These experiments, and others that may be proposed, will provide important new information about cosmic rays and the rate of expansion of the universe which will in turn lead to a better understanding of dark matter, dark energy, and the original big bang. The AMS and GLAST experiments, which are joint DOE-NASA projects, have received NASA mission approval.

Scientific Facilities Utilization

The High Energy Physics request includes $495,506,000 to maintain support of the Department's scientific user facilities. This investment will provide significant research time for several thousand scientists in 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 Stanford Linear Accelerator Center (SLAC). The Alternating Gradient Synchrotron (AGS) at the Brookhaven National Laboratory (BNL), is now part of the Nuclear Physics (NP) funded Relativistic Heavy Ion Collider (RHIC) complex and is being operated for HEP purposes on a limited basis.

Workforce Development

The High Energy Physics program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program 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), space exploration, and the stock market.

About 1250 post-doctoral associates and graduate students supported by the High Energy Physics program in FY 2001 were involved in a large variety of experimental and theoretical research. About one-fifth 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 have worked at one of the three High Energy Physics User Facilities: Fermi National Accelerator Laboratory, Stanford Linear Accelerator Center, and Brookhaven National Laboratory.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Current Appropriation	FY 2002 Request
High Energy Physics					
Research and Technology	236,028	234,720	+8,116 [a]	242,836	247,870
High Energy Physics Facilities	418,322	459,010	-22,174 [a]	436,836	456,830
Subtotal, High Energy Physics	654,350	693,730	-14,058	679,672	704,700
Construction	28,700	32,400	-71	32,329	11,400
Subtotal, High Energy Physics	683,050 [b]	726,130	-14,129	712,001	716,100
General Reduction	0	-7,101	7,101	0	0
General Reduction for Safeguards and Security	0	-5,458	5,458	0	0
Omnibus Rescission	0	-1,570	1,570	0	0
Subtotal, High Energy Physics	683,050 [c] [d]	712,001	0	712,001	716,100
Pending Budget Amendment	0	0	0	0	5,000 [e]
Total, High Energy Physics	683,050	712,001	0	712,001	721,100

Public Law Authorization:

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

Public Law 103-62, "Government Performance and Results Act of 1993"

[a] Includes $12,969,000 transferred from High Energy Physics Facilities to Research and Technology in FY 2002 to realign capital equipment funding.

[b] Excludes $13,797,000 which has been transferred to the SBIR program and $828,000 which has been transferred to the STTR program.

[c] Includes $5,180,000 for Waste Management activities at Lawrence Berkeley National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[d] Excludes $5,248,000 for Safeguard and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[e] A Budget Amendment transferring $5,000,000 from this program will be submitted shortly. The narrative description for this program has already been adjusted to reflect the revised levels.

Funding by Site

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	1,375	711	661	-50	-7.0%
Sandia National Laboratory	0	4	0	-4	-100.0%
Albuquerque Operations Office............	13	0	0	0	0.0%
Total, Albuquerque Operations Office	1,388	715	661	-54	-7.6%
Chicago Operations Office					
Argonne National Laboratory	10,828	8,858	9,990	+1,132	+12.8%
Brookhaven National Laboratory..........	38,778	26,507	32,595	+6,088	+23.0%
Fermi National Accelerator Laboratory .	294,627	289,507	314,878	+25,371	+8.8%
Princeton Plasma Physics Laboratory ..	157	394	364	-30	-7.6%
Chicago Operations Office..................	89,067	85,107	72,566	-12,541	-14.7%
Total, Chicago Operations Office................	433,457	410,373	430,393	+20,020	+4.9%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	45,376	37,782	35,170	-2,612	-6.9%
Lawrence Livermore National Laboratory	1,185	1,425	1,357	-68	-4.8%
Stanford Linear Accelerator Center	152,858	158,681	164,343	+5,662	+3.6%
Oakland Operations Office	38,713	37,788	34,804	-2,984	-7.9%
Total, Oakland Operations Office	238,132	235,676	235,674	-2	0.0%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	186	130	130	0	0.0%
Oak Ridge National Laboratory	536	327	307	-20	-6.1%
Thomas Jefferson National Accelerator Facility.............................	90	5	5	0	0.0%
Oak Ridge Operations Office	27	15	0	-15	-100.0%
Total, Oak Ridge Operations Office	839	477	442	-35	-7.3%
Washington Headquarters	9,234	64,760	48,930	-15,830	-24.4%
Subtotal, High Energy Physics..................	683,050[abc]	712,001	716,100	+4,099	+0.6%
Pending Budget Amendment	0	0	5,000[d]	+5,000	--
Total, High Energy Physics........................	683,050	712,001	721,100	+9,099	+1.3%

[a] Excludes $13,797,000 that has been transferred to the SBIR program and $828,000 that has been transferred to the STTR program.

[b] Includes $5,180,000 for Waste Management activities at Lawrence Berkeley National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $5,248,000 for Safeguards and Security activities transferred to the consolidated Safeguards and Security program in FY 2001.

[d] A Budget Amendment transferring $5,000,000 from this program will be submitted shortly. The narrative description for this program has already been adjusted to reflect the revised levels.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a multiprogram laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. High Energy Physics supports a program of physics research and technology R&D at ANL, using unique capabilities of the laboratory in the areas of accelerator R&D techniques and participation in the CDF and MINOS detector collaborations.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a multiprogram laboratory located on a 5,200-acre site in Upton, New York. High Energy Physics supports a program of physics research and technology R&D at BNL, using unique capabilities of the laboratory, including the Accelerator Test Facility and its capability for precise experimental measurement. High Energy Physics also makes limited use of the Alternating Gradient Synchrotron (AGS), a 28 GeV proton accelerator, which is principally supported by the Nuclear Physics program. The AGS is used for high-energy physics experiments that need its unique high quality and high intensity beams of secondary particles such as pions, kaons, and muons.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory (Fermilab) is a program-dedicated laboratory (High Energy Physics) located on a 6,800-acre site in Batavia, Illinois. Fermilab operates the Tevatron accelerator and colliding beam facility, which consists of a four-mile ring of superconducting magnets and is capable of accelerating protons and antiprotons to an energy of one trillion electron volts (1 TeV). Thus the Tevatron is the highest energy proton accelerator in the world, and will remain so until the LHC begins physics operation in 2006. With the recent shutdown of the LEP machine at CERN in Switzerland, the Tevatron became the only operating particle accelerator at the energy frontier. Thus Fermilab has an excellent window of opportunity for making important new scientific discoveries. Fermilab also includes the Main Injector, a pre-accelerator 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. Fermilab and SLAC are the principal experimental facilities of the DOE High Energy Physics program.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a multiprogram laboratory located in Berkeley, California. The laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. High Energy Physics supports a program of physics research and technology R&D at LBNL, using unique capabilities of the laboratory primarily in the areas of participation in the BaBar collaboration, expertise in superconducting magnet R&D, world-forefront expertise in laser driven particle acceleration, and expertise in design of forefront electronic devices.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a multiprogram laboratory located on an 821 acre site in Livermore, California. High Energy Physics supports a program of physics research and technology R&D at LLNL, using unique capabilities of the laboratory primarily in the area of advanced accelerator R&D and participation in the B-factory effort.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a multiprogram laboratory located on a 27,000 acre site in Los Alamos, New Mexico. High Energy Physics 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, and computational techniques for accelerator design.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on a 150 acre site in Oak Ridge, Tennessee. The High Energy Physics program supports a small effort at ORISE in the area of program planning and review.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a multiprogram laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The High Energy Physics program supports a small research effort using unique capabilities of ORNL primarily in the area of particle beam shielding calculations.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 72 acres in Princeton, New Jersey. The High Energy Physics program supports a small research effort using unique capabilities of PPPL in the area of advanced accelerator R&D.

Sandia National Laboratory

Sandia National Laboratory (SNL) is a multiprogram laboratory located on a 3,700 acre site in Albuquerque, New Mexico, with other sites in Livermore, California and Tonopah, Nevada. The High Energy Physics program supports a small effort at SNL in the area of logic modeling.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. SLAC operates for High Energy Physics the recently completed B-factory and its detector, BaBar, and a program of fixed target experiments. The B-factory, a high-energy electron-positron collider, was constructed to support a high quality search for and 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 DOE High Energy Physics program.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport, News, Virginia dedicated to the exploration of nuclear and nucleon structure. The High Energy Physics program supports an R&D effort aimed at computer modeling of accelerator behavior.

All Other Sites

The High Energy Physics program supports about 260 research groups at more than 100 colleges and universities located in 37 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. These university based components of the HEP program provides access to some of the best scientific talent in the nation, and train the next generation of scientists.

The High Energy Physics program also funds research at a small number of non-DOE laboratories and non-government laboratories and institutes (National Institute for Standards and Technology, Naval Research Laboratory).

Research and Technology

Mission Supporting Goals and Objectives

The Research and Technology subprogram provides support for the university and laboratory based research groups carrying out the planned physics research and technology development programs for FY 2002 described below and planning the programs to be carried out in future years. **Performance will be measured by** the results of reviews of ongoing activities, by sustained achievement in advancing knowledge, as measured by the quality of the research based on results published in refereed scientific journals, and by the degree of invited participation at national and international conferences and workshops.

Physics Research

The Physics Research category in the Research and Technology subprogram supports the university and laboratory based scientists performing experimental and theoretical HEP research.

Experimental research activities include: planning, design, fabrication and installation of experiments; conduct of experiments; analysis and interpretation of data; and publication of results. Theoretical physics research provides the framework for interpreting and understanding observed phenomena and, through predictions and extrapolations based on current understanding, identifies key questions for future experimental investigation. The research groups are based at ANL, BNL, Fermilab, ORNL, LANL, LBNL, LLNL, and SLAC, and about 100 colleges and universities.

The major planned Physics Research efforts in FY 2002 are:

- The research program at the B-factory/BaBar facility at SLAC. This research program is being carried out by a collaboration including scientists from SLAC, LBNL, LLNL, ORNL, 31 U.S. universities, and institutions from 6 foreign countries.
- The research program using the Tevatron/CDF facility at Fermilab. This research program is being carried out by a collaboration including scientists from Fermilab, ANL, LBNL, 25 U.S. universities, and institutions in 10 foreign countries.
- The research program using the Tevatron/D-Zero facility at Fermilab. This research program is being carried out by a collaboration including scientists from Fermilab, BNL, LBNL, 33 U.S. universities and institutions in 16 foreign countries.
- Planning and preparation for the U.S. portion of the research program of the LHC when it becomes operational in 2006. A major effort in FY 2002 will be the design and initial implementation of the U.S. data handling and computing capabilities needed for full participation in the LHC research program.
- The research program using the AGS at BNL. This research program is being carried out by a collaboration including scientists from BNL, Fermilab, one U.S. university and institutions in three foreign countries.
- A program of theoretical research at both universities and laboratories to identify questions for future research, and further the understanding of new experimental results.

- A group of experimental research activities using the Cornell Electron Storage Ring and various international facilities with special capabilities, and experimental activities, which do not require an accelerator beam.

High Energy Physics Technology

The High Energy Physics Technology category in the Research and Technology subprogram provides support for the specialized advanced technology R&D required to sustain and upgrade the presently operating facilities, to support new accelerator and detector facilities presently under construction, and to extend the technology base so as to make possible and cost effective use of the new future facilities which will be needed to continue progress in the field.

The major planned High Energy Physics Technology efforts in FY 2002 are:

Support for R&D related to existing facilities and facilities under construction. This R&D ensures the cost-effective performance of the facility, the ready adaptation for new research requirements, and the machine and detector performance improvements needed to address new research frontiers. This R&D is carried out at Fermilab, SLAC and BNL for the AGS.

Support for general Technology R&D. A component of the R&D at each of the HEP laboratories is focused on improvements in the general areas of technology important at that laboratory but not directly connected to the operating machine or a facility under construction. The principal activity is R&D on high field superconducting accelerator magnets and new detection technologies.

Support for R&D related to a possible future muon collider or muon storage ring (neutrino source). The muon is over 200 times heavier than an electron, but otherwise very similar in properties. The mass of the muon effectively eliminates the radiation losses, which severely limit circular electron machines. Thus a muon colliding beam machine, if it can be made to work, is an attractive alternate (to large linear colliders) approach to research needing high-energy colliding beams of leptons. Moreover, the decay of the circulating muons can result in a well-collimated, intense beam of neutrinos, with additional interesting physics possibilities, such as searching for evidence of neutrino mass.

The fundamental problem with muon storage rings is that the muon has a finite lifetime measured in millionths of a second. Thus the production, capture, acceleration, storage, and collision of the muons must be done very rapidly. A key feasibility issue is the need to show experimentally that this production, capture, acceleration and storage can be done with sufficient speed and efficiency so as to provide usable beam intensity. The other key feasibility issue is that after the muons are stored in the ring, the beam must be focused and the beam size reduced so as to provide a useful muon-muon collision rate (this is known as “cooling”). R&D, and planning for appropriate experimental verification is underway aimed at both issues. The requirements present major challenges to the development of extremely high power beam targets, high power radio frequency systems, and intense beam transport systems.

This R&D program involves a collaboration of national laboratories and universities. Fermilab is the lead laboratory for work related to the “cooling” issue, and BNL is the lead laboratory for work related to the “production” issue.

Support for Linear Collider R&D. Electrons (and muons) are simple point particles; protons (and antiprotons) are composite particles made up of three different quarks. In electron-positron collisions, the initial state is quite simple, and the collision receives all the available energy. In proton-antiproton collisions the initial state is more complex consisting of two sets of three quarks. Only one pair of quarks actually collide, and the energy transferred to the collision is only that portion of the total available which is carried by the two colliding quarks. (This fraction of the total energy varies from collision to collision significantly, complicating the experimental analyses.) In short, electron and proton colliders provide very complementary capabilities and there is general agreement in the research community that it is essential for the HEP program to pursue both techniques to the highest energies, and that an electron complement to the LHC is needed.

The apparent research advantage for electron colliders is significantly offset by the difficulty in providing very high-energy electron collisions. In the 1 TeV energy regime, circular electron accelerators are impossible due to the enormous radiation losses from the stored beams. (The higher masses of protons or even muons completely avoid this limitation). The alternative is a linear arrangement in which beams from two linear accelerators are aimed at each other and produce electron-positron collisions. This approach was demonstrated to work with the operation of the Stanford Linear Collider (SLC) at SLAC. Following on the success of the SLC, an international R&D collaboration (with SLAC as a major participant) has identified and attacked the technical barriers to the construction of a TeV scale linear collider. The SLAC version of this concept is called the Next Linear Collider (NLC) and the focus of the R&D effort has shifted toward cost reduction strategies.

The R&D program focused on solution of the technical challenges related to building TeV scale linear electron-positron colliders is being carried out on an international basis. The international collaboration includes the Japanese high energy physics center, KEK, through a SLAC-KEK inter-laboratory memorandum of understanding, and by less formal arrangements, with R&D groups at the German DESY Laboratory, CERN, and the Budker Institute in Russia. The U.S. is a world leader in this R&D program. The program is being carried out by a national collaboration that includes SLAC as the principal laboratory, Fermilab as the major collaborator, and with significant contributions from Lawrence Berkeley National Laboratory and Lawrence Livermore National Laboratory.

The specific goals of the present NLC R&D program include developing new technologies that enable a higher performance, lower cost machine; carrying out systems engineering, value engineering, and risk analysis studies to identify additional R&D issues that could effect cost and performance and to select from available technologies; and using industrial firms to carry out R&D on selected technologies, thus exploiting the special “design-for-manufacture” expertise available in industry and effecting technical transfer from the NLC R&D program to industry. In addition, cost analysis and scheduling tools are being developed that can be used to guide the R&D program by identifying cost driving technologies. In FY 2002, the R&D program led by Fermilab and SLAC will focus on reliably achieving accelerating gradients in radio frequency structures in the range of 75 to 100 MeV/meter. There will also be significant studies of design alternatives for electron-positron sources with a goal of higher performance (higher brightness) and much lower cost, and studies of designing for ease of manufacturability (i.e. lower cost) of subsystems and major components.

Support for future oriented, high risk R&D. Advances in HEP are strongly dependent upon the development of new, higher-performance research instruments. Probing ever more deeply into the structure of matter and energy requires particle accelerators, and detectors operating at higher and higher energies and intensities. The principal technologies that have been used to produce high particle energies are radio frequency acceleration and high field magnets. Today, the needs of high-energy physics are pushing these technologies to limits unimagined twenty years ago. To respond, HEP funds research looking for new approaches to these underlying technical needs. A further goal is to develop a program for graduate training in the science and technologies underlying charge particle beam sources – the accelerators and storage ring systems essential to forefront research in high-energy particle physics.

The range of topics explored in the HEP Technology activity is very broad, but the principal goals are improved accelerating systems, stronger and more precise beam focusing systems, and improved mathematical understanding and computer modeling of accelerators. Conventional radio frequency accelerating systems probably cannot operate above gradients of 100 to 200 million volts per meter, so the use of lasers and plasmas as advanced accelerating devices is being studied. Today's magnetic fields routinely reach up to about 10 Tesla. This R&D program has as a goal, magnets that can operate at 16 to 18 Tesla and are cost effective to build. This goal requires improved industrially available superconductors and new magnet geometries and structures and all of these are being explored. A major part of the research program is devoted to developing new theoretical, mathematical and computational approaches. These efforts focus heavily on the areas of classical non-linear dynamics, space charge dominated charged particle beams, and physical phenomenon associated with plasma waves moving close to the speed of light.

The HEP Technology research is carried out at BNL, ANL, LBNL, LANL, two non-DOE laboratories (Naval Research Laboratory and National Institute for Science and Technology), and thirty-four universities, the largest programs being at the University of Maryland and University of California, Los Angeles.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Physics Research	161,706	156,386	155,140	-1,246	-0.8%
High Energy Physics Technology	74,322	84,971	84,779	-192	-0.2%
SBIR/STTR	0	1,479	7,951	+6,472	+437.6%
Total, Research and Technology	236,028	242,836	247,870	+5,034	+2.1%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Physics Research	**161,706**	**156,386**	**155,140**

Physics Research			
Universities	105,266	101,307	96,637
Fermilab	8,756	8,980	10,747
SLAC	12,812	12,187	13,795
BNL	11,212	10,834	10,242
LBNL	14,178	14,556	13,743
ANL	6,652	6,483	6,125
Other Physics Research	2,830	2,039	3,851
Total, Physics Research	161,706	156,386	155,140

Universities	**105,266**	**101,307**	**96,637**

The University Program consists of groups at more than 100 universities doing experiments and theory. These university groups plan, build, execute, analyze and publish results of experiments; train graduate students and post-docs; and provide theoretical concepts, simulations and calculations of physical processes involved in high energy physics. The university groups usually work in collaboration with other university and laboratory groups. University based research efforts will be selected based on review by appropriate peers. The last HEPAP Subpanel (1998), recommended that the level of funding for the university-based portion of the program be substantially increased over inflation over a two-year period.

The university program is reduced by about 4.6%. The funds are shifted to support the strong initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. To the extent possible, the reductions 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 at CDF, D-Zero, BaBar, etc., work on the design and fabrication of the LHC detector components, and work on the preparation for U.S. participation in the LHC research program.

These university based research activities are described in more detail below. The funding levels presented are estimates based on FY 2000 experience.

University Based Research at Fermilab	**30,375**	**29,160**	**27,885**

Some 55 DOE-funded universities participate in large international collaborations doing experiments at Fermilab. These experiments involve the CDF and D-Zero collider detectors, and the KTeV, MINOS, and Mini Boone experiments using external beams of kaons, and, neutrinos. Other experiments are performed in the antiproton accumulator. The experiments: study the production and interaction of quarks and gluons as a probe for new particles such as the Higgs;

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

search for evidence for the possible mass of the neutrino and for the transition of neutrinos among the various types; search for possible sources for the asymmetry of matter over antimatter in the universe, and a number of other topics. These universities help to fabricate the detectors, plan and execute the experiments, analyze data and publish the results. The emphasis of groups working at Fermilab is shifting as activity related to 800 GeV fixed target experiments diminishes and activities related to Tevatron, MINOS, and other new experiments increase.

	FY 2000	FY 2001	FY 2002
University Based Research at SLAC............................	**12,205**	**11,755**	**11,205**

Some 22 DOE-funded universities participate in large international collaborations doing experiments at SLAC. The experiments involve the BaBar detector and other smaller detectors for fixed target experiments. These experiments are investigating fundamental constituents of matter such as the b quark. In particular, the BaBar detector is being used to study the nature of CP violation in the B meson system. These universities help to build the detectors, plan and carry out experiments, analyze the data and publish the results.

	FY 2000	FY 2001	FY 2002
University Based Research at BNL	**2,685**	**2,585**	**2,465**

Some 8 DOE-funded universities participate in collaborative experiments at BNL. These experiments involve fixed targets and kaon or pion beams, colliding beams of protons (RHIC-SPIN) or nuclei (PHOBOS) at RHIC, and an external storage ring measuring the muon anomalous magnetic moment to high precision.

	FY 2000	FY 2001	FY 2002
University Based Research at Cornell..........................	**5,195**	**5,005**	**4,765**

Some 11 university High Energy Physics groups with DOE funding participate in the electron-positron colliding beam experiments at Cornell's CESR facility utilizing the collaboratively built CLEO detector studying various aspects of b meson interactions and decay.

	FY 2000	FY 2001	FY 2002
University Based Non Accelerator Research...............	**10,960**	**10,555**	**10,060**

Some 34 DOE-funded universities are involved in supporting the High Energy Physics experiments not utilizing accelerators. The principal experiments being supported in FY 2002 are:

- The Cryogenic Dark Matter Search (CDMS) and Pierre Auger projects that are currently being fabricated. A description of CDMS is under the Fermilab section and Auger is described under the Other Physics Research section.
- The first phase of the Alpha Magnetic Spectrometer (AMS) experiment is complete and the data are being analyzed to obtain key information on the presence of antimatter in the cosmic radiation. The Detector is being upgraded for a second shuttle flight. The planned FY 2002 funding is $1,000,000 and the TEC for the DOE portion of the AMS upgrade is $3,028,000.
- Other active experiments, which are primarily in the areas of high-energy astrophysics and cosmology, include MACRO (Italy), Super-Kamiokande (Japan), KamLAND (Japan), SNO (Canada), CHOOZ (France), SOUDAN (Minnesota), GRANITE (Mt. Hopkins, Arizona), Palo Verde (Arizona), GLAST and SNAP (satellite).

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
University Based Research at Foreign Labs	**20,405**	**19,660**	**18,735**

Universities funded by the DOE are doing experiments with international collaborations using facilities at foreign accelerator labs. Some 45 universities are conducting experiments at CERN (Switzerland), 11 at DESY (Germany), 10 at KEK (Japan), 1 at IHEP (Russia), 1 at BINP (Russia), and 2 at Beijing (China). This research addresses a wide range of fundamental questions such as the search for the Higgs boson, which may be a key to understanding the source of mass. The emphasis of university groups is shifting to the LHC research program at CERN/LHC and away from activities at DESY and the older programs at CERN.

University Research in Theory	**21,810**	**21,015**	**20,025**

Some 75 universities with DOE funding participate in research in theoretical high-energy physics. Theoretical ideas, concepts, calculations and simulations of physical processes in high energy physics are a key to progress in that they provide guidance for the design of experiments and the basis for program priorities.

Other University Funding	**1,631**	**1,572**	**1,497**

Primarily includes funding held pending completion of peer review of proposals that have been received, and funds to respond to new and unexpected physics opportunities. The Outstanding Junior Investigator program, that is intended to identify and provide support for highly promising investigators at an early stage in their careers, will continue at a level of about $400,000.

Fermilab..	**8,756**	**8,980**	**10,747**

In FY 2002, the experimental physics research groups at Fermilab will be focused mainly on data-taking with the upgraded CDF and D-Zero collider detector facilities, analysis of data taken in the 800 GeV fixed-target program and the FY 2001 collider run, fabrication of the MINOS detector, and fabrication of the CMS detector for the LHC. Also includes funding for work in theory and astrophysics. The request includes funds to continue the Cryogenic Dark Matter Search (CDMS). The CDMS detector will use cryogenic techniques to search for weakly interacting massive particles (WIMPS). WIMPS are proposed as a possible explanation for the “missing” mass in the universe. CDMS is being done by a collaboration of universities and laboratories. The detector will be installed in the Soudan II underground laboratory in northern Minnesota. The planned FY 2002 funding is $1,060,000 and the TEC for CDMS is $8,600,000. Funding is increased substantially reflecting the importance of collecting and analyzing data from the Run II Campaign. **Performance will be measured by** capitalizing on the opportunities to discover the Higgs Boson, to search for physics not adequately described by the standard model, and to confirm and characterize neutrino oscillations and neutrino mass.

SLAC...	**12,812**	**12,187**	**13,795**

The experimental physics research groups at SLAC will concentrate their efforts in FY 2002 on data taking and analysis of data from the BaBar detector operating with the PEP-II accelerator facility. This data will be used to study CP violation in B meson decays and to help explain the preponderance of matter over antimatter in the universe. They will also work on completing the analysis of the data from the operation of the SLD detector. Fabrication of the Gamma Large Area

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

Space Telescope (GLAST) will be a significant effort in FY 2002 in preparation for the launch projected to be in FY 2005. GLAST will study the very high-energy cosmic rays reaching the earth before they have interacted in the atmosphere. Some physics research will also be done by fixed target experiments. The theoretical physics group will continue to emphasize topics related to BaBar and the other SLAC experimental physics programs as well as tests of the Standard Model Quantum chromodynamics (QCD) and Supersymmetry. Funding is increased substantially to reflect the importance of having the scientific data collected and analyzed by the scientists.

	FY 2000	FY 2001	FY 2002
BNL	**11,212**	**10,834**	**10,242**

In FY 2002, the BNL experimental physics research groups will be primarily working on the D-Zero experiment, which will be taking data at Fermilab, and overseeing the fabrication of the U.S. portion of the ATLAS detector for the LHC. Data collection for the precision measurement of the anomalous magnetic moment of the muon will be completed. An upgraded rare kaon decay experiment at the AGS facility will begin operation. Also includes funding for theoretical research.

Funding is decreased to support the strong initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. This will significantly impact the viability and productivity of the BNL physics research groups.

	FY 2000	FY 2001	FY 2002
LBNL	**14,178**	**14,556**	**13,743**

In FY 2002, LBNL researchers will be focused on a number of research activities, including: data-taking with the CDF collider detector at Fermilab; data-taking with the BaBar detector at the PEP-II storage ring at SLAC; data-analysis on the HYPER-CP experiment at Fermilab will be underway; and fabrication of the ATLAS detector, primarily the silicon tracking system, for the LHC. The researchers will also be working on supernova measurements to establish values of cosmological parameters. Funding is included for the Particle Data Group at LBNL, which continues as an international clearinghouse for particle physics information.

Funding is decreased to support the strong initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. This will significantly impact the viability and productivity of the LBNL physics research groups.

	FY 2000	FY 2001	FY 2002
ANL	**6,652**	**6,483**	**6,125**

The experimental high-energy physics group will continue collaborating in research on the CDF at Fermilab, and ZEUS at the DESY/HERA facility in Hamburg, Germany. They also will be working on the fabrication of two major new detector facilities: the ATLAS detector for the LHC facility, and the MINOS detector at the Soudan site in Minnesota. The MINOS detector is part of the NuMI project and will use a neutrino beam from Fermilab. The theoretical physics group will continue their research in formal theory, collider phenomenology, and lattice gauge calculations.

Funding is decreased to support the strong initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. This will significantly impact the viability and productivity of the ANL physics research groups.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
Other Physics Research...	**2,830**	**2,039**	**3,851**

Includes $1,000,000 in FY 2002 for the Scientific Discovery through Advance Computing (SDAC) program. (Additional SDAC funding in the amount of $3,960,000 is included in the High Energy Physics Facilities Subprogram. In FY 2001, these funds were all in the High Energy Physics Facilities Subprogram). The principal objective of this program is to provide software tools which will reduce the effort needed to utilize very large scale computing resources in the solution of key scientific questions. The program includes the development of these software tools, and the application of these tools to high priority scientific questions. The funds will be allocated on the basis of a proposal and peer review process. Possible areas of application include precision, multiple turn orbit calculations for particle accelerators; numerical calculations on the details of particle substructure; development of systems for collecting, processing, storing and distribution for analysis of the very large data sets resulting from operation of the current generation of HEP and NP detectors; and astrophysical calculations.

This activity includes funds to continue the Pierre Auger project. The Pierre Auger Project (Auger) is intended to detect and study very high energy cosmic rays using a very large array of surface detectors spread over 30,000 square kilometers. Auger is being done by a large international collaboration. The presently approved part of the project includes an array at a site in Argentina. The U.S. will provide only a small portion of the cost of the Argentine array. The planned FY 2002 funding is $1,150,000 and the TEC for the U.S. portion of this phase of Auger is $3,000,000.

Full and effective participation by U.S. scientists in the LHC research program (the LHC will begin operation in 2006) requires an effective way for the data recorded by the detectors at CERN to be available for analysis by scientists at U.S. universities and laboratories. This problem is compounded by the enormous magnitude of the amount of data that will be recorded. This category includes increased (+$980,000) funding for planning and R&D activities to continue implementing the U.S. based computing system to process, store and support the analysis of the large body of data anticipated when the LHC begins operation for physics in FY 2006. Additional funding is included in the High Energy Physics Technology activity (+$240,000). The total funding for LHC related computing in FY 2002 will be $2,720,000.

This category also includes funding for smaller labs, conferences, studies, and workshops, and funding for research activities that have not yet completed their peer review, which is reduced by $168,000.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
High Energy Physics Technology	**74,322**	**84,971**	**84,779**

High Energy Physics Technology			
Fermilab	16,084	24,421	24,300
SLAC	23,620	22,159	22,770
BNL	7,400	5,574	5,265
LBNL	11,737	11,343	10,595
ANL	2,389	2,203	2,075
Universities	10,028	9,568	8,680
Other Technology R&D	3,064	9,703	11,094
Total, High Energy Physics Technology	74,322	84,971	84,779

Fermilab	**16,084**	**24,421**	**24,300**
Accelerator R&D	**9,618**	**19,259**	**18,100**

The major focus of the Accelerator R&D program in FY 2002 will be the continuation of the effort to design and install modifications aimed at improving the luminosity (intensity) and operational efficiency of the Tevatron complex to aid in the search for the Higgs, etc. The planned improvements include improved beam focusing magnets, improvements to the RF beam acceleration and control systems, and improvements to the beam position monitors.

Other activities in FY 2002 include design of an electron cooling system to improve the quality of an antiproton beam processed through the recycler ring; R&D in support of the NuMI project; R&D on superconducting RF cavities for a separated kaon beam; R&D and engineering on and fabrication of quadrupole magnets for the LHC interaction regions; and R&D to lay the technology foundations, long term, for possible future accelerators and experiments.

R&D on the NLC began formally at Fermilab in the first quarter of FY 2000 by a memorandum of understanding with SLAC. Funding will be at about the same level as FY 2001 ($3,000,000). Fermilab has assumed the principal R&D responsibility for the two main linac beam lines, including accelerating structures, supports, and instrumentation and control. A major SLAC and Fermilab collaborative R&D activity is application of the Fermilab developed permanent magnet technology throughout the entire NLC beam optics chain. Fermilab is also responsible for applying their expertise in conventional civil construction to issues that could significantly reduce the NLC construction cost. There will also be an accelerator physics effort, in collaboration with SLAC, to more fully understand all aspects of the beam optics and beam transport for the NLC from the electron and positron sources to the electron-positron collision point.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Longer range R&D addresses the feasibility and design issues for muon colliders/neutrino sources. Fermilab is lead laboratory for the muon cooling experiment, and LBNL is a major collaborator. This is a critical test issue for demonstrating the feasibility of ionization cooling in the muon collider context. Muon collider R&D is funded at about $900,000.

Fermilab is also engaged in an advanced superconducting magnet and materials program (principally niobium tin) to develop magnetic optical elements for use in a muon collider/neutrino source and, in the very far term, a possible 100 TeV proton collider.

The decrease of $1,159,000 reflects the anticipated completion of R&D in support of the initiation of the Tevatron operation with two new detectors in FY 2001 offset, in part, by increased efforts related to planned luminosity improvements.

Experimental Facilities R&D.......................................	**6,466**	**5,162**	**6,200**

Activities in FY 2002 will focus on R&D (increased about $1,000,000) needed for upgrades to the two large detectors so as to accommodate the increased luminosity from the planned upgrades of the Tevatron. R&D will continue at a lower level on pixel silicon detectors, on a possible dedicated collider detector for studying B meson interactions (B-Tev); on photon veto systems for an experiment searching for rare decays of kaons; and on computing techniques and on specialized electronics to better process the high event rates seen and anticipated in the large detectors.

SLAC...	**23,620**	**22,159**	**22,770**
Accelerator R&D	**19,975**	**21,216**	**21,680**

An important component of the FY 2002 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 improve the collision luminosity from the design value of $3x10^{33}cm^{-2}s^{-1}$ to greater than $10^{34}cm^{-2}s^{-1}$. The planned improvements include additional RF acceleration systems, improvements to the vacuum pumping system, and improvements to the beam control systems.

Activities in FY 2002 will include R&D on issues central to the design of the Next Linear Collider (NLC), an electron-positron colliding beam facility to operate in the 500 GeV to 1 TeV center-of-mass energy regime and upgradable to 1.5 TeV. The R&D activity at SLAC will focus on design and supporting engineering R&D on the electron and positron sources, damping rings, and connecting beam transport systems. Much of this work is done in collaboration with the Japanese laboratory for HEP, KEK. Technology development for the 11.4 GHz high-powered microwave sources that generate the power to accelerate electrons and positrons will continue with the goal of proving new, more cost effective technical approaches. Systems engineering, value engineering and risk analysis studies will be carried out to identify R&D opportunities to lower cost, exploit new technologies, and improve performance. The NLC R&D program at SLAC will be funded at $14,810,000 in FY 2002, about the same as in FY 2001.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

A program of general R&D into very advanced collider concepts will continue at a low level. This activity at SLAC will be closely coordinated with other participants in the high risk R&D program in advanced accelerator physics that is exploring the potential of lasers, plasmas, and ultra high frequency microwave systems to accelerate charged particles at ultra high gradients that is described in the introduction.

	FY 2000	FY 2001	FY 2002
Experimental Facilities R&D	**3,645**	**943**	**1,090**

In FY 2002, the emphasis will be on work to support and improve performance of BaBar, the newly operating B-factory detector, and a modest program of R&D, on developing preliminary designs for a detector to operate with a possible new electron-positron linear collider operating at the TeV center of mass energy scale.

	FY 2000	FY 2001	FY 2002
BNL	**7,400**	**5,574**	**5,265**
Accelerator R&D	**6,360**	**4,561**	**4,315**

Activities in FY 2002 will include, R&D on new methods of particle acceleration such as laser acceleration and inverse free electron laser (IFEL) accelerators, primarily using the excellent capabilities of the BNL Accelerator Test Facility.

BNL also has a major involvement in muon collider R&D, primarily in the area of the muon production target and collection systems. This target/capture R&D is critical for demonstrating the feasibility of a muon collider.

The BNL superconductor test facility will be used to study the characterization of new high critical temperature superconductors as well as the special requirements for high field magnet fabrication.

Funding for the above activities is decreased to support the strong initiative to exploit the "window of opportunity" for exciting new physics results described in the HEP program mission section above. This will significantly impact the viability and productivity of the BNL technology groups.

	FY 2000	FY 2001	FY 2002
Experimental Facilities R&D	**1,040**	**1,013**	**950**

In FY 2002, semiconductor drift photo diodes for detection of photons of energies as low as 50 eV will be designed and produced. Development of radiation hardened monolithic electronics for a number of experiments will continue. Development of lead-tungstate crystals with improved light output will continue. Testing of the modules that constitute the ATLAS barrel calorimeters will begin.

Funding is decreased to support the strong initiative to exploit the "window of opportunity" for exciting new physics results described in the HEP program mission statement above. This will significantly impact the viability and productivity of the BNL technology groups.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
LBNL	**11,737**	**11,343**	**10,595**
Accelerator R&D	**9,624**	**9,225**	**8,605**

The high-gradient, all-optical, laser-plasma wakefield accelerator at LBNL will begin accelerating electron bunches in preparation for a series of experiments in novel acceleration techniques.

LBNL is a major contributor to accelerator and superconducting magnet R&D for advanced accelerator concepts, including the muon collider and the next linear collider. Development of these concepts is needed to advance the energy and luminosity frontiers to better understand the structure of matter. In FY 2002, preparations for muon cooling experiments to be performed at Fermilab, needed to confirm the practicality of a muon collider, will continue, using components fabricated at LBNL.

Funding for some of the above activities is decreased to support the strong initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. This will significantly impact the viability and productivity of the LBNL technology groups.

LBNL is also involved in the NLC R&D program in FY 2001. Continuation of this effort in FY 2002 will be at about the same level of funding ($650,000).

Experimental Facilities R&D	**2,113**	**2,118**	**1,990**

LBNL has an industry forefront capability for designing and producing custom state-of-the-art electronics, such as silicon vertex detectors, integrated circuit (IC) systems, and other components for high-energy particle detectors such as BaBar at the B-factory and the upgrades to CDF and D–Zero for the next, higher luminosity, runs at Fermilab. LBNL is also involved in developing computer programs for experimental data taking and analysis. In FY 2002, work will continue on large area charge-coupled devices and high-resolution imaging systems, plus the production and testing of IC systems.

Funding is decreased to support the strong initiative to exploit the "window of opportunity" for exciting new physics results described in the introductory sections. This will significantly impact the viability and productivity of the LBNL technology groups.

ANL	**2,389**	**2,203**	**2,075**
Accelerator R&D	**1,481**	**1,299**	**1,220**

R&D will continue on the acceleration of electrons using structures with plasmas or structures made of dielectric materials called wakefield accelerators. Researchers have achieved predicted accelerating gradients at encouraging levels using this new technique. Results are expected in obtaining high accelerating gradients with greatly enhanced beam stability using dielectric structures, and planning is underway for an upgraded experimental capability to generate much higher accelerator gradients using plasmas in structures driven by intense bunches of electrons. Related theoretical work will also continue.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Funding is decreased to support the strong initiative to exploit the “window of opportunity” for exciting new physics results described in the introductory sections. This will significantly impact the viability and productivity of the ANL technology groups.

Experimental Facilities R&D......................................	**908**	**904**	**855**

In FY 2002 work will be underway on the MINOS detector, the ATLAS detector for the LHC, and a possible upgrade of the ZEUS detector at DESY.

Funding is decreased to support the strong initiative to exploit the “window of opportunity” for exciting new physics results described in the introductory sections. This will significantly impact the viability and productivity of the ANL technology groups.

Universities...	**10,028**	**9,568**	**8,680**

The funding will provide for a program of high priority technology R&D at about 20 universities relevant to the development of particle accelerators. This R&D effort is primarily a part of the high risk R&D described in the Mission Supporting Goals and Objectives – Technology R&D discussion. The R&D is aimed at breakthrough technologies; superconductors for high-field magnets; laser and collective-effect accelerator techniques; novel, high-power radio frequency generators; muon colliders; theoretical studies in particle beam physics, including the non-linear dynamics of particle beams; and at lowering the cost and improving the performance of future experiments and facilities. University based research efforts will be selected based on review by appropriate peers.

Funding is decreased to support the strong initiative to exploit the “window of opportunity” for exciting new physics results described in the introductory sections. This will significantly impact the viability and productivity of these technology groups.

Other Technology R&D..	**3,064**	**9,703**	**11,094**

The funding will provide for a program of high priority technology R&D at a number of other federal laboratories and industrial sites relevant to the development of particle accelerators. This R&D effort is primarily a part of the high risk R&D described in the Mission Supporting Goals and Objectives – Technology R&D discussion. The R&D is aimed at breakthrough technologies; superconductors for high-field magnets; laser and collective-effect accelerator techniques; novel, high-power radio frequency generators; theoretical studies in particle beam physics, including the non-linear dynamics of particle beams; and at lowering the cost and improving the performance of future experiments and facilities.

The increase of $1,391,000 is primarily for Other Technology R&D activities that has not been allocated pending completion of peer review or program office detailed planning.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
SBIR/STTR	**0**	**1,479**	**7,951**

In FY 2000, $1,100,000 was transferred to the SBIR program. This includes $615,000 for the SBIR program and $864,000 for the STTR program in FY 2001 and $7,090,000 for the SBIR program and $861,000 for the STTR program in FY 2002. Additional funding for the SBIR program is contained in the High Energy Physics Facilities subprogram.

Total, Research and Technology	**236,028**	**242,836**	**247,870**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Physics Research	
At Fermilab, an increase in the Physics Research category to provide increased support for Fermilab scientists to exploit the window of opportunity to search for the source of mass	+1,767
At SLAC, an increase in the Physics Research category to provide increased support for SLAC scientists collecting and analyzing data from the BaBar detector to exploit the window of opportunity to study CP violation in B meson decays and help explain the preponderance of matter over antimatter in the universe	+1,608
Funding for research at a number of sites has been decreased to make funds available for the operation and upgrade of the high priority "window of opportunity" efforts at Fermilab and SLAC as discussed in the introductory sections.	
In University Physics Research, a decrease of $4,670,000..................................	-4,670
At BNL, a decrease of $592,000..	-592
At LBNL, a decrease of $813,000.	-813
At ANL, a decrease of $358,000	-358
In Other Physics Research, an increase of $1,000,000 reflecting the transfer of a portion of the funding for the large scale computer modeling and simulation initiative from the High Energy Physics Facilities Subprogram. This is based on further analysis of the objectives of the program. An additional $3,960,000 for computer modeling and simulation remains in the High Energy Physics Facilities Subprogram. The total for this activity is increased slightly relative from FY 2001.	

	FY 2002 vs. FY 2001 ($000)
In Other Physics Research an increase of $980,000 in funding for preparation for handling the data from LHC.	
In Other Physics Research, other adjustments totaling a decrease of $168,000.	+1,812
Total, Physics Research	-1,246
High Energy Physics Technology	
At Fermilab, a decrease of about $121,000 reflecting the anticipated completion of the final commissioning and shakedown operation of the Tevatron with the new Main Injector which occurred during FY 2001, offset by an increased emphasis on R&D needed for the planned luminosity upgrades of the Tevatron. The cooperative (with SLAC) R&D program on the Next Linear Collider and the program of R&D on muon colliders are held at about a constant level.	-121
At SLAC, an increase to support the R&D needed to further increase the luminosity of the B-factory and to make the BaBar detector fully effective at these higher intensities.	+611
Funding for technology at a number of sites has been decreased to make funds available for the operation and upgrade of the high priority "window of opportunity" programs at Fermilab and SLAC as discussed in the introductory sections.	
In the University program, a decrease of $888,000	-888
At BNL, a decrease of $309,000	-309
At LBNL, a decrease of $748,000	-748
At ANL, a decrease of $128,000	-128
In Other Technology R&D, an increase of $240,000 in funding for activities related to meeting the anticipated computing needs of the LHC research program, and an increase of $1,151,000 primarily in the funding held in reserve pending the completion of peer review and program office considerations.	+1,391
Total, High Energy Physics Technology	-192
SBIR/STTR	
An increase of $6,472,000 in the SBIR allocation	+6,472
Total Funding Change, Research and Technology	+5,034

The following table displays funding in High Energy Physics for R&D on possible future HEP facility concepts:

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Next Linear Collider	17,400	19,157	19,200
Muon-Muon Collider...	9,675	5,269	4,993

High Energy Physics Facilities

Mission Supporting Goals and Objectives

The High Energy Physics Facilities subprogram includes the provision and operation of the large accelerator and detector facilities, the essential tools that enable scientists in university and laboratory based research groups to perform experimental research in high-energy physics.

The FY 2002 program described earlier contains the following facility operation elements.

- Full operation of the Tevatron at Fermilab and the B-factory at SLAC for the research program planned at those facilities. This includes operation of the accelerators and storage rings, and operation of the ancillary and support facilities including in particular the computing facilities.
- Continuation of the planned program of upgrades for these two facilities. The physics goals of the HEP program described earlier (detection of Higgs; study of CP Violation, etc.) require a substantial amount of data collection. Facility upgrades that increase the beam intensity are extremely important since they increase the data collection rate just as effectively as does additional operation. The data collection goals needed to achieve the physics objectives requires both extended running and an ongoing program of facility upgrades.
- Strong operation of the AGS at BNL for the research program planned at the AGS as described earlier.
- Continued work on the agreed to components and subsystems for the LHC accelerator and detectors.
- Site infrastructure maintenance and improvement. The High Energy Physics Facilities subprogram includes general plant projects (GPP) funding (at Fermilab, SLAC and LBNL) and general purpose equipment (GPE) funding (at LBNL).

The principal objective of the High Energy Physics Facilities subprogram is to maximize the quantity and quality of data collected for approved experiments being conducted at the High Energy Physics facilities. The ultimate measure for success in the High Energy Physics Facilities subprogram is whether the research scientists have data of sufficient quantity and quality to do their planned measurements or to discover new phenomena. The quality of the data is dependent on the accelerator and detector capabilities, and on the degree to which those capabilities are achieved during a particular operating period. The quantity of the data relates primarily to the beam intensity, the length of the operating periods, and the operational availability of the accelerator and detector facilities. **Performance will be measured by** reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

	(in weeks)		
	FY 2000	FY 2001	FY 2002
Fermilab	29	22	39
SLAC[a]	44	34	35
BNL	15	16	16

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Fermi National Accelerator Lab	212,590	211,406	244,739	+33,333	+15.8%
Stanford Linear Accelerator Center	111,787	116,449	125,078	+8,629	+7.4%
Brookhaven National Laboratory	3,471	5,729	5,690	-39	-0.7%
Other Facility Support	10,384	20,204	14,655	-5,549	-27.5%
Large Hadron Collider	70,000	58,870	49,000	-9,870	-16.8%
Waste Management	10,090	10,391	10,410	+19	+0.2%
SBIR/STTR	0	13,787	7,258	-6,529	-47.4%
Total, High Energy Physics Facilities	418,322	436,836	456,830	+19,994	+4.6%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Fermilab	**212,590**	**211,406**	**244,739**

Provides support for operation, maintenance, improvement, and enhancement of the Tevatron accelerator and detector complex and for maintenance of the laboratory physical plant. This complex includes the Tevatron, that can operate in a collider mode with protons and antiprotons, or in a fixed target mode with protons only; the new Main Injector that was completed and commissioned in FY 1999 and is fully operational; the Booster; the Linac; and the Antiproton Source and Accumulator. The Tevatron collider and the 800 GeV fixed target modes are mutually exclusive; however, a fixed target program at 120 GeV using the new Main Injector is possible in parallel with Tevatron collider operation.

Tevatron operation in FY 2002 will be focused on an extended run to collect the maximum amount of data for the physics goals (Higgs, etc.) described earlier. This will include full operation of the two large detectors – CDF and D-Zero – and the supporting computing facilities. The Tevatron will operate for about 39 weeks in FY 2002. **Performance will be measured by** adherence to planned running schedules and by progress on maintaining and enhancing luminosity and operational efficiency for the Tevatron at Fermilab in its new mode of operation with the new Main Injector.

[a] The number of weeks is projected on the basis of the continuing availability of electrical power at affordable prices, an assumption that is now questionable in California.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
Operations	**182,455**	**177,993**	**194,409**

Operation at Fermilab will include operation of the Tevatron in collider mode for about 39 weeks. This will be a major physics run with the higher intensity available from the new Main Injector and with the newly upgraded D-Zero and CDF detectors. This is to be a major data collection period for the experiments searching for the Higgs and related phenomena as described in more detail earlier.

The increased funding ($16,416,000) will support the additional Tevatron operation, will provide for increased operations staffing to enhance the reliability and efficiency of the planned operations, and will assist with installation and commissioning of planned luminosity upgrades.

Tevatron Operation

	(in weeks)		
	FY 2000	FY 2001	FY 2002
Fixed Target	6	0	0
Collider	15	22	39
Commissioning	8	0	0
Total, Tevatron Operation	29	22	39

	FY 2000	FY 2001	FY 2002
Support and Infrastructure	**30,135**	**33,413**	**50,330**

Capital Equipment funding is increased from $24,789,000 to $39,280,000. These funds provide for initiation of two new Major Items of Equipment involving the replacement of the Silicon Tracker Subsystems with new state-of-the-art radiation-hard silicon for both the CDF Detector (TEC of $15,000,000) and D-Zero Detector (TEC of $15,000,000), the MINOS Detector (TEC of $47,118,000), and general laboratory needs. Increases of $7,000,000 for the two new detector MIE's, $3,976,000 for MINOS and $7,811,000 for general laboratory needs are partially offset by the completion of the D-Zero Upgrade project in FY 2001. AIP is increased by $2,415,000 to $6,250,000. 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 operation of the Tevatron. The Silicon Tracker Subsystem replacements will be necessary since in the normal course of operation the silicon in the detectors gets damaged by radiation and needs to be replaced. The technology involving radiation-hard silicon has improved significantly since the design for the last upgrades to the detectors was completed five years ago. This will allow them to better withstand the higher intensities needed in the search for the Higgs. MINOS is the detector part of the NuMI project that will provide a major new capability for neutrino research. GPP funding increased slightly ($11,000) to $4,800,000 to assist with urgent ES&H and infrastructure needs.

	FY 2000	FY 2001	FY 2002
SLAC	**111,787**	**116,449**	**125,078**

Provides for the operation, maintenance, improvement and enhancement of the accelerator and detector complex on the SLAC site. The accelerator facilities include the electron linac, the B-factory, completed in FY 1999, and the NLC Test Accelerator. The B-factory is fully operational and is performing well. The detector facilities include BaBar, the detector for the B-factory, the End Station A experimental set-ups, and the Final Focus Test Beam. This will be a major data collection period for the experiment

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

studying the B meson system and looking for information about CP Violation as described earlier.

B-factory operation in FY 2002 will be focused on an extended run to collect the maximum amount of data for the physics goals (CP Violation, etc.) described earlier. This will include full operation of the large detectors – BaBar – and the supporting computing facilities. The B-factory will operate for about 35 weeks in FY 2002. **Performance will be measured by** adherence to planned running schedules and progress on achieving and increasing luminosity and operational efficiency for the B-factory at SLAC as measured by comparison with stated project goals.

Also provides for the fabrication of the GLAST detector which is to be a satellite-based study of high-energy gamma rays in the cosmic radiation.

Also provides for maintenance of the laboratory physical plant.

▪ **Operations**	**88,945**	**94,298**	**99,705**

The increased funding will provide operations at SLAC in FY 2002 for about 35 weeks of strong utilization of the asymmetric B-factory colliding beam storage rings to maximize the data collected by the BaBar detector facility, and for corresponding support of detector operations and computing operations. This will be the priority research program at SLAC in FY 2002. This will be supplemented by a modest (8 weeks) fixed target research program in End Station A which will be run in parallel with B-factory operation. The linac will serve as the injector of positrons and electrons to the B-factory storage rings during this time.

The increased funding ($5,407,000) will provide for increased operation (1 week), increased operations staffing to enhance the reliability and effectiveness of the planned operations, and assist with installation and commissioning of luminosity upgrades.

SLAC Operation [a]

	(in weeks)		
	FY 2000	FY 2001	FY 2002
Fixed Target [b]	15	8	8
B-factory Operation..	44	34	35
Total, SLAC Operation	44	34	35

Support and Infrastructure	**22,842**	**22,151**	**25,373**

Funding for capital equipment for general laboratory purposes is decreased by $2,140,000 to $5,140,000. Funding for AIP is increased by $2,872,000 to $8,360,000. These funds are primarily related to urgent upgrades needed to improve the luminosity and operational efficiency of the B-factory. Capital equipment funding for GLAST, a large gamma ray detector designed to study cosmic gamma rays from a satellite, is increased by $2,481,000 to $7,673,000. GLAST is a joint

[a] The number of weeks is projected on the basis of the continuing availability of electrical power at affordable prices, an assumption that is now questionable in California.

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

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		

DOE-NASA project aimed at studying gamma rays in the cosmic radiation using a satellite-based instrument. Additional funding of $497,000 is provided under Other Facilities Support for GLAST. The total funding (including the $497,000 in Other Facilities Support) requested for GLAST in FY 2002 is $8,170,000 and the TEC is $35,000,000. Funding for GPP is increased slightly (+$9,000) to $4,200,000 to assist with urgent ES&H and infrastructure needs.

	FY 2000	FY 2001	FY 2002
BNL	**3,471**	**5,729**	**5,690**

Provides support for the HEP related operation, maintenance, improvement, and enhancement of the AGS complex at BNL and its complement of experimental set ups. The AGS is operated by the Nuclear Physics program as part of the RHIC facility and operation of the AGS for the HEP program is on an incremental cost basis.

The AGS will be operated for the HEP program for about 16 weeks in FY 2002 in support of further operation of the experiment studying the magnetic properties of the muon and the new experiment searching for a very rare decay mode of the K meson. **Performance will be measured by** adherence to planned running schedules.

	FY 2000	FY 2001	FY 2002
Operations	**3,377**	**5,634**	**5,595**

Funding will provide for the incremental cost of running the AGS complex for HEP. Operation for High Energy Physics in FY 2002 will be for about 16 weeks for a major data-taking run for muon experiment and for the initiation of the upgraded rare kaon decay experiment.

AGS Operation

	(in weeks)		
	FY 2000	FY 2001	FY 2002
AGS Operation for HEP	15	16	16

	FY 2000	FY 2001	FY 2002
Support and Infrastructure	**94**	**95**	**95**

Includes capital equipment funding for HEP use of the AGS.

	FY 2000	FY 2001	FY 2002
Other Facility Support	**10,384**	**20,204**	**14,655**

Includes $3,960,000 (-$959,000) for the Scientific Discovery through Advance Computing program. Additional funding in the amount of $1,000,000 is included in the Research and Technology subprogram and is more fully described there.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Includes $1,050,000 (-$397,000) for General Purpose Equipment and $1,900,000 (-$1,592,000) for General Plant Projects at LBNL for landlord related activities.

In FY 2001, included $3,000,000 of MINOS Other Project Costs expended through the University of Minnesota for excavation at the Soudan Laboratory. This phase of the activity is complete and no funding is planned in FY 2002 (-$3,000,000).

In FY 2001, LBNL was provided $499,000 for modifications to the Oakland Scientific Facility and $253,000 for work related to the BaBar computing facilities at SLAC. Both activities are complete and no funding is planned in FY 2002 (-$752,000).

Includes funding for a number of small activities including computer networking and funding held in reserve pending the completion of peer review and programmatic considerations.

Large Hadron Collider...	**70,000**	**58,870**	**49,000**

The reduction in funding in FY 2002 ($11,000,000 below the previously planned profile) reflects a further analysis of the detailed expenditure plans for the project. This funding will allow the project to continue on the approved schedule and will not affect the planned completion date and the total cost of the U.S. projects and the LHC itself. CERN has indicated agreement with this change.

The European Center for Nuclear Research (CERN) in Geneva, Switzerland initiated the Large Hadron Collider (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 the LHC will open up substantial new frontiers for scientific discovery. Completion of the LHC is projected for 2006.

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 around the middle of the next decade. 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 (Drell) 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. Although LHC will have a lower energy than the Superconducting Super Collider (canceled in 1993), it 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.

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

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 are being used to pay for purchases by CERN of material needed for construction of the accelerator. As a result of the negotiations, CERN has agreed to make these purchases from U.S. vendors.

The agreement provides for a U.S. DOE contribution of $450,000,000 to the LHC accelerator and detectors over the period FY 1996 through FY 2005 (with approximately $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. Thus the U.S. contribution represents less than 10 percent of the total. (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 feasible.

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 500 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.

Fabrication of LHC subsystems and components by U.S. participants began in FY 1998. Funding was provided in FY 1996 ($6,000,000) and FY 1997 ($15,000,000) for preliminary R&D, design and engineering work on the subsystems and components being proposed for inclusion in the agreement with CERN. This funding was essential in order to provide the cost and technical bases for the proposed U.S. responsibilities in LHC, and to be ready for rapid start to satisfy the anticipated timetable for the project.

U.S. LHC Accelerator and Detector Funding Profile

(dollars in thousands)

Fiscal Year	Department of Energy			National Science Foundation[a]
	Accelerator	Detector	Total	
1996[b]	2,000	4,000	6,000	0
1997[b]	6,670	8,330	15,000	0
1998[b]	14,000	21,000	35,000	0
1999	23,491	41,509	65,000	22,150
2000	33,206	36,794	70,000	15,900
2001	27,243	31,627	58,870	16,370
2002	21,303	27,697	49,000	16,860
2003	22,100	37,900	60,000	9,720
2004	29,330	30,670	60,000	0
2005	20,657	10,473	31,130	0
Total	200,000[c]	250,000	450,000	81,000

[a] The NSF funding has been 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] 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 2000	FY 2001	FY 2002
High Energy Physics Facilities			
LHC			
Accelerator Systems			
Operating Expenses	4,160	5,371	1,800
Capital Equipment	20,758	3,991	12,400
Total, Accelerator Systems	24,918	9,362	14,200
Procurement from Industry	8,288	17,881	7,103
ATLAS Detector			
Operating Expenses	5,135	7,285	3,647
Capital Equipment	11,359	7,190	6,860
Total, ATLAS Detector	16,494	14,475	10,507
CMS Detector			
Operating Expenses	9,100	11,465	8,480
Capital Equipment	11,200	5,687	8,710
Total, CMS Detector	20,300	17,152	17,190
Total, LHC	70,000	58,870	49,000

In FY 2002, funding will be used for: R&D and measurement/testing on superconducting materials, cable, and wire; calculations and R&D on accelerator physics issues regarding the design, instrumentation, and prototypes of the magnets for the colliding beam intersection regions and RF accelerating regions. Activities on the detectors will include R&D and prototype development of subsystems such as tracking chambers, calorimeters, and data acquisition electronics.

The LHC work is being performed at various locations including 4 major DOE labs and more than 55 U.S. universities.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Accelerator Systems	**24,918**	**9,362**	**14,200**

In FY 2002, funding will support continued production of interaction region quadrupole magnets, dipole magnets, feedboxes, and absorbers; production of radio-frequency region dipole magnets; and completion of fabrication of the superconducting cable for these magnets. Production testing of wire and cable for the LHC main magnets and accelerator physics calculations will continue.

Procurement from Industry	**8,288**	**17,881**	**7,103**

In FY 2002, funding will continue to support reimbursement to CERN for purchases from U.S. industry including superconducting wire, cable, cable insulation materials, and other technical components. The reduction reflects the latest information on the planned expenditure profile.

ATLAS Detector	**16,494**	**14,475**	**10,507**

In FY 2002, funding will support production of detector hardware and electronics. The barrel cryostat procurement for the liquid argon calorimeter will be completed and procurement and testing will continue for the silicon strip electronics, and the transition radiation tracker electronics. Fabrication efforts will continue for the silicon strip modules, the forward calorimeter, the extended barrel tile calorimeter modules and submodules, the endcap monitored drift tubes, and the cathode strip chambers. Fabrication will be completed for the liquid argon calorimeter feed-throughs and motherboards and installation will begin. The reduction reflects the latest information on the planned expenditure profile.

CMS Detector	**20,300**	**17,152**	**17,190**

In FY 2002, funding will support full rate production and testing of endcap muon system chambers and the procurement of the electronics and cables for the muon system. The hadron calorimeter barrel will be completed and delivered to CERN and the scintillator and brass absorber assembly will continue along with the testing of the associated electronics. The trigger designs will be completed and testing of the electronics will continue. The data acquisition system will complete prototyping efforts and continue test beam studies. The forward pixel system will complete advanced testing and prepare for production of readout chips and sensors.

Waste Management	**10,090**	**10,391**	**10,410**

Provides funding for packaging, shipment and disposition of hazardous, radioactive or mixed waste generated in the course of normal operations at Fermilab, SLAC, and LBNL. The laboratories continue to explore opportunities to reduce the volume of newly generated waste and its associated management and disposal costs.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
SBIR/STTR	**0**	**13,787**	**7,258**

In FY 2000, $12,697,000 was transferred to the SBIR program and $828,000 was transferred to the STTR program. Includes $13,787,000 in FY 2001 and $7,258,000 in FY 2002 for the SBIR program. The balance of the SBIR and STTR allocations are included in the Research and Technology Subprogram.

	FY 2000	FY 2001	FY 2002
Total, High Energy Physics Facilities	**418,322**	**436,836**	**456,830**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Fermilab	
At Fermilab, an increase of $16,416,000 in Operations to support 39 weeks of operation of the Tevatron with the Main Injector and the newly upgraded CDF and D-Zero detectors	+16,416
At Fermilab, increases of $7,000,000 for two new detector MIE's, $3,976,000 for MINOS and $7,811,000 for general laboratory needs are partially offset by a decrease of $4,296,000 resulting from the completion of the D-Zero Upgrade project for capital equipment. AIP funding is increased by $2,415,000. Also, GPP funding is increased by $11,000 to assist with urgent ES&H and infrastructure needs.	+16,917
Total, Fermilab	+33,333
Stanford Linear Accelerator Center	
At SLAC, an increase of $5,407,000 in Operations to support 35 weeks of operation of the B-factory for data collection on the key question of understanding the ratio of matter to antimatter in the universe.	+5,407
At SLAC, a decrease of $2,140,000 in capital equipment and an increase of $2,872,000 in AIP is provided to support planned upgrades of the B-factory needed to achieve the planned luminosity increases. There is also an increase of $2,481,000 in the GLAST project, and an increase of $9,000 in GPP to assist with urgent ES&H and infrastructure needs.	+3,222
Total, Stanford Linear Accelerator Center	+8,629

	FY 2002 vs. FY 2001 ($000)
Brookhaven National Laboratory	
At BNL, a decrease of $39,000.	-39
Other Facility Support	
A decrease of $959,000 reflects the transfer of a portion of the funding for the large scale computer modeling and simulation initiative to the Research and Technology subprogram. Decreases of $397,000 in GPE funding and $1,592,000 in GPP funding at LBNL. A decrease at LBNL in operating funding for modifications to the Oakland Scientific Facility (-$499,000) and a project related to computing needs for the BaBar detector (-$253,000) is reflected. Both projects are complete and no FY 2002 funding is planned. A decrease of $3,000,000 in the funding provided to the University of Minnesota for excavations for the Soudan Laboratory which will house the MINOS detector since the project is complete and no FY 2002 funding is planned. An increase of $1,151,000 mainly in funding held pending completion of peer review and program office consideration is proposed.	-5,549
Large Hadron Collider	
A decrease of $9,870,000 reflecting the revised expenditure profile	-9,870
Waste Management	
An increase of $19,000.	+19
SBIR/STTR	
A decrease of $6,529,000 in funding for SBIR	-6,529
Total Funding Change, High Energy Physics Facilities	+19,994

The following table shows the details of the funding for the GLAST and MINOS projects.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
GLAST (SLAC Capital Equipment)...	2,719	5,192	7,673
GLAST (Other Facility Support Capital Equipment)	281	497	497
Total..	3,000	5,689	8,170
MINOS			
Operating...	4,632	3,000	2,050
Capital Equipment	6,671	11,974	15,950
Total..	11,303	14,974	18,000

Construction

Mission Supporting Goals and Objectives

This provides for the construction of major new facilities needed to meet the overall objectives of the High Energy Physics Program.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Neutrinos at the Main Injector	22,000	22,949	11,400	-11,549	-50.3%
Wilson Hall Safety Improvement Project	4,700	4,191	0	-4,191	-100.0%
SLAC Research Office Building	2,000	5,189	0	-5,189	-100.0%
Total, Construction	28,700	32,329	11,400	-20,929	-64.7%

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Neutrinos at the Main Injector (NuMI)	**22,000**	**22,949**	**11,400**

This project provides for the construction of new facilities at Fermilab and at the Soudan Underground Laboratory in Soudan, Minnesota that are specially designed for the study of the properties of the neutrino and in particular to search for neutrino oscillations. The FY 2002 funding is primarily for the underground beam tunnel. Work on the neutrino production target, neutrino focusing horns, underground detector and detector halls, and surface buildings at Fermilab will continue. **Performance will be measured by** accomplishment of scheduled milestones as detailed in the benchmark plan.

Wilson Hall Safety Improvement Project (Fermilab)	**4,700**	**4,191**	**0**

This project provides for urgently needed rehabilitation of the main structural elements of Wilson Hall, and for urgently needed rehabilitation of windows, plumbing, the roof and the exterior of the building. Funding was completed in FY 2001 and the project is on schedule for completion in FY 2002. **Performance will be measured by** the total cost at completion and by the completion date.

SLAC Research Office Building	**2,000**	**5,189**	**0**

This project provides urgently needed office space for the substantial expansion of visiting scientists, or "users", resulting from the B-factory becoming operational. The visiting user population is projected to increase from 200 visitors per year to 1,100 visitors per year. The new building will provide about 30,000 square feet and is on schedule for completion at the end of FY 2001. **Performance will be measured by** the total cost at completion and by the completion date.

Total, Construction	**28,700**	**32,329**	**11,400**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Provides for completion of the Fermilab NuMI project on the planned profile.	-11,549
The Wilson Hall Safety Improvement Project at Fermilab will be completed as planned in FY 2002.	-4,191
The Research Office Building at SLAC will be completed as planned in FY 2001.	-5,189
Total Funding Change, Construction	-20,929

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	10,645	12,472	10,900	-1,572	-12.6%
Accelerator Improvements Projects........	10,233	9,323	14,610	+5,287	+56.7%
Capital Equipment	89,828	69,300	94,878	+25,578	+36.9%
Total, Capital Operating Expense	110,706	91,095	120,388	+29,293	+32.2%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Unapprop-riated Balance
98-G-304 Neutrinos at the Main Injector [a]	76,149	19,800	22,000	22,949	11,400	0
99-G-306 Wilson Hall Safety Improvements	15,591	6,700	4,700	4,191	0	0
00-G-307 SLAC Research Office Building	7,189	0	2,000	5,189	0	0
Total, Construction................................		26,500	28,700	32,329	11,400	0

[a] A Cost, Scope, and Schedule Review of the NuMI project is planned for this spring. The results of this review may change the funding profile, TEC, and TPC.

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Accept-ance Date
D-Zero Upgrade	61,208	52,547	4,365	4,296	0	FY 2001
CDF Upgrade	56,646	51,037	5,609	0	0	FY 2001
Large Hadron Collider — Machine	88,769	25,680	20,758	3,991	12,400	FY 2005
Large Hadron Collider — ATLAS Detector	57,119	9,841	11,359	7,190	6,860	FY 2005
Large Hadron Collider — CMS Detector	64,390	24,338	11,200	5,687	8,710	FY 2005
MINOS	47,118	2,600	6,671	11,974	15,950	FY 2003
GLAST [a]	35,000	0	3,000	5,689	8,170	FY 2005
Cryogenic Dark Matter Search (CDMS)	8,600	0	800	1,798	1,060	FY 2007
Auger	3,000	0	0	100	1,150	FY 2003
Alpha Magnetic Spectrometer (AMS) Upgrade [b]	3,028	0	1,000	1,028	1,000	FY 2003
D-Zero Silicon Tracker Replacement	15,000	0	0	0	3,500	FY 2004
CDF Silicon Tracker Replacement	15,000	0	0	0	3,500	FY 2004
Total, Major Items of Equipment		166,043	64,762	41,753	62,300	

[a] Total estimated cost is subject to further negotiations with NASA and potential foreign collaborators.

[b] A change in the assignment of responsibilities within the international AMS collaboration is being discussed which would result in an increase of $1,700,000 in the TEC of the DOE portion of the project. A decision with regard to changing the DOE TEC and funding profile will be made when an appropriate proposal has been received and reviewed.

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

(Changes from FY 2001 Congressional Budget Request are denoted with a vertical line [|] in the left margin.)

Significant Changes

Total Project Cost and the Completion Date have been adjusted due to changes in the MINOS detector profile.

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 '98	4Q '98	NA	NA	5,500	6,300
FY 1999 Budget Request (Preliminary Estimate)...	--	3Q '99	1Q '99	4Q '02	75,800	135,300
FY 2000 Budget Request	3Q '98	2Q '00	3Q '99	2Q '03	76,200	136,100
FY 2001 Budget Request	3Q '98	2Q '00	3Q '99	2Q '04	76,200	138,600
FY 2001 Budget Request (Amended)...	3Q '98	2Q '00	3Q '99	4Q '03	76,200	138,400
FY 2002 Budget Request	3Q '98	4Q '00	3Q '99	4Q '03	76,149	139,390

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	26,949
2002	11,400	11,400	14,900
2003	0	0	12,225

*A Cost, Scope and Schedule Review of the NuMI Project is planned for this spring. The results of this Review may change the funding profile, TEC and TPC.

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 new Main Injector accelerator at the MI-60 extraction region. The beam components will be installed in a tunnel of approximately 1.5 km in length and 6.5 m diameter. The beam is aimed at two detectors (MINOS) which will be constructed in 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 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 (9.4% of TEC)	7,180	7,180
Construction Phase		
Buildings	8,320	8,320
Special Equipment	10,120	10,120
Other Structures	30,960	30,960
Construction Management (6.0% of TEC)	4,590	4,590
Project Management (2.8% of TEC)	2,170	2,170
Total, Construction Costs	56,160	56,160
Contingencies		
Design Phase (2.8% of TEC)	2,172	2,172
Construction Phase (14.0% of TEC)	10,637	10,688
Total, Contingencies (16.8% of TEC)	12,809	12,860
Total, Line Item Cost (TEC)	76,149	76,200

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 1996 through FY 2002 are 2.5, 2.8, 3.0, 3.1, 3.3, 3.4, and 3.4 percent respectively.

6. Schedule of Project Funding*

(dollars in thousands)

	Prior Years	FY 2000	FY 2001	FY 2002	Outyears	Total
Project Cost						
Facility Cost						
Total, Line item TEC	6,986	15,089	26,949	14,900	12,225	76,149
Other Project Costs						
Capital equipment [a]	2,560	5,067	11,974	15,950	11,567	47,118
R&D necessary to complete construction [b]	1,300	0	0	0	0	1,300
Conceptual design cost [c]	830	0	0	0	0	830
Other project-related costs [d]	3,480	5,062	3,000	2,050	401	13,993
Total, Other Project Costs	8,170	10,129	14,974	18,000	11,968	63,241
Total Project Cost (TPC)	15,156	25,218	41,923	32,900	24,193	139,390

* A Cost, Scope and Schedule Review of the NuMI Project is planned for this spring. The results of this Review may result in a need to change the funding profile, TEC and TPC.

[a] Costs to fabricate the near detector at Fermilab and the far detector at Soudan. Includes 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.

[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.

[d] Include funding required to complete the construction and outfitting of the Soudan Laboratory for the new far detector by the University of Minnesota.

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 2003 through FY 2007)*	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 2002.

Nuclear Physics

Program Mission

The mission of the Nuclear Physics program is to advance our knowledge of the properties and interactions of atomic nuclei and nuclear matter in terms of the fundamental forces and particles of nature. To accomplish this mission, the program supports the research of scientists, the operations of facilities and the development of forefront facilities and technology. These activities are carried out under the mandate provided in Public Law 95-91 that established the Department of Energy, and assigns the Nuclear Physics program the lead responsibility for Federal support of fundamental research in nuclear physics.

Since early in the twentieth century, the study of nuclear physics has made important contributions to our knowledge about the natural universe and has had great impact on human life. Nuclear fusion powers our sun and provides the energy that supports life on earth. Fusion processes that occurred in the early universe and later in stars formed the nuclei of all the types of atoms we find on earth. Accelerators were developed in the 1920's and 1930's to study the nucleus and are today the primary tool for nuclear physics research. As accelerators evolved and became increasingly more powerful, a new field of science called high energy physics emerged from nuclear research in the 1940's and 50's to pursue the mysterious array of unexpected particles discovered in nuclear physics research. Both fields are still closely related in physics and technology; however, their focus is quite different. High energy physics focuses on understanding the interactions and properties of the elementary particles, while the focus of nuclear physics is on understanding the structure and properties of nuclei and nuclear matter in terms of their constituents. For example, based on high energy physics studies, it is now understood that the most elementary building blocks of matter are particles, called quarks, which interact by the exchange of gluons. Nuclear Physics attempts to understand how quarks bind together in groups of three to form the nucleons (protons and neutrons) and then, in turn, how these nucleons become the basic building blocks to produce the nuclei we observe in nature.

Attendant upon this core mission are responsibilities to educate and enlarge the nation's pool of technically trained talent, primarily at the graduate student and postdoctoral levels, and to facilitate transfer of knowledge and technology acquired to support the nation's needs. 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. Particle beams are used for cancer therapy and in a broad range of materials science studies, and synchrotron light from electron accelerators is used for a wide variety of research studies, including biochemical and materials science. Nuclear physics techniques continue to develop and provide new capabilities for use in these applied areas. Highly trained manpower with knowledge of fundamental nuclear physics continues to be essential to progress in many of these areas.

The program works in close coordination with the nuclear physics program at the National Science Foundation (NSF) and, jointly with the NSF, charters the Nuclear Science Advisory Committee (NSAC) to provide advice on scientific opportunities and priorities for the nation's Nuclear Physics program. During 2001, NSAC will prepare, with community input, a new Long Range Plan for Nuclear Science, building on the previous plan submitted in 1996. The quality of the research and effectiveness of facility operations in this program are continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goal

The goal of the Nuclear Physics program is to maintain U.S. world leadership or be among the world leaders in the major scientific thrusts of fundamental nuclear physics research. These scientific thrusts, as identified in the 1996 NSAC Long Range Plans for Nuclear Science, seek to understand:

- the properties of nuclei at their limits of stability
- the structure of nucleons and nuclei in terms of their quark substructure
- the properties and behavior of nuclear matter under conditions of extreme pressure and temperature
- fundamental symmetries and astrophysical phenomena using nuclear physics techniques

Nuclear physics research is poised to make important new discoveries, as major facilities have come on-line to address physics in two of the major thrusts of the field. High intensity electron beams from the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) now allow detailed studies of how quarks and gluons bind together to make protons and neutrons. The Relativistic Heavy Ion Collider (RHIC), now beginning operations at Brookhaven National Laboratory (BNL), will instantaneously form submicroscopic specimens of quark-gluon plasma by colliding gold nuclei, thus allowing a study of the primordial soup of quarks and gluons thought to have existed at an early stage of the universe. The Sudbury Neutrino Observatory (SNO), constructed by a collaboration of Canadian, English and U.S. supported scientists, is now taking data on solar neutrino fluxes, and will provide the first results on the "appearance" of oscillations of electron neutrinos into another neutrino type. Evidence of such oscillation would confirm indications that neutrinos have mass, an observation that would force a re-evaluation of the existing Standard Model of particle physics.

In the 1996 NSAC Long Range Plan a Rare Isotope Accelerator (RIA) facility was identified as needed to maintain a leadership role. By producing and studying highly unstable nuclei that are now formed only in stars, scientists would use exotic isotope beams produced by RIA to explore the limits of nuclear existence and to better understand stellar evolution and the origin of the elements. R&D and preconceptual activities are being supported for this proposed facility.

Program Objectives

The management objectives of the Nuclear Physics program are to:

- Conduct a research program of maximum effectiveness, at the cutting edge of all major scientific areas in nuclear physics, that will lead to new knowledge and insights on the nature of energy and subatomic matter.
- Conceive, develop, construct, and operate the scientific accelerator, detector and computing facilities that are needed to address forefront science in a timely and effective manner. In the execution of this responsibility, together with other Office of Science organizations, act as the nation's leader in developing management techniques to optimize construction and operation of facilities in a cost effective, safe, and environmentally responsible manner.
- Leverage United States effort by means of international cooperation through the exchange of scientists and financial and technical contributions to cooperative projects.
- Continue the advanced education and training activities of young scientists to develop the new skills and concepts that will become the underpinnings of the nation's broad array of nuclear related sciences and technologies in the future.

- Manage the operations of the Nuclear Physics program to high standards, by ensuring that the processes of planning, reviewing, selecting and managing science projects and programs are sound and based on peer review and merit evaluation, and reflect input from the NSAC advisory group in coordinating DOE and NSF activities in nuclear physics.

To meet these objectives, the Nuclear Physics program is organized into four subprograms:

- The **Medium Energy Nuclear Physics** subprogram supports research and facility operations that are directed towards understanding the quark structure of matter. Two national user facilities, the Bates Linear Accelerator Center at MIT and CEBAF at TJNAF, are supported by this subprogram.
- The **Heavy Ion Nuclear Physics** subprogram supports research and the operations of RHIC at BNL that are directed towards understanding the properties and behavior of hot, dense nuclear matter, and in particular, the predicted quark-gluon plasma. This subprogram also has stewardship responsibilities for BNL.
- The **Low Energy Nuclear Physics** subprogram supports research and facility operations that are directed towards understanding the properties of nuclei at their limits of stability and the fundamental properties of nucleons and neutrinos. The operations of three national user facilities, the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL), the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) and the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL), and the operations of accelerators for in-house research programs at four universities (Yale University, Washington University, Texas A&M University, and Triangle Universities Nuclear Laboratory at Duke University) are supported by this subprogram. This subprogram also supports non-accelerator experiments, such as the SNO facility which is jointly operated by Canada, England and the U.S.
- The **Nuclear Theory** subprogram supports all nuclear physics theoretical research. The subprogram also provides support for the U.S. Nuclear Data program which has archival responsibilities for information generated in low- and intermediate-energy nuclear physics research worldwide.

All subprograms support researchers and graduate students at both universities and national laboratories and operations of facilities, and are responsible for achieving the program's objectives. Funding for the Small Business Innovation Research (SBIR) program is in the three experimental subprograms. Funding for the Small Business Technology Transfer (STTR) program is in the Medium Energy subprogram.

Evaluation of Objectives

The Nuclear Physics program evaluates the progress being made towards achieving its scientific and management objectives in a variety of ways. Regular peer review and merit evaluation is conducted for all activities, except those Congressionally mandated, based on procedures set down in 10 CFR 605 for the extramural grant program and under a similar modified process for the laboratory programs and scientific user facilities. All new projects are selected by peer review and merit evaluation for their scientific excellence. The program regularly conducts external reviews of its construction management programs to ensure they are on schedule and on budget. All experimental proposals at the national user facilities operated by the Nuclear Physics program are reviewed and evaluated for their merit and priority by Program Advisory Committees (PACs) prior to getting approval for beam time. Specific performance measures are included within the detailed program justification as appropriate.

The overall quality of the research in the Nuclear Physics (NP) Program will be judged excellent and relevant by external evaluation by peers, and through various forms of external recognition.

Leadership in key NP disciplines that are critical to DOE's mission and the Nation will be measured through external review and other mechanisms.

At least 80% of all new research projects supported by NP will be peer reviewed and competitively selected, and will undergo regular peer review merit evaluation.

Upgrades and construction of NP scientific facilities will be managed to keep within 10 percent of schedule and cost milestones.

NP will ensure that operational downtime of the facilities it manages will be, on average, less than 10 percent of scheduled operating days, barring unforeseen circumstances.

NP will ensure the safety and health of the workforce and members of the public and the protection of the environment in all its program activities.

Significant Accomplishments and Program Shifts

In FY 2000, the DOE Nuclear Physics (NP) program was the major sponsor of fundamental nuclear physics research in the nation, providing about 85% of the federal support, with the National Science Foundation (NSF) providing most of the remaining support.

Over one-third of the program's funding was provided to scientists at universities and laboratories to conceive and carry out the research. The DOE NP 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. University researchers play a critical role in the nation's research effort and in the training of graduate students. About two-thirds of the nation's university researchers and graduate students doing fundamental nuclear physics research in FY 2000 were supported by the DOE Nuclear Physics program. Typically ~ 95 Ph.D. degrees are granted annually to students for research supported by the program. State-of-the-art facilities to address forefront physics are essential for the U.S. to maintain its world leadership role in nuclear physics research. They are necessary not only to make progress in our understanding of fundamental nuclear physics, but also to provide scientific opportunities for discovery that generate sufficient interest and excitement to attract the brightest students.

SCIENCE ACCOMPLISMENTS

Medium Energy Nuclear Physics

- *Role of the strange quark in the structure of the proton:* The SAMPLE experiment at Bates provided data that represents the first direct information on how different quark flavors contribute to the proton's magnetic moment. It was found that the strange quarks play a surprisingly small role.
- *Development of a new technique with potential for important applications:* A new precision technique for Atom Trap Trace Analysis to study rare isotopes has been developed at Argonne National Laboratory. This technique also has broad new applications, such as dating ground water, polar ice, and bones, measuring the charge radius of some ions for the first time, measuring the integrated solar neutrino flux over several million years, and tracking bone loss in humans.

Heavy Ion Nuclear Physics

- *First Relativistic Heavy Ion Collider results:* First RHIC measurements indicate that the energy density – a measure of the energy deposited in the collision region by the colliding nuclei – is the highest ever achieved in a laboratory, at least 70% higher than in similar experiments at CERN, and sufficient to create the long sought quark-gluon plasma, believed to be the state of matter of the universe shortly after the "Big Bang." Two papers reporting results have already been published and several others are expected to follow shortly.

- *Possible evidence of the observation of a quark-gluon plasma:* The WA98 collaboration, that includes several U.S. groups, reported the first measurement of direct photon emission from the initial stages of relativistic lead-lead collisions, using beams from the SPS accelerator at CERN. This measurement suggests evidence for the possible formation of a quark-gluon plasma.

Low Energy Nuclear Physics

- *Unexpected behavior in the structure of heavy nuclei:* The Gammasphere detector, coupled with the Fragment Mass Separator at the ANL ATLAS facility, provided results on the structure of the Nobelium isotope ^{254}No, showing that nuclear shell structures, entirely responsible for the stability of nuclei with charges greater than 100, persist to higher angular momentum than had been expected.

- *Discovery of a new state in ^{18}Ne changes predicted rates of nucleosynthesis:* A series of experiments with short-lived beams of fluorine at HRIBF at Oak Ridge National Laboratory discovered a new quantum state in the neon isotope, ^{18}Ne. The inclusion of this missing state in the fusion chain changes the predicted nucleosynthesis of certain elements in stellar explosions by a factor of 1000. An expanded series of measurements will be carried out in FY 2000-2001 as new neutron rich beam species are developed and beam intensities increase.

Nuclear Theory

- *Advances in microscopic calculations:* A collaboration of DOE national laboratory theorists and an NSF supported university theorist reported the successful description of nuclear structure properties in *ab initio* calculations of nuclei with up to ten interacting protons and neutrons. This work has demonstrated that properties of light nuclei can be described to high precision only by including three-body forces. Previous calculations had been limited to three interacting particles; a theoretical and technical breakthrough was achieved, permitting these studies to be extended to much larger systems.

- *Supernovae explosions* are now being simulated in spherically symmetric computer models, after decades of theoretical and computational effort by a number of leading nuclear astrophysicists.

- *New calculations of the production of neutrinos in the sun* by proton capture on helium-3 predict a rate five times larger than used in the previous standard solar model. The improved calculations still indicate that there is a deficit in the observed flux of solar neutrinos. Such specific nuclear structure calculations are beginning to be utilized, with increased frequency, in models of astrophysical processes to improve the reliability of the predicted behaviors.

- *Previously unexplored fundamental properties of Quantum Chromodynamics (QCD) in two new phases of quark matter* - a color superconducting phase and a color-flavor locked phase – have been discovered by theorists. Unlike the quark-gluon plasma, which is a high temperature phase, these phases are found at low temperature and high matter density, and may exist in the core of a neutron star.

FACILITY ACCOMPLISHMENTS

Medium Energy Nuclear Physics

- In FY 2000, the *Continuous Electron Beam Accelerator Facility at the Thomas Jefferson National Accelerator Facility provided beams up to 5.7 GeV* (42% greater than the design energy of 4 GeV) to all three experimental halls for research with polarized and unpolarized beams. Further improvements in accelerator cavity performance are expected to increase the maximum energy to 6 GeV by FY 2002.
- In FY 2000, the *MIT/Bates facility* completed its beam development program and delivered a 1 GeV beam from the linear accelerator. In addition, the Siberian Snake solenoid system was successfully operated in the South Hall Ring. These are significant milestones in the development of capabilities for the planned Bates Large Acceptance Spectrometer Toroid (BLAST) research program using the new BLAST detector.
- The *BLAST detector* at the MIT/Bates facility will be completed in FY 2001, and in FY 2002 a research program will be initiated to study the structure of the nucleon and few-body nuclei. Upon completion of the BLAST research program in FY 2004, the Bates facility will begin a 2-year phaseout.
- *Fabrication of the G0 detector* at the Thomas Jefferson National Accelerator Facility (TJNAF) will be completed in FY 2002 and commissioning will begin. It will provide the capability of mapping out the strange quark contribution to nucleon structure over a wide range of momentum transfer.

Heavy Ion Nuclear Physics

- *Construction of the Relativistic Heavy Ion Collider (RHIC)* at Brookhaven National Laboratory was completed in FY 1999 on cost and schedule. Commissioning started in FY 1999 and data taking started in FY 2000, as scheduled. The first collisions between gold ions occurred in June 2000. It is planned that RHIC will approach full luminosity (collision rate) by the end of FY 2001.
- *All four RHIC detectors (BRAHMS, PHENIX, PHOBOS and STAR) completed their planned fabrication on schedule in FY 2000*; the detectors were commissioned and took first data. These experimental collaborations include 1000 researchers and students from 90 institutions and 19 countries.
- *RHIC detector enhancements* remain on schedule. The STAR Silicon Vertex Tracker (SVT), a high-resolution, high-granularity, particle tracking system very close to the collision region, and the RHIC Detector Analysis System were completed in FY 2000. One PHENIX muon arm will be completed in FY 2001; the second arm (funded substantially by Japan) will be completed in FY 2002. The Electromagnetic Calorimeter (EMCal) for STAR began production fabrication of modules in FY 2000.
- *Computing capabilities for STAR simulations and data analysis* is being developed at LBNL, in alliance with the National Energy Research Scientific Computing Center (NERSC). Funding in FY 2000-2002 will provide a system that will assist the STAR collaboration to effectively analyze RHIC events, of which each one requires track reconstruction of thousands of particles.
- In FY 2000, BNL announced *receipt of the International Standards Organization (ISO) 14001 registration for its RHIC project*, certifying the quality of the project's environmental management system. ISO 14001 enables an organization to define potential environmental impacts and establish controls needed to prevent any impact, to monitor and communicate environmental performance, and to establish a framework for continual improvement of the system. The RHIC project is the first

DOE Office of Science and first Long Island-based organization to obtain third-party registration to the ISO 14001 standard.

Low Energy Nuclear Physics

- *US/Canadian Sudbury Neutrino Observatory (SNO)* detector began the first full year of data taking in FY 2000. Initial physics results, on the measurement of solar neutrino fluxes relevant to the question of whether neutrinos have mass, are anticipated in FY 2001. The determination that neutrinos have mass would necessitate a revision of our present understanding of the "standard model" of matter and of the dynamics of the expanding universe.
- A three-year *R&D plan for the proposed Rare Isotope Accelerator (RIA) was developed* and initiated in FY 2000. RIA has been identified by the NSAC Isotope Separation On-Line (ISOL) Task Force as the optimal configuration for a next-generation world-class facility for low energy, nuclear astrophysics and nuclear structure research.
- Assembly of the *Japanese/US Kamioka Large Anti-Neutrino Detector (KamLAND)* began in FY 2000 and will continue in FY 2001. The experimental program for the detection of anti-neutrinos from Japanese nuclear power plants will be underway in FY 2002 with measurements that will provide information regarding whether neutrinos have mass. Eleven U.S. universities participate in KamLAND. U.S. participation in KamLAND is supported jointly with the High Energy Physics program.
- Fabrication of a *novel experiment with ultra-cold neutrons* began at the Los Alamos National Laboratory in FY 2000. Measurements from this experiment at the LANSCE facility will test theories of the weak coupling of quarks. First data are expected in FY 2002.

Nuclear Theory

In FY 2000, the *Institute for Nuclear Theory (INT)* at the University of Washington continued its activities as a premier international center for new initiatives and collaborations in nuclear theory research. Started in 1990, the INT has conducted three programs each year on topics identified by an international advisory committee. U.S. and foreign researchers spend varying lengths of time at the Institute during the 2-3 month period of the program to establish collaborations and carry out projects.

PROGRAM SHIFTS

- In the FY 2002 budget request the scope of the program is maintained, pending guidance from the community. A priority in the FY 2002 budget request is to maintain utilization of its major user facilities. The research programs at these major user facilities are integrated partnerships between DOE scientific laboratories and the university community. In FY 2002, the proposed experimental research activities are considered essential for effective utilization of the facilities. Within each of the subprograms, funding for university and national laboratory research is kept constant compared to FY 2001, and lower priority activities will be phased out in order to maintain manpower and focus efforts on the higher priority activities at these facilities. In the FY 2002 budget request, funding for capital equipment is reduced compared to FY 2001 to provide a ~1% increase for facility operations to mitigate the loss of critical personnel. There will be reductions in the number of Ph.D. researchers, technical staff and graduate students in the research program as well as at the facilities. Input and guidance from the community will be sought regarding the scientific opportunities to pursue for an optimal national program within the context of available funding and to maintain the nation's leadership role in fundamental nuclear physics research.
- In FY 2001, the Office of Science assumed from the Office of Environmental Management management and budget responsibilities for activities related to packaging, shipping, disposing of,

and reducing the volume of hazardous, radioactive or mixed waste generated in the course of normal operations at Brookhaven National Laboratory.

- In FY 2000, responsibilities in the Nuclear Physics program were reassigned to better manage the activities. The low energy heavy ion component of the Heavy Ion subprogram was moved to the Low Energy subprogram to bring those scientists who are focussed on nuclear structure, reactions, and nuclear astrophysics together into one subprogram. The Nuclear Data program, which had previously been managed by the Low Energy subprogram, was moved into the Nuclear Theory subprogram.

Scientific Facilities Utilization

The Nuclear Physics request includes $240,870,000 to maintain support of the Department's scientific user facilities. This investment will provide research time for several thousand scientists in 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 six National User Facilities supported by the Nuclear Physics program: the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL), the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF), the Bates Linear Accelerator Center at Massachusetts Institute of Technology (MIT), the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL), the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory (ANL), and the 88 Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL). The Alternating Gradient Synchrotron (AGS) at BNL, which is part of the RHIC complex, is also operated by the program for a limited research program. Further information on these facilities can be found in the Site Description and Detailed Justifications under the subprogram in which they are funded.

These facilities have provided over 20,000 hours of beams annually for a research community of about 3000 scientists. The FY 2002 level of operations is below the FY 2001 level. Programmatic decisions will be made, with input and guidance from the community, to reduce the program's scope with a focus on the highest priority program elements. This reduction in scope will also result in a somewhat smaller research community, particularly postdoctoral assistants and graduate students.

Workforce Development

The Nuclear Physics program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. It also provides talent for a wide variety of technical, medical, 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, national security and the stock market.

About 800 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2000 were involved in a large variety of experimental and theoretical research projects. Nearly one quarter 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 six Nuclear Physics User Facilities. In FY 2002, emphasis is placed on national facility operations at the expense of basic research and hardware investments until the program can be restructured based on guidance from NSAC and the community. The number of postdoctoral research associates and graduate students that can be supported in the current FY 2002 levels will decrease approximately 10% in comparison to FY 2000 numbers.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Nuclear Physics					
Medium Energy Nuclear Physics ..	108,752	120,910	-2,289	118,621	118,020
Heavy Ion Nuclear Physics..........	150,696	160,875	-5,058	155,817	156,295
Low Energy Nuclear Physics	60,448	64,175	-1,482	62,693	62,690
Nuclear Theory	20,973	23,930	-553	23,377	23,505
Subtotal, Nuclear Physics..................	340,869	369,890	-9,382	360,508	360,510
Construction	0	0	0	0	0
Subtotal, Nuclear Physics..................	340,869 [a]	369,890	-9,382	360,508	360,510
General Reduction	0	-3,766	3,766	0	0
General Reduction for Safeguards and Security	0	-4,821	4,821	0	0
Omnibus Rescission	0	-795	795	0	0
Total, Nuclear Physics.....................	340,869 [b c]	360,508	0	360,508	360,510

Public Law Authorization:

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

Public Law 103-62, "Government Performance and Results Act of 1993"

[a] Excludes $7,670,000 which has been transferred to the SBIR program and $460,000 which has been transferred to the STTR program.

[b] Includes $6,363,000 for Waste Management activities at Brookhaven National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $5,078,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Funding by Site

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	10,714	9,479	9,798	+319	+3.4%
Sandia National Laboratory	0	4	0	-4	-100.0%
Total, Albuquerque Operations Office	10,714	9,483	9,798	+315	+3.3%
Chicago Operations Office					
Argonne National Laboratory	17,912	17,782	16,568	-1,214	-6.8%
Brookhaven National Laboratory	136,462	139,450	140,429	+979	+0.7%
Fermi National Accelerator Laboratory	50	0	0	0	0.0%
Chicago Operations Office	50,018	52,548	50,113	-2,435	-4.6%
Total, Chicago Operations Office	204,442	209,780	207,110	-2,670	-1.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	18,060	18,213	17,899	-314	-1.7%
Lawrence Livermore National Laboratory	792	732	672	-60	-8.2%
Oakland Operations Office	17,194	16,830	16,131	-699	-4.2%
Total, Oakland Operations Office	36,046	35,775	34,702	-1,073	-3.0%
Oak Ridge Operations Office					
Oak Ridge Institute for Science & Education	611	670	674	+4	+0.6%
Oak Ridge National Laboratory	15,910	15,720	15,376	-344	-2.2%
Thomas Jefferson National Accelerator Facility	72,779	73,336	73,830	+494	+0.7%
Oak Ridge Operations Office	72	0	0	0	0.0%
Total, Oak Ridge Operations Office	89,372	89,726	89,880	+154	+0.2%
Washington Headquarters	295	15,744	19,020	+3,276	+20.8%
Total, Nuclear Physics	340,869 [abc]	360,508	360,510	+2	+0.0%

[a] Excludes $7,670,000 which has been transferred to the SBIR program and $460,000 which has been transferred to the STTR program.

[b] Includes $6,363,000 for Waste Management activities at Brookhaven National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $5,078,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. The major Nuclear Physics program activity at ANL supported by the Low Energy subprogram is the operation and research program at the ATLAS national user facility. Other activities include: (1) a Medium Energy group which carries out a program of research at TJNAF, Fermilab, RHIC and DESY in Germany; (2) R&D directed towards the proposed Rare Isotope Accelerator (RIA) facility; (3) 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 (4) data compilation and evaluation activities as part of the National 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 atom trap apparatus. The Gammasphere detector, which ATLAS shares on a rotating basis with the LBNL 88-Inch Cyclotron, coupled with the Fragment Mass Analyzer is a unique world facility for measurement of nuclei at limits of angular momentum (high-spin states). ATLAS is a world leader in superconducting linear accelerator technology, with particular application to the proposed Rare Isotope Accelerator (RIA) facility. The combination of versatile beams and powerful instruments enables the ~240 users at ATLAS to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies.

Brookhaven National Laboratory (BNL)

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The major Nuclear Physics program effort at BNL, supported by the Heavy Ion subprogram, is the operation and research program of the new Relativistic Heavy Ion Collider (RHIC). Other activities include (1) a Medium Energy group that will use polarized protons in RHIC to understand the internal “spin” structure of the protons and pursue a limited program of fixed target experiments at the AGS, (2) the Laser Electron Gamma Source (LEGS) group, supported by the Medium Energy subprogram, that uses a unique polarized photon beam to carry out a program of photonuclear spin physics at the National Synchrotron Light Source (NSLS), (3) a Nuclear Theory group that provides theoretical support and investigations primarily in the area of relativistic heavy ion physics, (4) a Low Energy group that plays an important role in the research program at the Sudbury Neutrino Observatory (SNO) that is measuring the solar neutrino flux, and (5) the DOE managed 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 1050 scientists from 19 countries. RHIC uses the Tandem, Booster, 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.” Operations began in FY 2000 and first results have already been published. RHIC can also accelerate and collide polarized protons at energies up to 250 GeV for a research program directed at understanding the quark structure of the proton.

The **Alternate 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. Experiments explore the quark constituents of light nuclei, and test the theories of quantum chromo-dynamics and electro-weak forces. 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. Limited operations are supported by the Medium Energy subprogram for fixed-target experiments which utilize high intensity secondary kaon and pion beams.

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.

Lawrence Berkeley National Laboratory (LBNL)

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. A major Nuclear Physics effort at LBNL, supported by the Low Energy subprogram, is the operations and the research program of the 88-inch Cyclotron, a national user facility. Other activities include (1) a Relativistic Nuclear Collisions group, with activities primarily at RHIC, where the group has been a major player in the development of the STAR detector; (2) a Low Energy group which has a major role in the implementation and operation of the Sudbury Neutrino Observatory (SNO) detector in Canada, and provides the project management of the U.S. collaboration in the KamLAND detector in Japan which is looking for evidence of neutrino mass; (3) a Nuclear Theory group, that carries out a program with emphasis on the theory of relativistic heavy ion physics; (4) a Nuclear Data group whose activities support the National Nuclear Data Center at BNL; and (5) a technical effort involved in RIA R&D.

The **88-Inch Cyclotron** facility provides high intensity stable beams from protons to bismuth at energies above the Coulomb barrier (up to 15 MeV per nucleon). The electron-cyclotron resonance (ECR) ion sources at the facility are state-of-the-art and copied around the world. The Gammasphere array, widely regarded as the world’s most powerful gamma-ray detector, is used to study nuclei at the extremes of angular momentum and excitation energy. The Berkeley Gas-filled Separator, a world-class instrument, is used for discovery experiments in superheavy elements. The 88" Cyclotron is used by a community of about 230 scientists.

Lawrence Livermore National Laboratory (LLNL)

Lawrence Livermore National Laboratory is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. Nuclear Physics supports research in nuclear structure studies carried out with the GENIE detector that was installed and is maintained by the LLNL group at the LANSCE facility at Los Alamos National Laboratory, as well as for nuclear data and compilation activities, and a technical effort involved in RIA R&D.

Los Alamos National Laboratory (LANL)

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. Nuclear Physics supports a broad program of research including: (1) a program of neutron beam research that utilizes beams from the LANSCE facility; (2) a relativistic heavy ion effort using the PHENIX detector at the new Relativistic Heavy Ion Collider (RHIC); (3) 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; (4) the development of the Sudbury Neutrino Observatory (SNO) detector as well as involvement in the planned research program; (5) a broad program of theoretical research into a number of topics in nuclear physics; (6) nuclear data and compilation activities as part of the national nuclear data program; and (7) a technical effort involved in RIA R&D.

Oak Ridge Institute for Science and Education (ORISE)

Oak Ridge Institute for Science and Education is located on a 150 acre site in Oak Ridge, Tennessee. Nuclear Physics support is provided through ORISE for activities in support of the Holifield Radioactive Ion Beam Facility (HRIBF) and its research program.

Oak Ridge National Laboratory (ORNL)

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The major effort at ORNL is the Low Energy program support for research and operations of the Holifield Radioactive Ion Beam Facility (HRIBF), that is run as a national user facility. Also supported is (1) a relativistic heavy ion group, that is involved in a research program using the PHENIX detector at RHIC; (2) a theoretical nuclear physics effort at ORNL that emphasizes investigations of nuclear structure and astrophysics; (3) nuclear data and compilation activities that support the national nuclear data effort; and (4) 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 by about 200 scientists. It provides a wide range of both proton-rich and neutron-rich nuclei to a suite of instruments designed 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 such a broad selection of ions. The HRIBF conducts R&D on ion sources and low energy ion transport for radioactive beams.

Thomas Jefferson National Accelerator Facility (TJNAF)

Thomas Jefferson National Accelerator Facility (TJNAF) is a laboratory operated by the Nuclear Physics program located on 273 acres in Newport News, Virginia. Medium Energy subprogram support is provided for the operation and research program of 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, used by over 1100 scientists. CEBAF consists of two multi-pass parallel continuous beam superconducting linear accelerators connected by recirculating magnetic arcs. Polarized and unpolarized electron beams up to 200 microamperes at up to 5.7 GeV are available that can be simultaneously distributed to three target halls. A large variety of major instruments are available for studying the scattering and particle production of the electron with fixed gas and solid targets. Fabrication of the G0 detector, a joint NSF-DOE project, that will allow a detailed mapping out of the strange quark contribution to nucleon structure, will be completed during FY 2002. Support is provided for a nuclear theory group whose program of investigations supports the experimental program of the laboratory. An accelerator R&D group is supported for projects important to the Nuclear Physics program, such as the proposed 12 GeV upgrade of CEBAF and R&D for RIA.

All Other Sites

The Nuclear Physics program funds 180 research grants at 85 colleges/universities located in 35 states. Among these is a grant with the Massachusetts Institute of Technology (MIT) for the operation of the **Bates Linear Accelerator Center** as a national user facility used by about 250 scientists. The Bates facility, with electron beams up to 1 GeV, conducts experiments to study the properties and constituents of protons and light nuclei at energies below those of CEBAF. The research program probes the properties of the proton such as its shape and polarizability, and the charge distribution and magnetism of the deuteron. A major instrument for making these measurements will be the Bates Large Acceptance Spectrometer Torroid (BLAST) detector, whose fabrication will be completed in FY 2002. BLAST will observe collisions of polarized electrons in thin polarized gas targets located in the South Hall Pulse Stretcher Ring. Additional unique experiments are performed with the Out-Of Plane Spectrometer (OOPS). The Bates experimental program is scheduled to be concluded in 2004 and phased out in FY 2005-2006.

Grants for the operation of accelerator facilities at four university laboratories are supported by the Low Energy subprogram for research in selected and specialized areas conducted primarily by the in-house faculty members and students. The **Triangle Universities Nuclear Laboratory (TUNL)** utilizes a tandem Van de Graaff and polarized beams and targets to test and refine the theory of the nuclear force and its currents. A suite of instrumentation has been built up to take advantage of this unique combination of capabilities and to study fundamental symmetries and reactions important to nuclear astrophysics. **The Texas A&M Cyclotron Institute (TAMU)** operates a modern superconducting cyclotron to deliver a wide range of stable and selected radioactive beams for medium energy heavy-ion reaction studies, tests of fundamental constants of the standard model, and nuclear astrophysics. Modern instrumentation takes advantage of the heavy-ion beams, and a number of foreign collaborators use the facility. **The Yale Tandem Van de Graaff** provides a variety of stable beams for an extensive suite of instruments that, along with the opportunity for extended running times, provides the capability for detailed experiments on symmetry, collective structures, and evolution of properties in nuclei and nuclear astrophysics. The **University of Washington Tandem Van de Graaff** provides precisely characterized proton beams for extended running periods for research in fundamental nuclear interactions and nuclear astrophysics. These four 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. These facilities operate in a university environment and thus provide a unique setting for the training and education of graduate students in the U.S., where they have the opportunity to be involved in all aspects of low energy nuclear research. These centers of excellence have in the past and continue today to produce the next generation of national leaders in nuclear science research.

Medium Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Nuclear Physics program supports the basic research necessary to identify and understand the fundamental features of atomic nuclei and their interactions. The Medium Energy Nuclear Physics subprogram supports fundamental research that is ultimately aimed at achieving a quantitative understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects that are believed to combine in different ways to make all the other sub-atomic particles. Equally important is the achievement of an understanding of the "strong force," one of only four forces in nature, and the force that holds the nucleus of the atom together. Research efforts include studies of the role of excited states of protons and neutrons in nuclear structure, investigations of the role of specific quarks in the structure of protons and neutrons, studies of the symmetries in the behavior of the laws of physics, and investigations of how the properties of protons and neutrons change when embedded in the nuclear medium. Measurements are often carried out with beams of electrons or protons whose "spins" have all been lined up in the same direction (polarizing the beams) to determine what role the intrinsic spins of the quarks and gluons play in the structure of the nucleon.

This research is generally carried out using electron and proton beams provided by accelerator facilities operated by this subprogram, other Department of Energy programs (e.g., High Energy Physics and Basic Energy Sciences), and at other unique domestic or foreign facilities. These facilities produce beams of sufficient energy (small enough wavelength) that they can probe at a scale within the size of a proton or neutron. The Medium Energy Nuclear Physics subprogram supports the operations of two national user facilities - the Thomas Jefferson National Accelerator Facility (TJNAF) and the Bates Linear Accelerator Center operated by the Massachusetts Institute of Technology. These accelerator facilities serve a nationwide community of over 500 Department of Energy and National Science Foundation supported scientists and students from over 140 American institutions, of which over 80% are colleges and universities. Both facilities provide major contributions to education at all levels. At both TJNAF and Bates, the National Science Foundation (NSF) has made a major contribution to new experimental apparatus in support of the large number of NSF users. A significant number of foreign scientists collaborate in the research programs of both facilities. The research program at the TJNAF, for example, involves over 250 scientists from 19 foreign countries; many of these scientists are from Conseil Europeen pour la Recherche Nucleaire (CERN) member states. At TJNAF, foreign collaborators have also made major investments in experimental equipment.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Research					
University Research	16,654	16,498	15,295	-1,203	-7.3%
National Laboratory Research	14,523	16,162	16,345	+183	+1.1%
Other Research	360	5,221	5,415	+194	+3.7%
Subtotal, Research	31,537	37,881	37,055	-826	-2.2%
Operations					
TJNAF Operations	66,330	66,666	67,515	+849	+1.3%
Bates Operations	10,885	12,623	12,000	-623	-4.9%
Other Operations	0	1,451	1,450	-1	-0.1%
Subtotal, Operations	77,215	80,740	80,965	+225	+0.3%
Total, Medium Energy Nuclear Physics	108,752	118,621	118,020	-601	-0.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Research	**31,537**	**37,881**	**37,055**
▪ **University Research**	**16,654**	**16,498**	**15,295**

These activities comprise a broad program of research, and include 40 grants at 35 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 use other U.S. and international accelerator laboratories. Included in University Research is Bates Research, the effort performed at the MIT/Bates Linear Accelerator Center by MIT scientists. Other University Research includes all other university-based efforts using many research facilities, including activities by MIT scientists that are not carried out at Bates. **Performance will be measured by** triannual peer review.

Bates Research	**4,617**	**4,145**	**2,945**

MIT scientists along with other university researchers have completed "symmetry violation" studies on the proton and deuteron in the North Experimental Hall. The experiment (SAMPLE) provided important information on the quark flavor contribution to the proton's spin magnetism. "Out-of-Plane" measurements are being carried out using the new spectrometers (OOPS) in the South Experimental Hall on the proton, deuteron, and complex nuclei including measurements of the transition of the proton to its excited state.

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

Preparations are being made for a new program of research to study the structure of the nucleon and the nature of the nucleon-nucleon force, utilizing the new Bates Large Acceptance Spectrometer Toroid (BLAST) detector. The decrease in funding in the request for FY 2002 reflects the completion of the funding for BLAST fabrication in FY 2001. **Performance will be measured by** the initiation of measurements with BLAST on schedule in FY 2002 using thin gas targets and the high current circulating electron beam in the South Hall Pulse Stretcher Ring.

	FY 2000	FY 2001	FY 2002
Other University Research..	**12,037**	**12,353**	**12,350**

In FY 2002 university researchers are supported at the same funding level as FY 2001 to address forefront science at accelerator and non-accelerator facilities. Activities include:

University scientists are collaborating on important ongoing and future experiments at TJNAF. FY 2001-2002 activities include the completion of studies of the charge structure of the neutron in Hall C. Planned measurements in Hall A include the electric form factor of the proton. A series of studies of the excited states of the proton will continue in Hall B. First parity-violation measurements to look for the "strange quark" content of the proton in Hall A have been completed. Scientists are participating in major new detector fabrication to be completed in FY 2002 for the "G0" experiment in cooperation with the National Science Foundation. "G0" will allow a "complete mapping" of the strange quark content of the nucleon using parity violation techniques. An important experiment in hypernuclear spectroscopy has just completed data taking in Hall C. Plans are also underway to carry out a program of higher resolution hypernuclear spectroscopy in Hall A.

A number of university groups are collaborating in experiments using the new Out-of-Plane Spectrometers in the South Experimental Hall at the MIT/Bates Linear Accelerator Center to probe nucleon and few-body nuclear structure. BLAST will be completed in FY2001 and university research support will be provided in FY 2002 for use of this new detector.

University scientists and National Laboratory collaborators will continue to carry out the HERMES (HERa MEasurements with Spin) experiment at the DESY laboratory in Hamburg, Germany. This experiment is measuring which components of the proton or neutron determine the "spin" of these particles, an important and timely scientific issue which will be explored in the planned program at RHIC starting in FY 2003. In FY 2002, HERMES will utilize a new Ring Imaging Cerenkov counter for identification of quark flavor contributions to the spin of the nucleon.

Polarization experiments are being conducted at the SLAC (Stanford Linear Accelerator) facility. One parity violation experiment aims to make a precise determination of the weak mixing angle, an important fundamental parameter of the Standard Model of Particle Physics.

	FY 2000	FY 2001	FY 2002
▪ **National Laboratory Research**	**14,523**	**16,162**	**16,345**

Included is: (1) the research supported at the Thomas Jefferson National Accelerator Facility (TJNAF), that houses the nation's and world's unique 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**.** **Performance is measured by** peer review and merit evaluation.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
TJNAF Research	**5,700**	**5,741**	**5,770**

Scientists at TJNAF, with support of the user community, assembled the large and complex new experimental apparatus for Halls A, B, and C. All three experimental Halls are operational. TJNAF scientists provide experimental support and operate the apparatus for safe and effective utilization by the user community. TJNAF scientists participate in the laboratory's research program, and collaborate in research at other facilities.

As of FY 2001, both Hall A and Hall C will have completed fifteen experiments each. The complex large-acceptance spectrometer in Hall B is complete and the research program has completed over 50% of the data taking for 41 experiments. TJNAF researchers participate in all of these experiments.

TJNAF scientists are participating in the assembly of a new detector for the "G0" experiment, in cooperation with the National Science Foundation. The G0 detector will be completed in FY 2002.

Other National Laboratory Research	**8,823**	**10,421**	**10,575**

Researchers at National Laboratories are supported at about the same level as FY 2001 to address forefront science at accelerator and non-accelerator facilities. These activities include:

Argonne National Laboratory scientists are pursuing research programs at TJNAF, at the DESY Laboratory in Germany, and have proposed measurements of the quark structure of the nucleon at the new Main Injector at Fermilab. The theme running through this entire effort is the search for a detailed understanding of the internal quark-gluon structure of the nucleon. They have also made important advances in the technique of Atom Trap Trace Analysis to be used in measurements of rare isotopes for precision studies of nuclear structure.

At Brookhaven National Laboratory, the Medium Energy Research group, which in previous years has concentrated on hadron beam experiments at the AGS, will change its major emphasis. Since the AGS will now serve as a heavy ion and proton injector for the new RHIC accelerator, the group's scientific emphasis will shift to "RHIC Spin". This is the set of experiments planned for RHIC that will use colliding polarized proton beams to investigate the spin content of the nucleon and, in particular, what role gluons play. In FY2001-2002, additional funding is being provided to this group to assure that appropriate scientific effort has been assembled in support of the RHIC Spin effort. A limited program of fixed target experiments will continue at the AGS, including an important study of hypernuclei for which the Japanese have made significant investments and are major collaborators.

Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists will be utilizing a new spectrometer and a recently developed polarized ice target for a program of spin physics at low energies. This unique facility produces its polarized "gammas" by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source (NSLS). In FY 2002, the research program utilizing the new equipment will commence.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

At Los Alamos National Laboratory, scientists and collaborators will be preparing to carry out a next generation neutrino oscillation experiment which builds on the experience of the Liquid Scintillator Neutrino Detector (LSND) experiment at Los Alamos, that detected a signal of neutrino oscillations. If oscillations are proven, then neutrinos would have mass, requiring changes in our present understanding of the laws of physics. The Booster Neutrino Experiment (BooNE) will use neutrinos generated from the Fermi National Accelerator Laboratory Booster proton beam; data collection is planned to commence in FY 2002.

Los Alamos scientists also are involved in experiments at Fermilab and at RHIC (RHIC Spin) that continue to try to unravel the mysteries of the internal components and spin of the nucleon. 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**..	**360**	**5,221**	**5,415**

Amounts include funds for the SBIR and STTR programs and other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

Amounts include the estimated requirements for the FY 2001 and FY 2002 SBIR programs and other established obligations.

Operations...	**77,215**	**80,740**	**80,965**
▪ **TJNAF Operations**	**66,330**	**66,666**	**67,515**

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	**42,126**	**42,436**	**42,910**

Funding for accelerator operations in FY 2002 supports a 3,900 hour (26-week) running schedule. In a constrained budget, TJNAF is able to almost maintain the same level of operations as in FY 2001, with a smaller staff. The accelerator now routinely delivers beams of differing energies and currents simultaneously to the three experimental halls. A maximum beam energy of 5.7 GeV has been delivered to experiments. High current, high polarization beam capability is now also available and is being used for experiments.

	(hours of beam for research)		
	FY 2000	FY 2001	FY 2002
TJNAF	4500	4050	3900

Funding is provided for AIP projects for the polarized injector and beam handling components as well as other additions and modifications to the accelerator facilities. GPP funding is provided for minor new construction and utility systems.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
TJNAF Experimental Support	**24,204**	**24,230**	**24,605**

Operating and equipment funding is provided for the experimental support needed to effectively carry out the TJNAF experimental program.

Support is increased (1% or $181,000) for the scientific and technical manpower, materials, and services needed 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. Efforts in FY 2002 will be focused on effectively carrying out two-Hall simultaneous operation as opposed to three.

The G0 detector, a major item of equipment with a Total Estimated Cost of $7,570,000 is being assembled. DOE's contribution is $3,965,000 and the National Science Foundation is contributing $3,605,000 to this detector. As G0 construction is completed in FY 2002 (-$957,000), TJNAF is shifting their base capital equipment and AIP emphasis (including an increase of $194,000 in capital funds) towards assembly and installation of polarized electron injector improvements for the accelerator, ancillary equipment items such as polarized targets for experimental Halls A, B, 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. **Performance will be measured by** the completion of fabrication, commissioning and initiation of measurements with the G0 detector in FY 2002.

▪ **Bates Operations**	**10,885**	**12,623**	**12,000**

Funding is provided to support accelerator operations at the MIT/Bates Linear Accelerator Center.

Bates will operate in FY 2002, to carry out a program focused primarily on commissioning activities for the BLAST detector. The new BLAST detector will observe collisions in thin gas targets located on the South Hall Pulse Stretcher Ring. **Performance will be measured by** the commissioning of the BLAST detector and the initiation of its research program in FY 2002. When the scientific program of BLAST commences in FY 2002, the Bates research effort will concentrate on this new experimental facility. Upon completion of the BLAST research program in FY 2004, it is now planned that the Bates facility will begin a 2-year phaseout. Starting in FY 2005, Decontaminating and Decommissioning (D&D) activities will be initiated. The D&D cost and schedule will be determined at that time.

	(hours of beam for research)		
	FY 2000	FY 2001	FY 2002
Bates	2000	2000	2100

Accelerator operations in FY 2001 are providing beams for research programs in the South Hall utilizing the OOPS spectrometers, for testing of internal, polarized, continuous beams in the South Hall Ring, and for development of extracted continuous beams for delivery to the existing South Hall spectrometers.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		

AIP funding supports additions and modifications to the accelerator facilities; GPP funding supports minor new construction and utility systems. The decrease in FY 2002 funding reflects a decrease in the investments in AIP and capital equipment in anticipation of the phase out of the Bates facility.

	FY 2000	FY 2001	FY 2002
▪ **Other Operations**	**0**	**1,451**	**1,450**

Funding is provided to support accelerator operations at other facilities.

Funding is provided for 600 hours (6 weeks) of beam, to carry out a limited program of high priority experiments at the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory including an important study of hypernuclei for which the Japanese made an investment in detector fabrication.

	FY 2000	FY 2001	FY 2002
Total, Medium Energy Nuclear Physics	**108,752**	**118,621**	**118,020**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Research	
▪ **University Research**	
The MIT/Bates research activity decrease reflects the completion of funding of the BLAST detector system ($1.2 million in FY 2001). Research support is provided to carry out BLAST commissioning and its research program.	-1,200
Research support at other universities is at the same level as FY 2001. Lower priority activities will be phased out in order to maintain manpower and focus efforts on the high priority activities at TJNAF.	-3
▪ **National Laboratory Research**	
Funding for TJNAF and other National Laboratory groups is increased by about 1% to help maintain efforts. Lower priority activities will be phased out in order to maintain manpower and focus efforts on the high priority activities at TJNAF.	+183
▪ **Other Research**	
Estimated SBIR/STTR and other obligations increase.	+194
Total Research	-826

	FY 2002 vs. FY 2001 ($000)
Operations	
▪ **TJNAF Operations**	
TJNAF Accelerator Operations: Funding for accelerator operations is increased by about $410,000 (+1%) in order to carry out a 26 week running schedule. In FY 2001, TJNAF is expected to operate 27 weeks. Funding (about +$63,000) for general plant and accelerator improvements projects is provided. In a constrained budget, TJNAF is able to almost maintain the same level of operations as in FY 2001, with a smaller staff.	+474
TJNAF Experimental Support: Support is increased by about 1.0% (+$181,000) in order to help maintain the needed manpower and equipment required for carrying out the highest priority experimental programs. Effort will be focused on carrying out two-Hall simultaneous operation as opposed to three. Overall capital equipment funding is increased $194,000 with additional funds provided for the planned experimental program as funding for the G0 detector is decreased.	+375
▪ **Bates Operations**	
The reduction in Bates operations reflects the planned funding profile for Bates, in which operations concentrates on research with the new BLAST detector. Bates, with a smaller operating staff, will provide 2100 beam hours for the commissioning of the BLAST detector and the initiation of its research program. Funding for Capital equipment and AIP is reduced by about $500,000.	-623
▪ **Other Operations**	
Funding of the operation of the AGS at BNL is constant compared to FY 2001 and provides 600 hours (6 weeks) of beam time to complete high priority experiments.	-1
Total Operations	+225
Total Funding Change, Medium Energy Nuclear Physics	-601

Heavy Ion Nuclear Physics

Mission Supporting Goals and Objectives

The Heavy Ion Nuclear Physics subprogram supports research directed at understanding the properties of nuclear matter over the wide range of conditions created in nucleus-nucleus collisions, particularly the predicted phase changes from the liquid to gas state and from normal to quark matter. Using beams of accelerated heavy ions at intermediate bombarding energies, research is focused on the study of the fragmentation of nuclei in highly violent collisions and the flow of nuclear matter in less violent collisions. From such studies of the flow of nuclear matter, one can obtain information regarding the equation of state of nuclear matter; such information is important in understanding the dynamics of supernova explosions. At much higher relativistic bombarding energies, collisions producing hot, dense nuclear matter are studied with the goal of observing the deconfinement of normal matter into the quark-gluon plasma. This form of matter is predicted to have been the early phase of the universe, a millionth of a second after the Big Bang. Scientists and students at universities and national laboratories are funded to carry out this research at the DOE supported Relativistic Heavy Ion Collider (RHIC) facility, as well as at the National Science Foundation (NSF) and foreign supported accelerator facilities.

The Heavy Ion Nuclear Physics subprogram supports operation of RHIC at Brookhaven National Laboratory (BNL). This is a unique world-class facility that addresses fundamental questions about the nature of nuclear matter. With it one can study collisions of heavy nuclei at energies over 10 times of that previously available at any other facility in the world, namely at CERN. The RHIC is also the only accelerator facility in the world that provides collisions of polarized protons with polarized protons. From these collisions, important and unique information can be obtained regarding the composition of the gluons that provide the binding of the quarks to make the nucleons, the protons and neutrons that make up the nucleus. The construction of RHIC was completed in August 1999, and first collisions were observed in June 2000. The RHIC facility is utilized by over 1,050 DOE, NSF, and foreign supported researchers. The RHIC experimental program is determined with the guidance of a Program Advisory Committee, consisting of distinguished scientists, that reviews and evaluates proposed experiments and advises the BNL Associate Director for Nuclear and High Energy Physics regarding their merit and scientific priority. Capital Equipment and Accelerator Improvement Project (AIP) funds are provided for additions, modifications, and improvements to the research accelerators and ancillary experimental facilities to maintain and improve the reliability and efficiency of operations, and to provide new experimental capabilities. An annual peer review of the effectiveness of RHIC operations and its research program is conducted by the program. **Performance will be measured by** completing the first round of experiments at 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.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

The Heavy Ion Nuclear Physics subprogram also provides General Purpose Equipment (GPE), General Plant Project (GPP), and waste management funds to BNL as part of Nuclear Physics' landlord 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 the processing of hazardous, radioactive or mixed-waste generated during normal operations.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Research					
University Research	11,511	12,004	11,495	-509	-4.2%
National Laboratory Research	22,995	21,689	20,860	-829	-3.8%
Other Research	0	2,848	2,850	+2	+0.1%
Subtotal, Research	34,506	36,541	35,205	-1,336	-3.7%
Operations					
RHIC Operations	99,767	102,691	104,505	+1,814	+1.8%
Other Operations	10,060	10,641	10,640	-1	0.0%
BNL Waste Management	6,363	5,944	5,945	+1	0.0%
Subtotal, Operations	116,190	119,276	121,090	+1,814	+1.5%
Total, Heavy Ion Nuclear Physics	150,696	155,817	156,295	+478	+0.3%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Research	**34,506**	**36,541**	**35,205**
▪ **University Research**	**11,511**	**12,004**	**11,495**

Support is provided for the research of scientists and students at 27 universities in 18 states. **Performance will be measured** for all these research activities by peer review triannually.

- Researchers using primarily the NSF supported National Superconducting Cyclotron Laboratory at Michigan State University, at Texas A&M University, and at foreign facilities in France, Germany, 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.
- Research using relativistic heavy ion beams is focused on the study of the production and properties of hot, dense nuclear matter at initial experiments at RHIC, where an entirely new regime of nuclear matter now becomes available to study for the first time. The university groups provide core manpower for the operation of and data analysis from the four RHIC detectors. The ~$500,000 decrease reflects the completion of capital equipment projects in FY 2001 and no new projects in FY 2002.

	FY 2000	FY 2001	FY 2002
▪ **National Laboratory Research**	**22,995**	**21,689**	**20,860**

Support is provided for the research programs of scientists at four National Laboratories (BNL, LBNL, LANL and ORNL) that play critical roles especially in the instrumentation. **Performance is measured by** peer review and merit review.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
BNL RHIC Research	**13,192**	**10,888**	**10,065**

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. The planned running periods in FY 2001 and FY 2002 will be critical for this new research program as RHIC approaches its design luminosity (collision rate) and all four RHIC detectors reach their full potential for studies of the expected new forms of nuclear matter that will be created in the heavy ion collisions. In FY 2002 funding is increased by about 0.5% for research, but funding for capital equipment is decreased by about $856,000 with the completion of the PHENIX muon instrumentation. Funding continues for production of modules for the Electromagnetic Calorimeter enhancement for STAR.

- The muon instrumentation for PHENIX allows measurement of the yields of muons ("heavy electrons") that probe the early stages of quark-gluon plasma formation. The Japanese are contributing substantial support for the two PHENIX muon arms, which are also critical components of the detection systems for measurements in the PHENIX RHIC Spin Program.
- The Electromagnetic Calorimeter for STAR provides capability to distinguish electrons from photons, and extends the measurement of particle energy to high energies. The detector system is also a critical component for the RHIC Spin Program for STAR. Production of calorimeter modules began in FY 2000 and will continue through FY 2003.

Other National Laboratory Research	**9,803**	**10,801**	**10,795**

Researchers at LANL, LBNL, and ORNL provide leadership in the commissioning of the PHENIX muon arm and the STAR electromagnetic calorimeter, as well as play leadership roles in carrying out the research utilizing these detectors. At LBNL development of the analysis system for RHIC data, in alliance with the National Energy Research Scientific Computing Center (NERSC), will be completed.

▪ **Other Research**	**0**	**2,848**	**2,850**

Amounts include the estimated requirements for the continuation of the FY 2001 and FY 2002 SBIR programs and other established obligations.

Operations	**116,190**	**119,276**	**121,090**
▪ **RHIC Operations**	**99,767**	**102,691**	**104,505**

The Relativistic Heavy Ion Collider (RHIC) is anticipated to reach nearly full data production capabilities by the end of the planned running period in FY 2002. RHIC is a unique facility whose colliding relativistic heavy ion beams will permit exploration of hot, dense nuclear matter and recreate the transition from quarks to nucleons that characterized the early evolution of the universe. Studies with colliding heavy ion beams will provide researchers with an opportunity to explore a new regime of nuclear matter and nuclear interactions that up to now has only been characterized theoretically.

During the FY 2001-FY 2002 running periods, preparations of RHIC for its spin physics program will continue, with the anticipation that the spin physics experimental program will begin in FY 2003. The RHIC spin program accelerates polarized protons to study the internal structure of the

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

protons, in particular the role of the gluons whose interaction with the quarks binds the quarks together to make the protons and neutrons. Understanding the role of the gluons is important for understanding the properties of the quark-gluon plasma.

	FY 2000	FY 2001	FY 2002
RHIC Accelerator Operations	**73,525**	**74,975**	**76,345**

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. RHIC came into operations in FY 2000 with a total of 4,030 hour (27-week) operations schedule that was focused on commissioning the new accelerator and detector systems. Beam time for research is expected to increase significantly in FY 2001 with a similar total operating schedule. FY 2002 funding supports a 3,000 hour (20-week) RHIC total operating schedule. The schedule provides 1,650 hours of beam for research with the remainder of the schedule (1,350 hours) for beam studies, commissioning operations with polarized protons and cryogenic warm up. With a limited budget, NP has chosen to retain personnel and run as much as possible. The planned increase in luminosity will allow more data to be acquired within a given running period, as compared to previous experimental runs. **Performance will be measured by** achieving the design luminosity (collision rate) of RHIC for heavy ions in FY 2002. Capital equipment funding is provided for normal maintenance projects and AIP funding is provided for needed improvement projects. A 1% increase in RHIC operation funding supports a 3,000 hour (20-week) running schedule. As construction of major detector projects are completed, $651,000 of capital equipment funds are shifted from BNL RHIC Research to BNL Accelerator Operations in order to optimize and maintain these large detectors, as well as start AIP initiatives that will lead to more efficient operations.

RHIC Operations

	(hours of beam for research)		
	FY 2000	FY 2001	FY 2002
RHIC	380	1900	1650

	FY 2000	FY 2001	FY 2002
RHIC Experimental Support	**26,242**	**27,716**	**28,160**

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. RHIC detectors (STAR, PHENIX, BRAHMS and PHOBOS) will reach their initial planned potential by FY 2002. Over 1050 scientists and students from 90 institutions and 19 countries will participate in the research programs of these four detectors. Funding is increased by 1% compared to FY 2001 for experimental support.

	FY 2000	FY 2001	FY 2002
▪ **Other Operations**	**10,060**	**10,641**	**10,640**

As steward for Brookhaven National Laboratory (BNL), the Nuclear Physics program provides GPP funding for minor new construction, other capital alterations and additions, and for buildings and utility systems. Funding of this type is essential for maintaining the productivity and usefulness of

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. The total estimated cost of each project will not exceed $5,000,000. In addition, the program has landlord responsibility for providing General Purpose Equipment (GPE) at BNL.

▪ **BNL Waste Management**	**6,363**	**5,944**	**5,945**

Provides funding for the activities related to packaging, shipping, and disposing of, and reducing the volume of, hazardous, radioactive or mixed waste generated in the course of normal operations at Brookhaven National Laboratory.

Total, Heavy Ion Nuclear Physics	**150,696**	**155,817**	**156,295**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Research	
▪ **University Research**	
FY 2002 funding for University Research is maintained at a constant level compared to FY 2001. Equipment funding in FY 2002 is decreased by about $500,000 as projects are completed. Lower priority activities will be reduced in order to focus efforts on those activities at RHIC identified as providing the most promising physics opportunities.	-509
▪ **National Laboratory Research**	
BNL RHIC Research: Research support is increased by about 0.5% to effectively carry out research with the enhanced detectors at full luminosity at RHIC. Capital equipment is decreased by about $850,000 as projects are being completed. Lower priority activities will be reduced in order to focus efforts on those activities at RHIC identified as providing the most promising physics opportunities.	-823
Other National Laboratory Research: Research support is maintained at a constant level compared to FY 2001. Lower priority activities will be reduced in order to focus efforts on those activities at RHIC identified as providing the most promising physics opportunities. .	-6
▪ **Other Research:**	
Estimated SBIR and other obligations remain about the same.	+2
Total, Research	-1,336

	FY 2002 vs. FY 2001 ($000)
Operations	
▪ **RHIC Operations**	
Accelerator Operations: An increase of $719,000 (+1%) in operating funds provides an estimated 20-week running schedule, compared with 27 weeks in FY 2001. An increase of $651,000 is provided to bring Capital equipment and Accelerator Improvement Project funding (to a total of $3,600,000) to a level that will sustain operations. A revised physics program will be developed which will optimize the physics output with the proposed running schedule.	+1,370
Experimental Support: An increase of $240,000 (+1%) is provided to enhance support of manpower and services to effectively carry out research measurements. An additional $204,000 is provided for experimental equipment to enhance detector and computing capabilities that will be needed for full luminosity running.	+444
▪ **Other Operations**	
FY 2002 funding for General Plant Projects and General Purpose Equipment to Brookhaven National Laboratory is constant compared to FY 2001.	-1
▪ **BNL Waste Management**	
FY 2002 funding for Waste Management is provided at the same level as FY 2001 to maintain activities.	+1
Total, Operations	+1,814
Total Funding Change, Heavy Ion Nuclear Physics	+478

Low Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Low Energy Nuclear Physics subprogram supports research directed at understanding the structure of nuclei, nuclear reaction mechanisms, and experimental tests of fundamental symmetries. At the present time, emphasis is placed on addressing issues in nuclear astrophysics, and the structure of nuclei at the limits of energy, deformation, angular momentum, and isotopic stability. This research is generally conducted using beams provided by accelerator facilities operated by this subprogram, other Department of Energy programs, or at other domestic or foreign facilities.

The Low Energy Nuclear Physics subprogram supports the operation of the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory, the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory, and the 88-Inch Cyclotron facility at the Lawrence Berkeley National Laboratory. Research and development and preconceptual design activities at these facilities are in support of a next generation low-energy facility, the Rare Isotope Accelerator (RIA). All the National Laboratory facilities are utilized by DOE, NSF, and foreign-supported researchers whose experiments undergo peer review prior to approval for beam time. 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 experimental 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. These university centers of excellence each have a critical mass of nuclear physics faculty involved in research that is conducted both on and off campus, have about 15-25 graduate students at different stages of their education, and historically have produced a large fraction of the leaders in the field. The accelerator facilities are relatively small and appropriate for siting on university campuses, where they provide unique opportunities for hands-on training of nuclear experimentalists that complement the experience that can be obtained at the national user facilities. Many of these scientists, after obtaining their PhDs, contribute to a wide variety of nuclear technology programs of interest to the DOE.

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 study of neutrinos from the sun is an example. The Sudbury Neutrino Observatory (SNO) detector is designed to study the production rate and properties of solar neutrinos. The Kamioka Large Anti-Neutrino Detector (KamLAND) will study the properties of anti-neutrinos produced by reactors. Both of these experiments address the important and interesting question of whether neutrinos have a mass. The answer to this very fundamental question has profound implications for our understanding of the basic building blocks of matter and the evolution of the universe.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Research					
University Research	16,778	17,395	16,965	-430	-2.5%
National Laboratory Research	19,508	19,747	19,835	+88	+0.4%
Other Research	2,000	3,808	4,030	+222	+5.8%
Subtotal Research	38,286	40,950	40,830	-120	-0.3%
Operations					
HRIBF Operations	8,847	8,837	8,925	+88	+1.0%
ATLAS Operations	7,601	6,992	7,060	+68	+1.0%
88-Inch Operations	5,714	5,914	5,875	-39	-0.7%
Subtotal Operations	22,162	21,743	21,860	+117	+0.5%
Total, Low Energy Nuclear Physics	60,448	62,693	62,690	-3	0.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Research	**38,286**	**40,950**	**40,830**
▪ **University Research**	**16,778**	**17,395**	**16,965**

Support is provided for the research of scientists and students at 26 universities in 17 states. Nuclear Physics university scientists perform research as user groups 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 and the production mechanisms of chemical elements in stars and supernovae. **Performance will be measured by** triannual peer-review. FY 2002 funding for researchers and students is the same as FY 2001. The reduction reflects the completion of experimental equipment projects.

The major component of the research, involving that of about two-thirds of the university scientists, is conducted using the low energy heavy ion beams and specialized instrumentation at the three national laboratory user facilities supported by this subprogram (i.e., the ANL-ATLAS, LBNL – 88-Inch Cyclotron and ORNL – HRIBF facilities).

Accelerator operations are supported 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 which complement the capabilities of the National Laboratory user facilities. Equipment funds are provided for new instruments and capabilities, such as the intensity and energy upgrade of the TAMU cyclotron, and the gas-filled spectrometer at Yale.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Support is provided for 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 and with the Kamioka Large Anti-Neutrino Detector (KamLAND) in Japan. Equipment funding for KamLAND was completed in FY 2001.

	FY 2000	FY 2001	FY 2002
▪ **National Laboratory Research**	**19,508**	**19,747**	**19,835**

Support is provided for the research programs of scientists at six National Laboratories (ANL, BNL, LBNL, LANL, LLNL and ORNL). **Performance is measured by** peer review and merit evaluation.

	FY 2000	FY 2001	FY 2002
National Laboratory User Facility Research............	**14,035**	**13,995**	**14,065**

Scientists at ANL (ATLAS), LBNL (88-Inch Cyclotron) and ORNL (HRIBF) have major responsibilities for maintaining, improving and developing instrumentation for use by the user communities at their facilities, as well as playing important roles in carrying out research that addresses the program's priorities.

- At ORNL the research focuses on the use of radioactive beams from the HRIBF and specialized spectrometers to study nuclear astrophysics and 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, such as HYBALL for charged-particle detection and the high-pressure gas target, are being designed, built and commissioned.
- At ANL the research focuses on the use of stable and selected radioactive beams from ATLAS, coupled to ion traps and the Fragment Mass Analyzer to study fundamental processes and properties of nuclei, and to study nuclei at the extremes of isotope stability. Studies are undertaken with traps to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model. The Advanced Penning Trap is being constructed and commissioned.
- At LBNL the research focuses on the use of stable beams from the 88-Inch Cyclotron coupled with Gammasphere and the Berkeley Gas-filled Spectrometer (BGS) to study nuclei at high angular momentum and deformation, and the heaviest of elements. The world-leading effort to search for and characterize new very heavy elements and isotopes will continue. The Gamma-Ray Energy and Tracking Array (GRETA) is being designed, with test modules undergoing development.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Other National Laboratory Research	**5,473**	**5,752**	**5,770**

Scientists at BNL, LBNL, LLNL and LANL play important roles in a number of high-priority accelerator- and non-accelerator-based experiments directed towards fundamental questions. These include:

- The Sudbury Neutrino Observatory (SNO) experiment in Canada. The SNO detector 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 during the time it takes them to reach the earth. This latter explanation would imply that the neutrinos have mass. Results from the first measurements are expected in FY 2001. **Performance will be measured by** completing a preliminary analysis of the first data from neutral current interactions from SNO. These data will provide the first information regarding possible neutrino appearance due to neutrino oscillations. All previous measurements have measured neutrino deficits.
- The KamLAND experiment in Japan will measure the rate and properties of anti-neutrinos produced by several nuclear power reactors in an attempt to establish and measure the mass of the neutrino. Although KamLAND is less sensitive than SNO to the variety of neutrino oscillations it has the advantage of comparing the measured fluxes to a known source.
- Neutron beams at the LANSCE facility at LANL are "cooled" to very low energies for new cold and ultra-cold neutron experiments, which will make very precise measurements of fundamental neutron properties.

▪ **Other Research**..	**2,000**	**3,808**	**4,030**
RIA R&D Activities...	**2,000**	**2,794**	**3,000**

Funds are provided for R&D and pre-conceptual design activities directed at the development of an advanced Rare Isotope Accelerator (RIA) facility. A next-generation facility for beams of short-lived, radioactive nuclei for nuclear structure, reaction and astrophysics studies was identified in the 1996 Nuclear Science Advisory Committee (NSAC) Long Range Plan as a compelling scientific opportunity and as the highest priority for new construction. The proposed RIA facility is a new paradigm for producing intense beams of very short-lived nuclei that emerged from the 1998 NSAC Taskforce study involving international experts. 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. The increased funding for FY 2002 supports needed R&D activities in both critical accelerator components and detector development.

SBIR and Other...	**0**	**1,014**	**1,030**

The FY 2001 and FY 2002 amounts include the estimated requirement for the continuation of the SBIR and STTR programs 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.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
Operations	**22,162**	**21,743**	**21,860**

Support is provided for the operation of three National User Facilities, the Argonne Tandem-Linac Accelerator System (ATLAS) at ANL, the 88-Inch Cyclotron facility at LBNL and the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL, for studies of nuclear reactions, structure and fundamental interactions. Requests for beam time at these facilities exceed available beam time by 50-75%. Program Advisory Committees are utilized by all three of these facilities to evaluate proposed experiments and provide recommendations on merit and priority prior to approval for beam time.

▪ **HRIBF Operations**	**8,847**	**8,837**	**8,925**

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 with accelerated radioactive beams, and the Daresbury Recoil Separator and the Silicon Detector Array for nuclear astrophysics studies.

▪ **ATLAS Operations**	**7,601**	**6,992**	**7,060**

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.

▪ **88-Inch Cyclotron Operations**	**5,714**	**5,914**	**5,875**

The 88-Inch Cyclotron facility provides primarily stable heavy ion beams for research. Gammasphere and the Berkeley Gas-filled Spectrometer provide world-class instruments to study rapidly spinning nuclei, and search for and characterize the heaviest of elements and isotopes. An innovative BEARS (Berkeley Experiments with Accelerated Radioactive Species) system has been developed to provide selected light radioactive beams for experiments.

Included in the funding shown are Capital Equipment and Accelerator Improvement Project (AIP) funds provided to each of the facilities for the enhancement of the accelerator systems and experimental equipment.

In FY 2002 these low energy facilities will carry out about 100 experiments involving over 500 U.S. and foreign researchers. Planned beam hours for research are indicated below:

	(hours of beam for research)		
	FY 2000	FY 2001	FY 2002
HRIBF	2130	2100	2000
ATLAS	5385	5100	3500
88-Inch Cyclotron	4335	4950	4000
Total beam hours for research	11850	12150	9500

Total, Low Energy Nuclear Physics	**60,448**	**62,693**	**62,690**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Research	
▪ **University Research**	
FY 2002 funding for researcher and students is constant from FY 2001. Lower priority activities will be phased out in order to maintain manpower in the high priority activities at the low energy facilities and SNO. Funding for equipment decreases by $430,000 compared to FY 2001, as projects are completed. New experiments will not be started at this time.	-430
▪ **National Laboratory Research**	
National User Facilities Research: FY 2002 funding provides an increase of about 0.5% to try to maintain efforts. Activities will be phased out in order to focus efforts on the high priority activities at these facilities.	+70
Other National Laboratory Research: Research funding for the other groups is the same as FY 2001. Equipment funds will be used to complete projects underway with no new starts. Activities will be phased out in order to maintain manpower and focus efforts on the high priority activities at the national user facilities and SNO.	+18
▪ **Other Research**	
RIA R&D: In FY 2002 $3,000,000 is provided for R&D activities directed at the development of an advanced Rare Isotope Accelerator (RIA) facility. The R&D funding is directed at projects identified in a 3-year R&D plan that has been developed for work that will be performed at ANL, LANL, LBNL, LLNL, ORNL, TJNAF and Michigan State University.	+206
SBIR and Other: Estimated SBIR and other obligations increase slightly.	+16
Total Research........	-120
Operations	
▪ HRIBF Operations: FY 2002 funding is increased by 1% to carry out the highest priority research; it will operate with a smaller staff than in FY 2001.	+88
▪ ATLAS Operations: FY 2002 funding is increased by 1% to to carry out the highest priority research. ATLAS will go to 5-day operations with a smaller staff.	+68
▪ 88-Inch Operations: FY 2002 funding is increased by 3.3% (+$142,000) to carry out the highest priority research. This includes $100,000 for increased power costs. The 88 Inch Cyclotron will go to 5-day operations with a smaller staff. Funding for Accelerator Improvement and Capital equipment projects will be reduced by $181,000........	-39
Total Operations	+117
Total Funding Change, Low Energy Nuclear Physics	-3

Nuclear Theory

Mission Supporting Goals and Objectives

Theoretical Nuclear Physics is a program of fundamental scientific research that provides new insight into the observed behavior of atomic nuclei. With the establishment of quantum chromodynamics as the fundamental theory of the strong nuclear interaction, the ultimate goal of nuclear theory is to understand nuclei and the nucleon in terms of their constituent quarks and gluons. It is at the highest energy scales that the nuclear quark and gluon aspects manifest themselves, and it is precisely these high energy nuclear scales that are probed by the two nuclear physics flagship facilities, the Thomas Jefferson National Accelerator Facility (TJNAF) and the Relativistic Heavy Ion Collider (RHIC). More traditionally, nuclear theorists have understood the structure of the atomic nucleus most fundamentally in terms of interacting protons and neutrons. In certain regimes of energy and momentum transfer this approach is not only valid, but has been very successful, in understanding nuclei of ordinary matter where advancing computational power has allowed much more detailed descriptions of nuclei on this microscopic level. Collective models, in which the nucleus is treated as a drop of fluid or in which pairs of neutrons or protons are treated as single particles, have achieved great success in describing many aspects of nuclear behavior too complicated to treat with protons and neutrons. The various approaches of nuclear theory have recently been applied to nuclear astrophysics topics such as supernova explosions, nucleosyntheses of the elements, and properties of neutrinos from the sun.

The Nuclear Theory subprogram supports all areas of nuclear physics, and is carried out at universities and National Laboratories. Some of the investigations depend crucially on access to forefront computing, and to the development of efficient algorithms to use these forefront devices. Components of the program are selected primarily on the basis of peer review by internationally recognized experts. A very significant component of the program is the Institute for Nuclear Theory (INT), where there is an ongoing series of special topic programs and workshops that includes experimentalists. The Institute is a seedbed for new collaborations, ideas, and directions in nuclear physics.

The program is greatly enhanced through interactions with complementary programs overseas, with those 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 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 and particle physics.

Included in this 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.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Theory Research					
University Research	10,415	10,465	10,475	+10	+0.1%
National Laboratory Research	5,793	6,039	6,120	+81	+1.3%
Other Research	0	1,996	2,000	+4	+0.2%
Subtotal Theory Research	16,208	18,500	18,595	+95	+0.5%
Nuclear Data Activities	4,765	4,877	4,910	+33	+0.7%
Total, Nuclear Theory	20,973	23,377	23,505	+128	+0.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Theory Research	**16,208**	**18,500**	**18,595**
▪ **University Research**	**10,415**	**10,465**	**10,475**

Research of university scientists and graduate students is supported through 47 grants at 37 universities in 22 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 postdoc support is a major element of this program. **Performance is measured by** triannual peer-review.

The Institute for Nuclear Theory (INT) at the University of Washington hosts three programs a 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. Recent programs have resulted in a new set of solar "standard model" cross sections, the generation of interest in and motivation for making more precise electric dipole measurements and the formation of a collaboration among theorists to revisit numerical methods for strongly interacting quantum systems.

▪ **National Laboratory Research**	**5,793**	**6,039**	**6,120**

Research programs are supported at six National Laboratories (ANL, BNL, LANL, LBNL, ORNL and TJNAF). **Performance is measured by** peer-review and merit evaluation.

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.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

In all cases, the nuclear theory research at a given laboratory provides support to the experimental programs at that laboratory, or takes advantage of some unique facilities or programs at that laboratory.

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

▪ **Other Research**..	**0**	**1,996**	**2,000**

Funding provides for new activities to model and calculate complex astrophysical nuclear processes, for example, in stellar supernovae explosions, and the quark/gluon-based structure of nuclei using "lattice gauge" techniques. Both efforts require investments in new computational modeling and simulation research and show great promise in pushing our understanding of the physics of these processes to new levels.

Nuclear Data Activities...	**4,765**	**4,877**	**4,910**

The Nuclear Data Program collects, evaluates, stores, and disseminates information on nuclear properties and reaction processes for the community and the nation. The focal point for its national and international activities is at the DOE managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory.

The NNDC relies on the U.S. Nuclear Data Network (USNDN), a network of DOE supported individual nuclear data professionals located in universities and at other National Laboratories who assist in assessing data as well as developing new novel, user friendly electronic network capabilities.

The NNDC participates in the International Data Committee of the International Atomic Energy Agency (IAEA).

Total, Nuclear Theory	**20,973**	**23,377**	**23,505**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2001 vs. FY 2000 ($000)
▪ **University Research**	
FY 2002 funding level is essentially constant compared to FY 2001. Lower priority activities will be phased out in order to maintain manpower in the higher priority activities.	+10
▪ **National Laboratory Research**	
FY 2002 funding level is increased by about 1.3% compared to FY 2001. Lower priority activities will be phased out in order to maintain manpower in the higher priority activities.	+81
▪ **Other Research**	
FY 2002 funding for computational modeling and simulation research is maintained at the same level as FY 2001.	+4
▪ **Nuclear Data Program**	
FY 2002 funding level is about the same as FY 2001. Lower priority activities will be phased out in order to maintain manpower in the higher priority activities.	+33
Total Funding Change, Nuclear Theory	+128

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	6,785	6,420	6,470	+50	+0.8%
Accelerator Improvement Projects	4,341	5,119	5,450	+331	+6.5%
Capital Equipment	29,394	33,026	30,300	-2,726	-8.3%
Total, Capital Operating Expenses	40,520	44,565	42,220	-2,345	-5.3%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Accept-ance Date
STAR Silicon Vertex Tracker	7,000	6,250	750	0	0	FY 2000
PHENIX Muon Arm Instrumentation	12,897	8,610	2,925	1,362	0	FY 2002
Analysis System for RHIC Detectors	7,900	6,375	1,525	0	0	FY 2000
BLAST Large Acceptance Detector	5,200	2,500	1,500	1,200	0	FY 2001
STAR EM Calorimeter	8,600	0	2,100	2,694	3,000	FY 2003
G0 Experiment Detector[a]	3,965	1,757	1,133	1,016	59	FY 2002
Total, Major Items of Equipment		25,492	9,933	6,272	3,059	

[a] The G0 Experiment Detector at TJNAF began as an NSF project with a small contribution of DOE funds (below MIE threshold). Subsequently, the cost estimate for the detector increased, leading to increased DOE and NSF contributions. The DOE contribution was raised above the MIE threshold. Therefore, a MIE was identified in the FY 2001 budget. The TEC ($3,965,000) and funding profile for G0 has been changed from that ($3,387,000) indicated in FY 2001 to correctly include TJNAF overhead and does not represent any cost growth. The NSF contribution to this effort in actual year dollars is $3,605,000.