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.

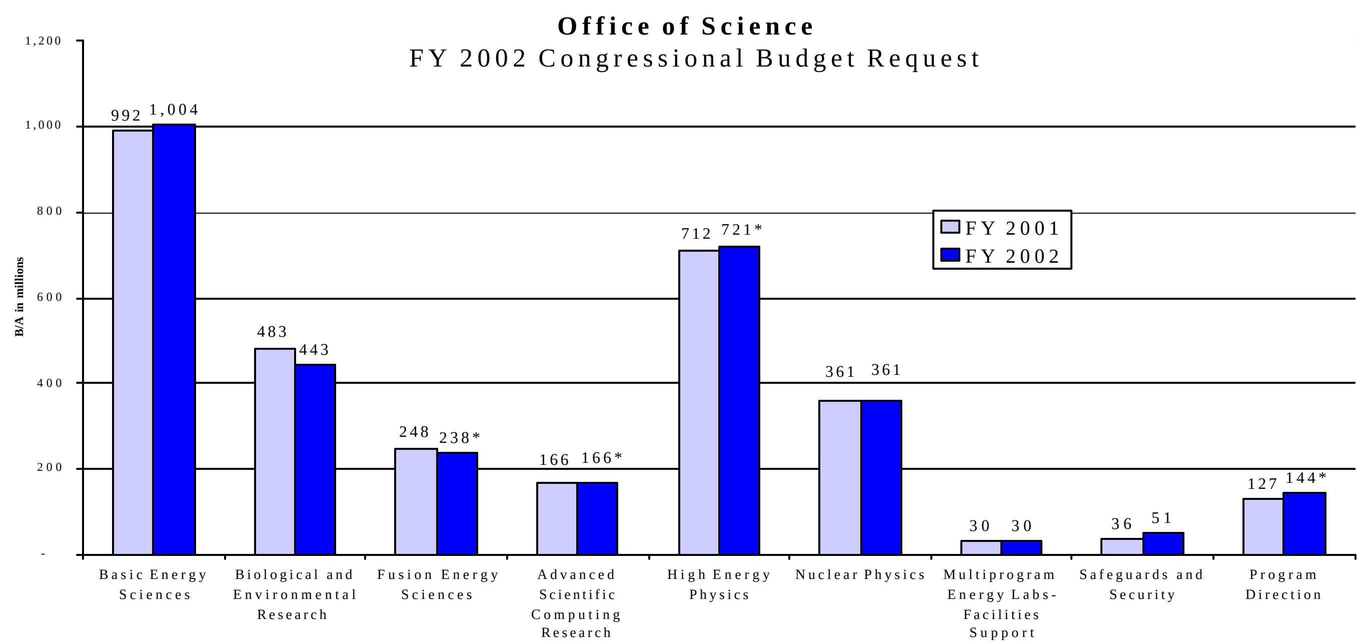
"How is this remarkable economic machine to be maintained, and how can we better ensure that its benefits reach the greatest number of people?

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).

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
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

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.

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.

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.

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.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
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.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
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.

	FY 2000	FY 2001	FY 2002
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.

	FY 2000	FY 2001	FY 2002
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.

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.

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.

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.

	FY 2000	FY 2001	FY 2002
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

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.

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.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

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.

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.

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

Support and Infrastructure	**94**	**95**	**95**

Includes capital equipment funding for HEP use of the AGS.

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.

	FY 2000	FY 2001	FY 2002
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.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
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.

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.

▪ **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.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
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.

	FY 2000	FY 2001	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.

	FY 2000	FY 2001	FY 2002
▪ **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.

	FY 2000	FY 2001	FY 2002
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.

	FY 2000	FY 2001	FY 2002
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.

▪ **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.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
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.

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

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.

▪ **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.

	FY 2000	FY 2001	FY 2002
▪ **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.

	FY 2000	FY 2001	FY 2002
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.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
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.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		

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.

	FY 2000	FY 2001	FY 2002
▪ **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.

	FY 2000	FY 2001	FY 2002
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).

	FY 2000	FY 2001	FY 2002
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.

Biological and Environmental Research

Program Mission

For over 50 years the Biological and Environmental Research (BER) program has been advancing environmental and biomedical knowledge connected to energy production, development, and use. As described in the DOE Strategic Plan, BER supports fundamental research providing the scientific foundation for the applied research missions of the Department of Energy (DOE). Through support of peer-reviewed research at national laboratories, universities, and private institutions, BER develops the knowledge needed to identify, understand, anticipate, and mitigate the long-term health and environmental consequences of energy production, development, and use. The research is also designed to provide the science base in support of the Energy Policy Act of 1992.

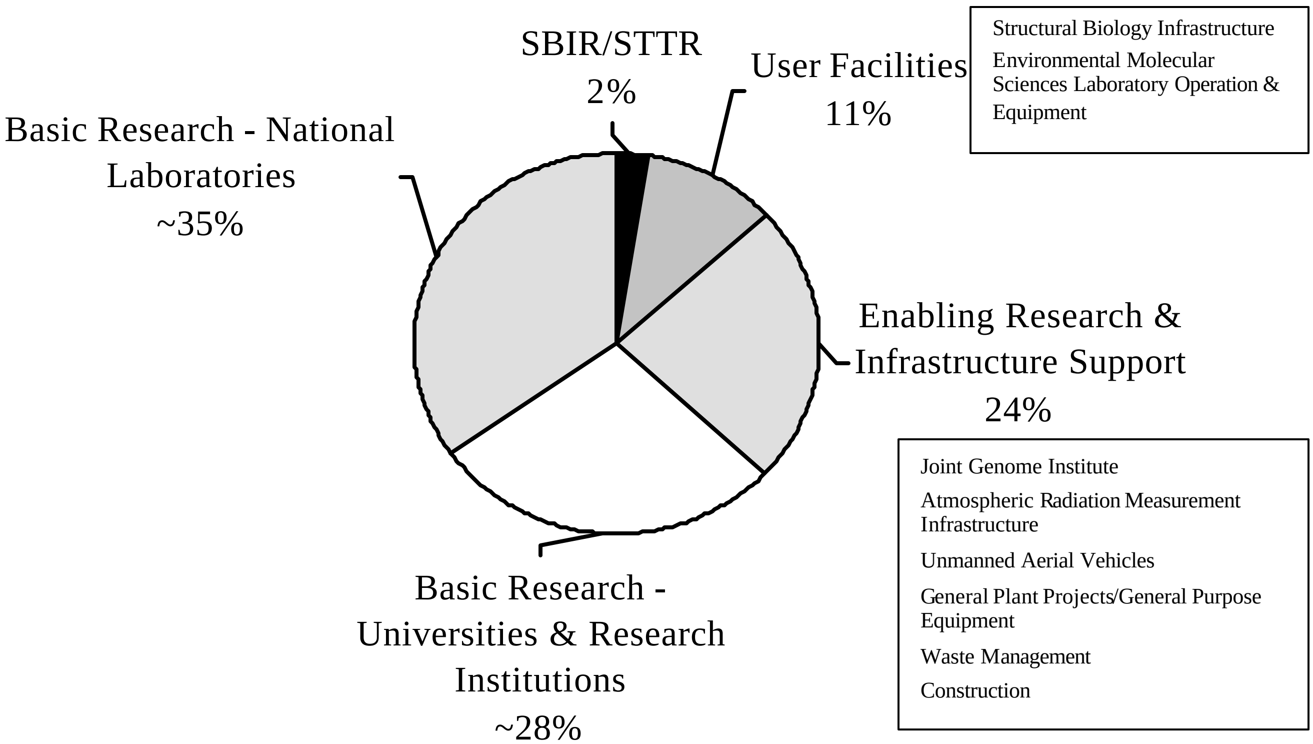
Program Goal

The BER program goal is to develop the information, scientific "know-how," and technology for identification, characterization, prediction, and mitigation of adverse health and environmental consequences of energy production, development, and use. Additionally, the program will provide the Department's researchers and the Nation's scientific community with leading-edge research facilities and other critical infrastructure that support this program goal.

Program Objectives

- Utilize the capabilities of the U.S. research community in universities and the DOE national laboratories to provide the basic research foundation for DOE's missions in energy and the environment through targeted investments in life, environmental and medical sciences, and related disciplines.
- Contribute to the environmental remediation and restoration of contaminated environments at DOE sites through basic research in bioremediation, microbial genomics, and ecological science.
- Provide new knowledge on microbes that will expand DOE's options for clean and affordable energy through research in microbial genomics and bioinformatics.
- Advance our understanding of key uncertainties and find solutions for the effects of energy production and use on the environment through research in global climate modeling and simulation, the role of clouds in climate change, carbon cycle and carbon sequestration, atmospheric chemistry, and ecological science.
- Help protect the health of DOE workers and the public by advancing our understanding of the health effects of energy production and use through basic research in key areas of the life sciences including functional genomics and structural biology as well as low dose radiation research.
- Ensure the greatest return on public investments by utilizing the unique capabilities of the DOE laboratories to advance the life and environmental sciences, advanced imaging, and medical applications of basic research and through stewardship of these capabilities to ensure that DOE has the scientific base to meet its technologically challenging missions.

To meet these objectives, BER budget request for FY 2002 is $442,970,000, including support for basic research, scientific user facility operations, and enabling research and infrastructure support. In addition, the program includes funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer program (STTR).



Evaluation Of Objectives

The quality and scientific relevance of the Biological and Environmental Research (BER) program and its individual research projects are maintained by rigorous peer reviews conducted by internationally recognized scientific experts. The criteria include scientific merit, appropriateness of the proposed approach, and qualifications of the principal investigator. BER expects the highest quality research and, when necessary, takes corrective management actions based on results of the reviews. A measure of the quality of the BER research is the sustained achievement in advancing scientific knowledge. This is demonstrated by the publication of research results in the leading refereed scientific journals pertinent to BER related research fields, by invited participation at national and international scientific conferences and workshops, and by honors received by BER-supported researchers. BER regularly compares its programs to the scientific priorities recommended by the Biological and Environmental Research Advisory Committee (BERAC), and by the standing committees created by the Office of Science and Technology Policy.

The BER program benefits from a diversity of program reviews. This is particularly the case for BER program elements that are components of international research endeavors, e.g., the International Human Genome Project and the U.S. Global Change Research Program. In addition to panel reviews used to evaluate and select individual projects and programmatic reviews by the chartered BERAC, BER evaluates its programs using interagency (and international) review bodies and by Boards and Committees of the National Academy of Sciences.

BER goes one step further in soliciting program reviews. Panels of distinguished scientists are regularly charged with evaluating the quality of individual programs and with exploring ways of entraining new ideas and research performers from different scientific fields. This strategy is based on the conviction that the most important scientific advances of the new century will occur at the interfaces between scientific disciplines, such as biology and information science. Groups like JASON and The Washington Advisory Group (TWAG), involving physicists, mathematicians, engineers, etc., are among the organizations that study BER program elements, such as the Atmospheric Radiation Measurement (ARM) program, climate change prediction activities, the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), and the Human Genome program. The BER program is ideally positioned to facilitate the interactions between the physical sciences and the life sciences and aggressively pursues every opportunity to stretch the interface between the two scientific domains.

BER facility operations are also monitored by peer reviews and user feedback. BER provides these facilities in a manner that meets user requirements as indicated by achieving performance specifications while protecting the safety of the workers and the environment. Facilities are operated reliably and according to planned schedules. Facilities are also maintained and improved to remain at the cutting edge of technology and scientific capability.

The reviews and user feedback are incorporated as BER plans for the future needs of DOE research in the life and environmental sciences including: planning for future directions, opportunities, and initiatives within the BER research portfolio; maintaining the flexibility to quickly move into promising new areas; contributing to the health of the educational pipeline in critical subfields and disciplines; planning for upgrades at existing facilities to expand the research capabilities or operational capacity; ensuring the proper balance between facilities and research; and planning for future facilities necessary to advance the science in areas relevant to BER's mission in close collaboration with the research community.

The overall quality of the research in the Biological and Environmental Research (BER) program will be judged excellent and relevant by external evaluation by peers, and through various forms of external recognition.

BER will continue to provide leadership in key subfields of life, environmental, and medical sciences research that are critical to DOE's mission and the Nation through external review and other mechanisms.

BER will keep within 10 percent, on average, of cost and schedule milestones for upgrades and construction of scientific user facilities.

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

BER-funded research facilities for environmental, genomic, and structural biology research will achieve or exceed technical milestones that are ambitious and critical to either DOE mission areas or the research needs of the scientific community.

The BER scientific user facilities will be operated and maintained so that unscheduled operational downtime will be less than 10 percent of total operating time, allowing nearly 3,500 scientists to conduct experiments on an annual basis.

BER 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.

BER LEADERSHIP AND UNIQUE ROLES

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

- Develop cutting edge technologies, facilities, and resources, including animal models, for the human genome project.
- Provide solutions to DOE problems in energy and the environment through microbial genome and bioremediation research.
- Provide the world leadership in low dose radiation research.
- Provide world-class structural biology user facilities and unique computational and experimental structural biology research emphasizing protein complexes.
- Provide world leadership in ground-based measurement of clouds and atmospheric properties, key uncertainties in climate change, through the Atmospheric Radiation Measurement (ARM) program.
- Develop advanced predictive capabilities using coupled climate models on massively parallel computers for decade to century long simulations of climate change.
- Provide fundamental research on carbon sequestration to develop technologies that enhance the uptake of carbon in terrestrial and ocean ecosystems.
- Provide world-class scientific user facilities for environmental and global change research.
- Provide world leadership in radiopharmaceutical development for wide use in the medical and research communities.
- Maintain world leadership in detector development for medical and biological imaging.
- Enable interdisciplinary teams of scientists for medical applications using the unique resources in physics, chemistry, material sciences, and biology at the National Laboratories.
- Jointly manage the Environmental Management Science Program (EMSP) with the Office of Environmental Management (EM) to identify science fields relevant to the DOE cleanup mission and select the appropriate research activities.

Ensure that the rights and welfare of human research subjects at the Department are protected while advances in biomedical, environmental, nuclear, and other research lead to discoveries that benefit humanity.

Significant Accomplishments and Program Shifts

SCIENCE ACCOMPLISHMENTS

Life Sciences

Genome Sequencing – Top Scientific Advance of 2000 **-** In December 2000, *Science* magazine named genome sequencing the top scientific advance of 2000, including the sequencing of the human, fruit fly and microbial genomes. *Science* magazine also acknowledged the ongoing sequencing of the mouse and puffer fish. BER made seminal contributions to the sequencing of the human genome, fruit fly, and more than 50 microbial genomes and is sequencing the puffer fish and portions of the mouse genome. These contributions culminated in the publication of the draft human DNA sequence in *Nature* on February 15, 2001.

DOE Completes Draft DNA Sequence of 3 Human Chromosomes **-** The DOE Joint Genome Institute's Production Sequencing Facility completed the draft DNA sequence of human chromosomes 5, 16, and 19 in April 2000 as the DOE contribution to the international effort to sequence the entire human genome. These chromosomes contain genes that contribute to a number of human diseases including, leukemia, colon, breast and prostate cancer as well as kidney disease, Crohn's disease, asthma, deafness, diabetes, obesity, atherosclerosis, attention deficit disorder, schizophrenia, and mental retardation.

Making DNA Sequencing Cheaper and Faster **-** Technology developments (e.g., capillary based sequencers, automated sample handling, reagents for DNA cloning such as Bacterial Artificial Chromosomes, and improved dyes for staining DNA) by the DOE and its international partners have dramatically decreased the cost of DNA sequencing while increasing the speed and efficiency. It took four years to produce the first billion base pairs of draft sequence and less than eight months to produce the next two billion base pairs. DOE's Joint Genome Institute currently produces more DNA sequence in eight days than it did in 1998, its first full year of sequencing. Similarly the cost of sequencing has dropped from over $2 per "finished" base to less than 20 cents during the same period.

Asthma-Linked Genes Discovered **-** Two genes that contribute to the development of asthma were discovered by Lawrence Berkeley National Laboratory scientists using mice carrying different human genes. More than 14 million people in the United States suffer from asthma and other chronic respiratory ailments. Finding the two genes raises the prospect that decreasing their activity could help reduce susceptibility to asthma attacks.

Drosophila Gene Collection Facilitates Genetics Research **-** Genetics research took a large step forward in 2000 with the determination of the complete Drosophila (the fruit fly) DNA sequence. This DNA sequence information was made even more valuable to biologists by the creation of a BER and Howard Hughes Foundation supported resource, the Drosophila Gene Collection. This resource, a molecular library that will contain individual DNA clones corresponding to each Drosophila gene, will be a powerful tool that will help scientists understand both fruit fly and human biology, given the strong conservation of many genes between the fruit fly and humans.

Genes & Justice: Special Issue of Judicature **-** As part of its continuing effort to educate and alert the judiciary to the flood of genetics-related cases on the horizon, the Ethical, Legal, and Social Issues (ELSI) component of the DOE Human Genome program supported the publication of a special issue of the legal journal Judicature, focused on Genes and Justice. The journal is a publication of the American Judicature Society, whose members include judges, lawyers, legal scholars, administrators, and others associated with the U.S. court system. BER funding enabled copies to be sent to an additional 8,000 judges.

PBS Special - Intimate Strangers - Unseen Life on Earth **-** The astonishing breadth and diversity of microbial life and the contributions that microbes make to the health of the Earth were highlighted in a highly regarded four-part PBS series, "Intimate Strangers: Unseen Life on Earth," that was partially funded by the BER Microbial Genome program.

Starting a Dialogue on Low Dose Radiation Research **-** The BER Low Dose Radiation Research program sponsored a workshop that was attended by scientists, federal agencies, scientific societies, regulators, and the public, including representatives of antinuclear and environmental activist groups. The goal of this program is to support high quality, credible, and widely accepted scientific research that underpins the development of future radiation risk policy. Dialogues such as this one are key to the acceptance of the results of this research.

Environmental Processes

ARM Data Improve Models **-** Analyses of atmosphere radiation data from long term measurement systems at the ARM sites have improved the understanding of the radiation spectrum at the Earth's surface and led to a new radiation code developed for General Circulation Models. By all measures used to date, implementation of this new radiation code in, for example, the European Centre for Medium-Range Weather Forecasting model improved forecast skill while maintaining model calculation time comparable to that of the previous model. Improvements in the physics of these models assure as much scientific realism as possible within the severe time constraints levied on climate prediction codes. This improvement is critical to increasing the validity, accuracy, and credibility of climate models.

Cloud Climatology Data Add Rigor to Model Testing **–** The first detailed climatology of cloud occurrence and vertical location was produced using three years of continuous ARM cloud radar and lidar data over the Southern Great Plains site in Oklahoma. This climatology shows expected variation of cloud properties from season to season, but also demonstrates the large interannual variation. Particularly large seasonal excursions were identified in the winter due to the 1997-98 El Niño and the subsequent LaNiña. Scientists have deduced the quantitative effect of clouds on the surface radiation budget on this same three-year time scale. The combination of these two climatologies provides a unique test for climate model cloud simulations.

Continuous Climate Data From Three Climatic Regions Available **-** With the opening of ARM Atmospheric Radiation and Cloud Stations (ARCS) in the Republic of Nauru located in the Western Tropical Pacific and on the North Slope of Alaska at Atqasuk, the ARM program now maintains continuously operating sites to measure cloud and radiation properties in three climatic regions. These sites provide an unprecedented look at cloud properties and radiation effects in the Southern Great Plains, the Tropical Western Pacific and on the North Slope of Alaska. These data are available via the ARM Archive to all interested scientists.

New Techniques for Early Warning of the Onset of Severe Storms **-** ARM has developed a new tool for forecasting the onset of severe convection. Weather events with extremely strong convection are characteristic of thunderstorm and tornado conditions. Several cases of pretornadic thunderstorm conditions were detected one to two hours ahead of the thunderstorm development. This new meteorological product is based on data from a grid of Atmospheric Emitted Radiance Interferometer (AERI) systems.

Electrical Generating Plant Contributes to Regional Ozone - Field campaigns in the southeastern U.S. have determined that even though electrical generating plants make a significant contribution to the ozone burden in this area, the natural emissions of biogenic hydrocarbons, and their influence on ozone formation, are so large that any regional ozone control strategy based upon further reduction in anthropogenic hydrocarbons will likely fail. This finding is supported by observations that ozone production per unit of nitrogen oxide (NO_x) emissions by power plants appears to be inversely related to size of the NO_x source.

Field Campaigns Yield Interesting Comparisons and New Information for Pollution Control Strategies **-** Field campaigns in selected urban areas with air quality problems show that the sources of ozone and aerosol pollution are not the same in different areas of the country. For example, the rate of ozone production in Phoenix is two to three times lower than that in the eastern U.S. In addition, aerosol loading in Phoenix was shown to be highly correlated with tracers of internal combustion engines suggesting that transportation is a major source of aerosols and their precursors in the Phoenix basin. In contrast, in Philadelphia, emissions from local fossil fuel power plants make a significant contribution to both the ozone and aerosol burden, indicating that electric energy production is a major source of aerosol and ozone precursors in this urban area. In Nashville, TN, ozone concentrations do not appear to be very sensitive to modest reductions of man-made emissions, suggesting that large reductions in either man-made hydrocarbons or nitrous oxides would be required to reduce ozone in this area.

Warmer Terrestrial Ecosystems Take Up More Carbon Than Expected **-** The AmeriFlux Network is producing unique measurements of the net annual exchange of carbon dioxide (CO_2) between the atmosphere and terrestrial ecosystems. The annual net ecosystem exchange (NEE) of CO_2 is the annual carbon gain or loss by all components (i.e., both above and below ground components) of an ecosystem and is being measured in different ecosystems, including boreal forests, northern temperate forests (coniferous, hardwood, mixed), southern coniferous and hardwood forests, and non-forested grasslands and croplands. Data on NEE from the sites can be reliably compared across geographic regions or climatic gradients because of the use of common measurement protocols and cross-site calibration procedures. Analysis of the relationship between NEE and mean annual temperature across 12 sites shows that sites with a warmer mean annual temperature have a greater NEE than colder sites along a north-to-south climatic gradient of eastern United States and Canada. If scaled across the North American landscape, the measured amount of carbon gained annually (2 to 4 tonnes per hectare) by terrestrial ecosystems accounts for a significant fraction of the CO_2 emitted to the atmosphere by energy production.

Effects of Elevated Carbon Dioxide on Terrestrial Ecosystems and Vegetation Estimated **-** Free-Air Carbon Dioxide Enrichment (FACE) experiments are providing important new information on the response of intact terrestrial ecosystems to increased atmospheric concentrations of carbon dioxide. Seven long-term experiments have provided new results on the physiological and growth responses of vegetation in forest, grassland, and cropland ecosystems to elevated CO_2. Although it is unclear how long the growth enhancement will persist, the results to date suggest that forests provide a substantial sink for atmospheric CO_2 and, thereby, can help to lessen its rise in the atmosphere in the future. Initial results suggest that increased CO_2 causes greater productivity of these systems. A significant part of the increased productivity occurs below ground with roots, soil microflora and the formation of soil organic matter. Results from a 2-year study in which portions of a loblolly pine forest were exposed to a 60 percent increase in atmospheric CO_2 concentration show a 25 percent increase in net productivity relative to that for areas of the forest exposed to ambient levels of atmospheric CO_2. The increase in productivity represents a substantial sink for carbon in trees during the first two years of the study. The storage of carbon in trees was accompanied by a proportionally smaller carbon sink in soils and groundwater relative to that in areas of the forest exposed to ambient CO_2 levels.

Investments in Integrated Assessment of Global Climate Change are Paying Off **-** In the past seven years, integrated assessment models of global climate change have been constructed that are contributing to the dialogue on scientific priorities and on the relation of policy actions to climate change. Several models supported by BER have been used to assess so-called “where and when” options for mitigating the increase in atmospheric carbon dioxide. Model results show that the costs of meeting a concentration target for carbon dioxide in the atmosphere, such as that envisioned by the Framework Convention on Climate Change, are lower by up to a factor of 10 when nations have the ability to be flexible in the timing and location of their emission reductions. Furthermore, results of the research indicate the value of flexibility in reducing emissions of several greenhouse gases rather than focusing solely on carbon dioxide to meet a particular target.

Environmental Remediation

Common Bacteria Super at Immobilizing Uranium **-** Research on the microorganism Geobacter promises to lead to new strategies for immobilizing metals and radionuclides in the subsurface that will result in reduced risk to humans and the environment. Natural and Accelerated Bioremediation Research (NABIR) studies have demonstrated that Geobacter can chemically reduce and precipitate common DOE contaminants, such as uranium, technetium, and chromium in subsurface environments. Moreover, Geobacter has been found to be nearly ubiquitous at subsurface sites, including those contaminated with uranium such as the Uranium Mill Tailing Remedial Action (UMTRA) Sites.

Communities of Bacteria at Selected Contaminated Sites Give Researchers Clues About How to Manipulate Communities at Other Contaminated Sites **-** NABIR has supported the successful development of new approaches that provide nucleic acid "fingerprints" of complex microbial communities in contaminated subsurface environments. Having these fingerprints from selected dynamic communities may provide clues on how to modify other communities with stimulants, such as nutrients that increase the ability of the organisms in those communities to carry on more effectively the desired biochemical reactions. The NABIR program has funded research that tags and amplifies the terminal fragment of RNA molecules to create a library of restriction fragment length polymorphisms (T-RFLP). This research correlates the ecology to T-RFLP signatures for various communities.

Medical Applications and Measurement Science

Making Drugs Safe for Children **-** PET/radiotracer studies at BNL have demonstrated that Ritalin, a drug commonly used in the treatment of attention deficit disorder, when given orally will effectively block the dopamine transmitter system without putting the child at risk or causing a "high" as observed with addictive drugs.

Treating Obesity **-** BNL scientists have used PET and specific radiotracers to demonstrate that the brain dopaminergic pathways are poorly developed in obese individuals. These data may enable alternative methods for treatment of obesity.

Scientists Develop Advanced Instruments to Study Disease Models in Animals - Using physics, engineering, and computational science, researchers at the UCLA-DOE laboratory have developed a prototype micro-PET scanner for studying animals. This instrument, which is now produced commercially, will become an essential method of studying animal models of human disease.

New Cancer Treatments Developed **-** Investigators at Memorial-Sloan Kettering Cancer Center have developed two new radiopharmaceuticals for improving the diagnosis and treatment of cancer. One utilizes the alpha emitter Bismuth 213 and the other is a genetic radiotracer (fluoro arabinyl uridine-Iodine 124).

BNCT Trials Completed **-** The Phase I BNCT clinical trial of patients with brain cancer performed at BNL and MIT/Harvard has been completed. The maximally tolerated neutron dose and phenyl-alanine dosages were established. This study will provide basic information enabling potential NIH-funded clinical trials.

Improved Radiation Therapy Planning **–** Investigators at LLNL have received the Food and Drug Administration approval for patient use of "Peregrine"—an improved computer program for planning radiation doses for cancer treatment.

FACILITY ACCOMPLISHMENTS

Life Sciences

Revealing the Structure of Life's Molecular Machines - Scientists using BER's unique structural biology beamlines at the DOE synchrotron facilities determined the high resolution structures of the RNA polymerase and the ribosome, by any measure two of nature's most sophisticated "molecular machines." These remarkable structures reveal in atomic detail how DNA is unwound, how a message for protein production is created, how this message is read by the ribosome and how the growing protein chain is made. This discovery was named by *Science* magazine as one of the runners-up for the top scientific advance of 2000.

Environmental Remediation

EMSL Develops First Combined Magnetic Resonance and Optical Microscope - Scientists at the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) worked with visiting scientists to develop a new type of microscope that uses both magnetic resonance and optical microscopy to image cells. The new type of microscope, termed the MROM (magnetic resonance optical microscope), combines the high resolution and sensitivity of an optical microscope with the chemical information provided by magnetic resonance. MROM will be used for cellular and structural biology studies providing a new non-invasive way to observe living cells in real time.

EMSL Develops an Advanced Mass Spectrometer - Scientists at the William R. Wiley Environmental Molecular Sciences Laboratory have developed an instrument to channel more sample ions into mass spectrometers, thereby allowing more accurate and sensitive measurements. The Electrodynamic Ion Funnel concentrates ions from samples into a small stream into the mass spectrometer. With this enhancement, scientists are better able to analyze low concentrations of samples. This enhancement will be of benefit to cell signaling studies and other health effects research.

EMSL Extends Collaboratory Approach - Remote use of instrumentation within the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) has now been extended to the Nuclear Magnetic Resonance (NMR) spectrometers and a few other instrument systems. EMSL staff have developed a suite of tools to enable secure operation of the NMR spectrometers remotely, while allowing real time computer display sharing and web-based data access and sharing. Additional instruments available for remote use include an ion trap mass spectrometer and the Molecular Beam Epitaxy system for the creation of thin (molecular-layer) films. Overall the collaboratory concept is increasing scientist efficiency and reducing the cost of doing research by enabling the remote use of EMSL instruments.

PROGRAM SHIFTS

For FY 2002, BER will focus on:

- "Genomes to Life" -- Utilizing DOE capabilities in genomics, structural biology, imaging, computation, and engineering to explore protein complexes and their on/off switches, encoded in an organism's DNA, that make a cell a living system.
- Developing computational models of microbial cells to advance understanding and help adapt them to DOE missions.
- Continuing to leverage advances in genomics and instrumentation to detect and characterize the biological effects of Low Doses of Radiation.
- Working with other federal agencies, continuing development of advanced predictive capabilities-- Highly Parallel Climate Models with improved abilities to predict climate on regional scales.
- Investing in enhanced computational capabilities at the Environmental Molecular Sciences Laboratory to solve environmental and biological problems.
- Funding is decreased for the Joint Genome Institute due to a programmatic shift to increase development of DNA sequencing technology research needed to meet the growing demand for cheaper, faster, and more accurate high-throughput DNA sequencing as a basic research tool in biology.

Redirected Research Programs in the Life Sciences

The FY 2002 budget includes funds for a research program, Genomes to Life, that expands and extends current BER programs. This program capitalizes on DOE's pioneering and leadership role in high-throughput DNA sequencing; its longstanding support of microbial biochemistry, metabolism and physiology; its support of national user facilities for determining protein structures; and the capabilities of its national laboratories in computational analysis, instrumentation research, and bioengineering. This program challenges scientists to take another large step forward in their thinking, their research, and their technology development. It begins where the FY 2001 initiative, the Microbial Cell Project, leaves off and builds on that project as part of a broader, bolder research program. This program challenges scientists to understand not only the complete workings of an individual cell from the DNA sequence to the identification of all of a microbe's proteins (the proteome) and their functions, the goal of the Microbial Cell Project, but also the regulation and behavior of complex multi-cellular systems and the responses of those systems to environmental cues. The overriding goal of this long-term research program is to understand biology well enough to be able to predict the behavior and response of biological systems--from cells to organisms.

Scientific Facilities Utilization

The Biological and Environmental Research request includes $48,754,000 to maintain support of the Department's scientific user facilities. Facilities used for structural biology research, such as beam lines at the synchrotron light sources and research reactors, are included. The BER request also includes operation of the William R. Wiley Environmental Molecular Sciences Laboratory where research activities underpin long-term environmental remediation. With this funding, BER will provide for the operation of the facilities, assuring access for scientists in universities, federal laboratories, and industry. BER will also leverage both federally and privately sponsored research.

Workforce Development

Workforce development is an integral and essential element of the BER mission to help ensure a science-trained workforce, including researchers, engineers, science educators, and technicians. The research programs and projects at the national laboratories, universities, and research institutes actively integrate undergraduate and graduate students and post-doctoral investigators into the work. This "hands-on" approach is essential for the development of the next generation of scientists, engineers, and science educators. Specific fellowship programs are also sponsored by BER to target emerging areas of need. Over 1,500 graduate students and post-doctoral investigators were supported at universities and at national laboratories in FY 2000. BER will continue its support for graduate students and post-doctoral investigators in FY 2002. The number of graduate students and post-doctoral investigators will remain approximately at the FY 2001 level.

Graduate students and postdoctoral investigators use Office of Science user facilities. For example, they use the structural biology experimental stations on the beam lines at the synchrotron light sources and the instruments at the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL). Using these unique research tools enables the graduate students and post-doctoral investigators to participate in and conduct leading edge research. Approximately half of all of the facility users are graduate students and postdoctoral investigators. The graduate students and post doctoral investigators are supported by resources from a wide variety of sponsors, including BER, other Departmental research programs, other federal agencies, and U.S. and international private institutions. Graduate students and post-doctoral investigators at the synchrotron light sources are included in the Basic Energy Sciences (BES) user facility statistics and are not included here. A total of 500 graduate students and post-doctoral investigators conducted their research at the EMSL in FY 2000.

COMMITMENT TO UNIVERSITIES

BER will continue its commitment to and dependence on research scientists at the Nation's universities. Approximately 45 percent of BER basic research funding supports university-based activities. University-based scientists are an integral part of research programs across the entire range of the BER portfolio. These scientists are funded through individual peer-reviewed grants and as members of peer-reviewed research teams involving both national laboratory and university scientists.

University-based scientists are the principal users of BER user facilities for structural biology at the Environmental Molecular Sciences Laboratory and the Natural and Accelerated Bioremediation Research (NABIR) Program's Field Research Center. University scientists also form the core of the Atmospheric Radiation Measurement (ARM) science team that networks with the broader academic community as well as with scientists at other agencies, such as the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. In addition, university-based scientists are funded through Requests for Applications across the entire BER program including genomics, structural biology, low dose radiation research, global change research, microbial cell project, bioremediation research, medical imaging, and radiopharmaceutical development. Furthermore, university scientists work in close partnership with scientists at national laboratories in many BER programs including genomics, and carbon sequestration research.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Biological and Environmental Research					
Life Sciences	161,338	198,791	-6,319	192,472	186,205
Environmental Processes	122,560	134,173	-4,469	129,704	129,469
Environmental Remediation	63,770	65,450	-3,989	61,461	66,137
Medical Applications and Measurement Science	68,369	100,346	-3,958	96,388	51,159
Subtotal, Biological and Environmental Research	416,037	498,760	-18,735	480,025	432,970
Construction	0	2,500	-5	2,495	10,000
Subtotal, Biological and Environmental Research	416,037[a]	501,260	-18,740	482,520	442,970
General Reduction	0	-10,872	+10,872	0	0
General Reduction for Safeguards and Security	0	-6,806	+6,806	0	0
Omnibus Rescission	0	-1,062	+1,062	0	0
Total, Biological and Environmental Research	416,037[b c]	482,520	0	482,520	442,970

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 $10,423,000 which was transferred to the SBIR program and $625,000 which was transferred to the STTR program.

[b] Includes $1,200,000 for Waste Management activities at Pacific Northwest National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $7,001,000 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	20,082	20,594	16,685	-3,909	-19.0%
National Renewable Energy Laboratory	99	0	0	0	0.0%
Sandia National Laboratories	2,597	3,139	2,756	-383	-12.2%
Albuquerque Operations Office	2,550	1,500	900	-600	-40.0%
Total, Albuquerque Operations Office	25,328	25,233	20,341	-4,892	-19.4%
Chicago Operations Office					
Ames Laboratory	948	652	690	+38	+5.8%
Argonne National Laboratory – East	13,700	24,939	17,184	-7,755	-31.1%
Brookhaven National Laboratory	21,723	16,948	18,169	+1,221	+7.2%
Chicago Operations Office	88,416	46,537	45,640	-897	-1.9%
Total, Chicago Operations Office	124,787	89,076	81,683	-7,393	-8.3%
Idaho Operations Office					
Idaho National Engineering & Environmental Lab	1,713	1,440	1,486	+46	+3.2%
Idaho Operations Office	0	962	0	-962	-100.0%
Total, Idaho Operations Office	1,713	2,402	1,486	-916	-38.1%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	48,869	54,231	43,277	-10,954	-20.2%
Lawrence Livermore National Laboratory	30,784	30,869	33,561	+2,692	+8.7%
Stanford Linear Accelerator Center	3,060	3,489	4,300	+811	+23.2%
Oakland Operations Office	69,132	40,007	35,239	-4,768	-11.9%
Total, Oakland Operations Office	151,845	128,596	116,377	-12,219	-9.5%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education	4,754	4,315	4,375	+60	+1.4%
Oak Ridge National Laboratory	30,805	36,545	39,761	+3,216	+8.8%
Oak Ridge Operations Office	419	350	350	0	0.0%
Thomas Jefferson National Accelerator Facility	155	100	85	-15	-15.0%
Total, Oak Ridge Operations Office	36,133	41,310	44,571	+3,261	+7.9%

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Richland Operations Office					
Pacific Northwest National Laboratory	75,292	67,142	66,172	-970	-1.4%
Washington Headquarters	939	128,761	112,340	-16,421	-12.8%
Total, Biological and Environmental Research	416,037 [a] [b] [c]	482,520	442,970	-39,550	-8.2%

[a] Excludes $10,423,000 which was transferred to the SBIR program and $625,000 which was transferred to the STTR program.

[b] Includes $1,200,000 for Waste Management activities at Pacific Northwest National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $7,001,000 in FY 2000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. At Ames, BER supports research into new biological imaging techniques such as fluorescence spectroscopy to study environmental carcinogens.

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. At ANL, BER supports the operation of a high-throughput national user facility for protein crystallography at the Advanced Photon Source, and research in protein structure relating to the process of photosynthesis. In support of global change research, ANL coordinates the operation and development of the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska ARM sites. The principal scientist for the Atmospheric Chemistry program is at ANL, providing broad scientific integration to the program. Research is conducted to understand the molecular control of genes and gene pathways in both microbes and mammalian cells and the molecular factors that control cell responses to low doses of radiation. ANL, in conjunction with ORNL and PNNL and six universities, co-hosts the terrestrial carbon sequestration research center, CSiTE.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. BER supports the operation of beam lines for protein crystallography at the National Synchrotron Light Source for use by the national biological research community, research in biological structural determination, research and operation of the protein structure database, and research into new instrumentation for detecting x-rays and neutrons. Research is also conducted on the molecular mechanisms of cell responses to low doses of radiation.

The nuclear medicine program supports research into novel techniques for imaging brain function in normal and diseased states.

Global change activities at BNL include the operation of the ARM External Data resource that provides ARM investigators with data from non-ARM sources, including satellite and ground-based systems. BNL scientists form an important part of the science team in the Atmospheric Sciences program, providing special expertise in atmospheric field campaigns and aerosol research. BNL scientists play a leadership role in the development of, and experimentation at, the Free-Air Carbon Dioxide Enhancement (FACE) facility at the Duke Forest used to understand how plants take up and store carbon dioxide from the atmosphere.

Idaho National Engineering and Environmental Laboratory

Idaho National Engineering and Environmental Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. Using unique DOE capabilities such as advanced software for controlling neutron beams and calculating dose, BER supports research into boron chemistry, radiation dosimetry, analytical chemistry of boron in tissues, and engineering of new systems for application of this treatment technique to tumors, including brain tumors. Research is also supported into the analytical chemistry of complex environmental and biological systems using the technique of mass spectrometry.

Lawrence Berkeley National Laboratory

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. LBNL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high-throughput human DNA sequencing techniques and studies on the biological functions associated with newly sequenced human DNA. A significant component of the JGI's sequencing goal is the development and integration of instrumentation, automation, biological resources, and data management and analysis tools into a state-of-the-art DNA sequencing assembly line that is highly efficient and cost effective. The laboratory also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on the use of model organisms to understand and characterize the human genome.

LBNL operates beam lines for determination of protein structure at the Advanced Light Source for use by the national biological research community, research into new detectors for x-rays, and research into the structure of proteins, including membrane proteins.

The nuclear medicine program supports research into novel radiopharmaceuticals for medical research and studies of novel instrumentation for imaging of living systems for medical diagnosis.

LBNL supports the Natural and Accelerated Bioremediation Research (NABIR) program and the geophysical and biophysical research capabilities for NABIR field sites. BER supports research into new technologies for the detailed characterization of complex environmental contamination. LBNL also develops scalable implementation technologies that allow widely used climate models to run effectively and efficiently on massively parallel processing supercomputers. LBNL also develops and operates the carbon cycle facility at the ARM Southern Great Plains site.

LBNL co-hosts, with LLNL and six universities, an ocean carbon sequestration research center.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. LLNL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high-throughput human DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. A significant component of the JGI's sequencing goal, is the development and integration of instrumentation, automation, biological resources, and data management and analysis tools into a state-of-the-art DNA sequencing assembly line that is highly efficient and cost effective. LLNL also conducts research on the molecular mechanisms of cell responses to low doses of radiation, on the use of model organisms to understand and characterize the human genome, and on the development of new technologies for rapidly determining the structures of many more proteins than is currently possible.

Through the Program for Climate Model Diagnostics and Intercomparison, LLNL provides the international leadership to understand and improve climate models. Virtually every climate modeling center in the world participates in this unique program.

LLNL co-hosts, with LBNL and six universities, the ocean carbon sequestration research center.

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. LANL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high-throughput human DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. A significant component of the JGI's sequencing goal is the development and integration of instrumentation, automation, biological resources, and data management and analysis tools into a state-of-the-art DNA sequencing assembly line that is highly efficient and cost effective. LANL also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on research to understand the molecular control of genes and gene pathways in microbes. Activities in structural biology include the operation of an experimental station for protein crystallography at the Los Alamos Neutron Science Center for use by the national biological research community and research into new techniques for determination of the structure of proteins.

LANL provides the site manager for the Tropical Western Pacific ARM site. LANL also has a crucial role in the development, optimization, and validation of coupled atmospheric and oceanic general circulation models using massively parallel computers.

LANL also conducts research into advanced medical imaging technologies for studying brain function and research into new techniques for rapid characterization and sorting of mixtures of cells and cell fragments.

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. ORISE coordinates several research fellowship programs for BER. ORISE also coordinates activities associated with the peer review of most of the research proposals submitted to BER.

ORISE conducts research into modeling radiation dosages for novel clinical diagnostic and therapeutic procedures.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. ORNL has a leadership role in research focused on the ecological aspects of global environmental change. The Throughput Displacement Experiment at the Walker Branch Watershed is a unique resource for long term ecological experiments. ORNL is the home of the newest FACE experiment supported by BER. ORNL also houses the ARM archive, providing data to ARM scientists and to the general scientific community. ORNL scientists provide improvement in formulations and numerical methods necessary to improve climate models. ORNL scientists make important contributions to the NABIR program, providing special leadership in microbiology applied in the field.

ORNL conducts research on widely used data analysis tools and information resources that can be automated to provide information on the biological function of newly discovered genes identified in high-throughput DNA sequencing projects. The laboratory also conducts research on the use of model organisms to understand and characterize the human genome and the molecular mechanisms of cell responses to low doses of radiation.

ORNL conducts research into the application of radioactively labeled monoclonal antibodies in medical diagnosis and therapy, particularly of cancer, as well as research into new instrumentation for the analytical chemistry of complex environmental contamination using new types of biosensors.

ORNL recently has upgraded the High Flux Isotope Reactor (HFIR) to include a cold neutron source that will have high impact on the field of structural biology. BER is developing a station for Small Angle Neutron Scattering at HFIR to serve the structural biology community.

ORNL, in conjunction with ANL and PNNL and six universities, co-hosts a terrestrial carbon sequestration research center, CSiTE.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. PNNL is home to the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL). PNNL and EMSL scientists play important roles in both supporting the NABIR program and in performing research for NABIR.

PNNL operates the unique ultrahigh field mass spectrometry and nuclear magnetic resonance spectrometry instruments at the Environmental Molecular Sciences Laboratory for use by the national biological research community.

PNNL provides the lead scientist for the Environmental Meteorology Program, the G-1 research aircraft, and expertise in field campaigns. PNNL provides the planning and interface for the Climate Change Prediction Program with other climate modeling programs. The ARM program office is located at PNNL, as is the ARM chief scientist and the project manager for the ARM engineering activity; this provides invaluable logistical, technical, and scientific expertise for the program. PNNL is developing the Second Generation Model for predicting the benefits and costs of policy actions with respect to global climate change.

PNNL conducts research into new instrumentation for microscopic imaging of biological systems and for characterization of complex radioactive contaminants by highly automated instruments.

PNNL also conducts research on the molecular mechanisms of cell responses to low doses of radiation.

PNNL, in conjunction with ANL and ORNL and six universities, co-hosts a terrestrial carbon sequestration research center, CSiTE.

PNNL also conducts research on the integrated assessment of global climate change.

In March 2001 the University of Maryland and Pacific Northwest National Laboratory created a Joint Global Change Research Institute in College Park, Maryland. The Institute investigates the scientific, social, and economic implications of climate change, both nationally and globally. BER funding will support research grants to the university and research projects to PNNL that have been successfully peer reviewed in open competition.

Sandia National Laboratory

Sandia National Laboratory (SNL) is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with sites in Livermore, California and Tonopah, Nevada. SNL provides the site manager for the North Slope of Alaska ARM site. The chief scientist for the ARM-UAV program is at SNL, and SNL takes the lead role in coordinating and executing ARM-UAV missions.

To support environmental cleanup, SNL conducts research into novel sensors for analytical chemistry of contaminated environments.

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, and is the home of the Stanford Synchrotron Radiation Laboratory (SSRL). The Stanford Synchrotron Radiation Laboratory was built in 1974 to utilize the intense x-ray beams from the SPEAR storage ring that was built for particle physics by the SLAC laboratory. Over the years, the SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third generation synchrotron sources. The facility is now comprised of 25 experimental stations and is used each year by over 700 researchers from industry, government laboratories and universities. Through the Stanford Linear Accelerator Center, BER (in coordination with the National Institutes of Health) is funding the operation of nine Stanford Synchrotron Radiation Laboratory beam lines for structural biology. This program involves synchrotron radiation-based research and technology developments in structural molecular biology that focus on protein crystallography, x-ray small angle scattering diffraction, and x-ray absorption spectroscopy for determining the structures of complex proteins of many biological consequences.

All Other Sites

The BER program funds research at over 340 institutions, including colleges/universities, private industry, and other federal and private research institutions located in 40 states. Also included are funds for research awaiting distribution pending completion of peer review procedures.

BER supports a broad range of peer-reviewed research at America's universities, including institutions that traditionally serve minority communities. BER research opportunities are announced through public solicitations in the Federal Register for research applications from universities and the private sector.

BER's Life Sciences research is conducted at a large number of universities in all aspects of the program. Research is conducted in support of high-throughput human DNA sequencing at the JGI, on the sequencing of entire microbial genomes with value to the DOE mission, to understand the molecular control of genes and gene pathways in microbes, on the use of model organisms to understand and characterize the human genome, and on the molecular mechanisms of cell responses to low doses of radiation.

In structural biology, universities provide new imaging detectors for x-rays, research in computational structural biology directed at the understanding of protein folding, and research into new techniques such as x-ray microscopy.

Peer reviewed projects are supported in each element of the Environmental Processes subprogram, with very active science teams, in particular, in the Atmospheric Chemistry Program and the ARM programs. Academic investigators are essential to the Integrated Assessment portfolio.

In the NABIR program, academic and private sector investigators are performing research in areas that include mechanistic studies of bioremediation of actinide and transition metal contamination, the structure of microbial communities in the presence of uranium and other such contaminants, gene function in microorganisms with degradative properties, geochemical and enzymatic processes in microbial reduction of metals, and the use of tracers to monitor and predict metabolic degradative activity.

In the nuclear medicine program, universities conduct research into new types of radiopharmaceuticals, particularly those based on application of concepts from genomics and structural biology. BER places emphasis on radiopharmaceuticals that will be of use in advanced imaging techniques such as positron emission tomography. The research supports new instrumentation for medical imaging. The Boron Neutron Capture Therapy program supports studies of novel boron compounds for use in treating brain cancer. The BER Measurement Science program supports research into novel types of biosensors for application in analytical chemistry of contaminated environments.

Life Sciences

Mission Supporting Goals and Objectives

BER's Life Sciences research is focused on developing, making available, and using unique DOE resources and facilities to understand and mitigate the potential health effects of energy development, energy use, and waste cleanup. BER supports research in five areas: structural and computational biology, low dose radiation, microbial biology, human genome, and biological research.

BER develops and supports user facilities for the Nation's structural biologists; combines computer science, structural biology, and genome research for analyses and predictions of gene function from the individual gene to the genomic level; and develops new technologies and methodologies to understand the dynamic processes of protein-protein interactions that are unique to living organisms.

BER supports research on low dose and low dose-rate radiation and addresses both the scientific issues and results with scientists, regulators, and the public to provide a better scientific basis for achieving acceptable levels of human health protection from low levels of radiation.

BER takes advantage of the remarkable diversity of microbes found in the environment and of the small size of their genomes to identify and develop unique solutions in energy, waste cleanup, and carbon management and to understand how biological functions follow from the DNA sequence to the behavior of an entire organism.

BER is an integral part of the International Human Genome Project that has already determined and made publicly available a working draft of the human DNA sequence and is now completing the highly accurate sequence. The BER Human Genome Program also develops resources, tools, and technologies needed to analyze and interpret DNA sequence data from entire organisms, determines the function of the genes identified from DNA sequencing, and studies the ethical, legal, and social implications (ELSI) of information and data resulting from the genome project.

Finally, BER's research program is developing the capability of predicting how single cells and multi-cellular organisms respond to biological and environmental cues. This new challenge starts with the remarkable progress being made in all other parts of the Life Sciences subprogram, from DNA sequencing to structural biology, and requires the development of new technologies, analytical methods, and modeling capabilities.

The Life Sciences subprogram's support of microbial genome research also underpins the BER carbon sequestration research program. Knowing the genomic sequence of microbes that are involved in carbon sequestration or that produce methane and hydrogen, will enable the identification of the key genetic and protein components of the organisms that regulate these processes. Understanding more fully how the enzymes and organisms operate will enable scientists to evaluate their potential use to remove excess carbon dioxide from the atmosphere or to produce methane or hydrogen from either fossil fuels or other carbonaceous sources, including biomass or even some waste products. Recently discovered extremophile organisms could be used to engineer biological entities that could ingest a feedstock like methane, produce hydrogen, and sequester the carbon dioxide by products.

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

Genomes to Life

The Microbial Cell Project, initiated in FY 2001, began a challenging and comprehensive effort to understand the complete workings of a microbial cell from its DNA sequence to its unique characteristics and behaviors. It represents a new, systems level way of doing biology that follows from the successes in genome-scale DNA sequencing. The Genomes to Life program takes another large step forward, beginning where the Microbial Cell Project leaves off, and includes this project as part of a broader, more comprehensive research program.

The initial scientific challenge is to couple genomic DNA sequencing capabilities with new methods for probing the dynamics of cellular behavior at the molecular level and with a new overall emphasis on computation. This program will begin with DOE relevant microbes and biochemical pathways to: (1) systematically characterize and relate to cellular function the composition and dynamic changes of microbial proteomes (all the cell's proteins), and the composition and function of the 'machines of life' (the multi-protein complexes that carry out most of life's essential functions); (2) discover the architecture, dynamics, and function of key molecular networks that regulate gene expression and make useful computer models of them; (3) measure microbial gene diversity in representative, natural communities of importance to the DOE mission; and (4) develop the computational methods and infrastructure needed to simulate and predict the behavior of microbial cells and communities in response to environmental perturbations related to DOE's mission.

The broad goals of this new program are complementary to the efforts of other federal agencies and many private sector companies. The BER program will focus on scientific challenges that can be uniquely addressed by DOE and its national laboratories in partnership with scientists at universities and the private sector. BER will aim for activities that are out of reach of individual investigators or even small teams, a feature that will distinguish this program from complementary programs at other agencies like the National Institutes of Health and the National Science Foundation. This research promises unimaginable discoveries for biotechnology, pharmaceuticals, and medicine and will lead to new tools for the promotion of human health, for new therapies and for new predictive capabilities of human susceptibilities. The project will also address DOE needs in energy use and energy production, bioremediation, and carbon sequestration, providing exciting, new, and previously unavailable knowledge to the entire biological community. Many of the experimental tools developed using microbes in the initial phases of this project will also be useful in other programs, e.g., the DOE Low Dose Radiation Research program, to help clarify the biological mechanisms responsible for adverse human responses to these materials. Having the capability to characterize the molecular machines involved in adverse responses to specific toxicants and to develop models to help predict these responses will be powerful tools that can be used to better protect people by identifying those individuals at greatest risk from exposure to weapons-related materials.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Structural Biology	25,869	34,759	27,847	-6,912	-19.9%
Molecular and Cellular Biology	30,862	51,277	51,191	-86	-0.2%
Human Genome	87,499	86,438	88,238	+1,800	+2.1%
Health Effects	17,108	15,409	14,251	-1,158	-7.5%
SBIR/STTR	0	4,589	4,678	+89	+1.9%
Total, Life Sciences	161,338	192,472	186,205	-6,267	-3.3%

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Structural Biology	**25,869**	**34,759**	**27,847**
Basic Research	**12,561**	**13,715**	**12,547**

In an advance named by *Science* magazine as runner-up for the top scientific advance of 2000, scientists using BER's unique structural biology beamlines at the DOE synchrotron facilities determined the high resolution structures of the RNA polymerase and the ribosome, by any measure two of nature's most sophisticated "molecular machines." These remarkable structures reveal in atomic detail how DNA is unwound, how a message for protein production is created, how this message is read by the ribosome, and how the growing protein chain is made.

These two molecular machines illustrate a central phenomenon in biology that most proteins do not act independently or statically in living systems. In carrying out their functions within cells, proteins form complexes with other proteins and interact with a variety of structural, regulatory, and ligand molecules on which proteins carry out their designated functions. The role of structure in determining protein interactions with diverse molecules in a cell is still poorly understood. As illustrated by these remarkable first structures of the ribosome and RNA polymerase, understanding how these and other molecular machines carry out their biological functions requires that we observe dynamic changes in protein structure and study protein modifications, translocation, and subcellular concentrations.

Novel research approaches are being supported to develop and use both experimental and computational approaches to characterize molecular machines of interest to DOE mission needs. Research is supported to predict or identify, from DNA sequence information, proteins that are involved in the recognition or repair of radiation-induced DNA damage or in the bioremediation of metals and radionuclides; and to determine the high-resolution three-dimensional structures of

	FY 2000	FY 2001	FY 2002

(dollars in thousands)

those proteins. To fully understand the mechanisms underlying the behavior of the molecular machines that carry out these functions, research is conducted and computer simulation models are developed: (1) on the dynamic changes in protein structure associated with protein modification and with protein-protein and protein-DNA interactions that occur in these molecular machines; (2) to image, including high resolution, real-time optical imaging, these machines at work in cells; and (3) to precisely measure their intracellular compartmentalization and translocations.

In FY 2002, basic research is decreased as emphasis shifts to development and use of structural biology user facilities.

Performance will be measured by the development of computational models that can successfully identify proteins that interact with protein complexes involved in DNA damage recognition and repair or bioremediation of metals and radionuclides from analysis of DNA sequence.

The decrease in basic structural biology research will be used to increase user support at synchrotron and neutron source facilities.

	FY 2000	FY 2001	FY 2002
Infrastructure Development	**13,308**	**21,044**	**15,300**

BER supports and develops user facilities for the Nation's structural biologists. It coordinates with the National Institutes of Health (NIH) and the National Science Foundation the development and operation of experimental stations at DOE synchrotrons (Advanced Photon Source, Advanced Light Source, Stanford Synchrotron Radiation Laboratory and National Synchrotron Light Source) and neutron beam sources (the Los Alamos Neutron Science Center (LANSCE) and High Flux Isotope Reactor at ORNL).

With the NIH, BER will improve the beamlines at the SSRL and improve the infrastructure at the Advanced Photon Source (APS) at Argonne National Laboratory. GPP funds ($2,994,000 in FY 2001) will be used to complete a Laboratory Module at the APS. Initiated in FY 2000 with $3,000,000 from the National Institutes of Health's Institute of General Medical Sciences (NIGMS), the module is part of an NIGMS/DOE partnership to advance the field of structural biology. The estimated total federal cost of this laboratory module is $5,994,000. The Laboratory Module will provide space for four additional beamlines needed by the structural biology user community.

University scientists are the principal users of these facilities. **Performance will be measured** by having more than 2,500 highly satisfied users of the structural biology facilities at the DOE synchrotron light sources and by the successful testing of a new pixel array detector prototype for crystallography at a synchrotron light source.

By the end of FY 2002, BER will begin the process leading to commissioning the DNA Repair Protein Complex Beamline (FY 2001 Major Item of Equipment (MIE) – TEC $4,490,000) at the Advanced Light Source at Lawrence Berkeley National Laboratory. This beamline will have novel features that include the ability to conduct both high-resolution (2 Angstrom) and low-resolution (2000 Angstrom) studies on important biomolecules using the same beamline. It will meet a rapidly growing need in the structural biology user community to provide unique information on

(dollars in thousands)

	FY 2000	FY 2001	FY 2002

functionally important conformational changes of multiprotein complexes and on factors that regulate the assembly of those complexes.

BER also operates the neutron protein crystallography station at the Los Alamos Neutron Science Center (LANSCE) and will complete a new station for small angle neutron scattering at the High Flux Isotope Reactor at ORNL. **Performance will be measured** by having ten external user groups use the Los Alamos Neutron Science Center's (LANSCE) protein crystallography station productivity during its first year of operation.

BER also supports, with NSF, the Protein Data Bank for three-dimensional protein structures.

Unique facilities being developed at BER's Environmental Molecular Sciences Laboratory (EMSL) are now being made available to the structural biology user community. **Performance will be measured** by the successful integration of new advanced mass spectrometry and nuclear magnetic resonance instrumentation at the Environmental Molecular Sciences Laboratory (EMSL) into the structural biology user facility at EMSL and the successful use of this new instrumentation by at least five external groups.

The major change in FY 2002 is due to the completion of the one-time General Plant Projects (GPP) and MIE projects in FY 2001 described above. In addition, there has been some redistribution of funds to support the general development and use of structural biology user facilities (increase of $1,340,000).

Molecular and Cellular Biology	**30,862**	**51,277**	**51,191**
Microbial Genomics	**8,473**	**14,909**	**10,928**

Microbial genomics research addresses DOE mission needs – The program continues to sequence and characterize microbes that could be used to impact several DOE missions including: microbes for energy production (methane or hydrogen producing microbes), as alternative fuel sources (methane production or energy from biomass), for carbon sequestration, for helping to clean up the environment, and that make industrially useful enzymes. The underlying scientific justification remains a central principle of the BER genome programs – complete genomic sequences yield answers to fundamental questions in biology. Knowing the complete DNA sequence of a microbe provides information on the biological capabilities of that organism and is the first step in developing strategies to more efficiently use or to reengineer that microbe to address DOE needs.

Scientific needs of the DOE microbial genome program – Now that the DNA sequence of more than 20 microbes with potential uses in energy, waste cleanup, and carbon sequestration have been determined, the emphasis of the microbial genome is shifting from microbial DNA sequencing to the use of DNA sequence information. In FY 2001, the microbial genome program will focus on 5 scientific challenges:

Functional analysis - It is presently difficult to predict biological function from microbial genomic sequence data. The program is developing better experimental and computational methods to identify novel open reading frames that code for proteins and predict their

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

functions at a whole-genome scale.

Bioinformatics – More than a third of the 50+ publicly available genomic sequences of archaea and bacteria are a result of DOE Microbial Genome Program funding. Novel computational tools are being developed to increase the value of microbial genomic information, such as identifying distant sequence homologies, reconstructing phylogenetic trees, predicting gene function, identifying and modeling gene expression networks, and extracting longer stretches of useable DNA sequence from raw sequence data.

Microbial Genomic Plasticity – Current microbial DNA sequence strongly suggests that entire blocks of genes have been transferred between microbes during evolution. Research is being conducted to assess the frequency, mechanisms, and circumstances of lateral gene exchanges among microbes. This understanding is important for interpreting sequence data and for designing novel strategies for using microbes to address DOE mission needs.

Novel Approaches to Microbial Genomic Sequencing - Research is being conducted on new methods to accelerate sequence comparisons without resequencing the entire genome of the related organism from scratch. Emphasis is being placed on novel uses of proven technologies with a particular emphasis on the identification of specific DNA sequence features that are associated with phenotypic differences between the microbes being compared.

Consortia and Hard-to-Culture Microbes – Most microbes in the environment neither live in isolation from other microbes or can be readily grown in the laboratory. Research is focused on the organization, membership, or functioning of consortia of microbes, especially those involved in environmental processes of interest to DOE, and on the development of technologies that enable genomic analyses of these consortia without the need for isolating individual microbes.

Microbial genomics research continues to underpin carbon sequestration research, the microbial cell project, and the Genomes to Life program. **Performance will be measured** by determining the complete DNA sequence of at least four additional microbes that could be used to sequester carbon or for biomass conversion. The reduced budget for FY 2002 reflects the reduced emphasis, greater efficiency, and reduced cost of microbial DNA sequencing as well as shifts of funds and emphasis to other programs, such as carbon sequestration research, the Microbial Cell Project, and Genomes to Life.

Carbon Sequestration Research	**5,496**	**7,127**	**7,138**

Microbes play a substantial role in the global cycling of carbon through the environment. The genomic sequence of up to ten microbes involved in carbon sequestration will have been determined by FY 2002. The main emphasis of the program in FY 2002 is to leverage this new genomic DNA sequence information to now characterize key biochemical pathways or genetic regulatory networks in these microbes. Analysis of biochemical pathways has previously focused on single genes or small numbers of genes at one time. Research in this program will focus, as described above, on the development and use of new, high-throughput technologies to determine the function of new genes discovered from microbial DNA sequencing. The information on the DNA sequence, key reaction pathways, and genetic regulatory networks will be used to develop strategies to use microbes capable of carbon sequestration more efficiently or to even reengineer these microbes to enhance their capacity to sequester excess atmospheric carbon.

Genomic sequencing will be started on a member of the genus *Populas* (trees like poplar, aspen, etc.). These rapidly growing trees not only offer an opportunity for carbon sequestration, but also for bioremediation and energy from biomass.

The increase in FY 2002 will be used to increase research to identify and characterize genes and proteins involved in carbon sequestration.

	FY 2000	FY 2001	FY 2002
Microbial Cell Project and Genomes to Life	**0**	**9,591**	**19,470**

DOE is well positioned to meet this challenge because of its unique resources and demonstrated ability (e.g., in genomics, structural biology, and imaging) to develop and use new technologies and tools to solve complex problems in biology that are then widely adopted by other agencies and industry.

Initiated in FY 2001, the Microbial Cell Project (MCP) represents a fundamental shift in the approach to biology. Instead of looking at an organism from the outside in, starting with its behavior and features and finding the responsible genes, scientists could start with the complete DNA sequence or parts list and work from the inside out to identify and understand the structures, functions, and interactions of an organism's entire complement of genes and gene products (the proteins). The goal of the MCP is to develop a comprehensive understanding of the complete workings of a microbial cell by: deciphering the individual gene sequence; understanding how the sequence is controlled; understanding the production of the genes' protein products; and understanding the complex interaction of all the genes and proteins in a cell. The MCP is focused on four key research challenges with a specific emphasis on DOE mission relevant protein complexes, pathways, and processes and their biochemistry, physiology, and regulation as a basis for understanding function. This unprecedented understanding of a biological system would provide remarkable opportunities to address DOE needs in energy use and energy production, bioremediation, and carbon sequestration.

Functional Analysis of the Microbial Proteome (all the proteins) – The program will develop whole genome approaches to predict and categorize the function and the regulation of proteins, protein complexes, pathways and processes relevant to DOE mission needs. Research will use new high-throughput technologies/tools to better understand expression patterns and protein profiles and will exploit available tools for functional manipulation of these proteins to better understand biochemical pathways relevant to the DOE. The research will also identify domains in gene sequences that mediate protein-protein interactions that are part of these pathways.

Biochemical and Physiological Characterization – The program will define the global interactions among components of these biochemical pathways to understand how individual proteins, metabolites or other cellular biomolecules interact to form functional networks. Research will make use of new high-throughput technologies/tools to better quantify the protein biochemistry occurring inside a cell in response to different conditions and to better understand regulatory molecules and noncoding regulatory sequences that corresponds to the biochemical pathways being studied. The program also explores the physical mechanisms of intracellular communication and information exchange that underlie the regulation of these DOE-related biochemical pathways.

Intracellular localization – The program will determine the intracellular distribution, localization, movement, temporal variations, and topological or mechanical constraints on the function of proteins involved in these pathways and their regulatory networks. This research also includes the development and use of technology for imaging microbial cell constituents in real time.

Cell modeling – Research is conducted to simulate these biochemical pathways and regulatory networks with computational models capable of making accurate predictions of the responses of these pathways and regulatory networks to perturbations in the microbe's environment. The goal of this research is to enable the use of terascale computers to explore fundamental biological processes and predict the behavior of a broad range of protein interactions and molecular pathways in prokaryotic microbes of importance to DOE.

The Genomes to Life program takes a large step forward, beginning where the FY 2001 Microbial Cell Project leaves off, incorporating it as part of a broader and bolder research program. This program was recommended by the BER Advisory Committee (BERAC). A large, diverse subcommittee drafted a research agenda for BER to challenge scientists to understand not only the complete workings of individual cells but also the regulation and behavior of complex multi-cellular systems and their responses to the environment. The overriding goal of this long-term research program is to understand biology well enough to be able to predict the behavior and response of biological systems–from cells to organisms. The initial scientific challenge is to couple genomic DNA sequencing capabilities with new methods for probing the dynamics of cellular behavior at the molecular level (the cell's proteins at work) with a new, overall emphasis on computation.

The Genomes to Life program will begin with DOE relevant microbes and biochemical pathways to:

(1) Identify life's molecular machines, the multiprotein complexes that carry out the functions of living systems.

(2) Characterize the gene regulatory networks and processes that control life's molecular machines.

(3) Characterize the functional repertoire of complex microbial communities in their natural environments.

(4) Develop computers and other computational capabilities needed to create models that describe the complexity of biological systems to enable prediction of their behavior and productive use of their functions to serve DOE's environmental and health measures.

The broad goals of Genomes to Life are complementary to other federal agencies and many private sector companies' efforts. The program will focus on scientific challenges that can be uniquely

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

addressed by DOE and its national laboratories in partnership with academic scientists. BER will aim for activities that are out of reach of individual investigators or even small teams. There are unique opportunities in interagency coordination, novel management, new technology innovation, and transition to use in production-scale experimental approaches. For the first time the opportunity exists to understand microbial cells and communities of microbes in enough detail to predict, test, and understand their responses to changes in their environment. This predictive capability will enable these microbes to be used more effectively or to be reengineered to address DOE mission needs in energy use and production, environmental cleanup, and carbon sequestration. This capability also promises broader, unimaginable discoveries for biotechnology and medicine and will, eventually, lead to new tools to predict human susceptibilities.

The increase in the FY 2002 request of $9,879,000 is due to the initiation of the research program described above, Genomes to Life, that includes the Microbial Cell Project (request of $9,735,000 in FY 2001) as a key component. This program funding level was recommended by the Biological and Environmental Research Advisory Committee.

	FY 2000	FY 2001	FY 2002
Human Frontiers Science Program	**1,000**	**1,000**	**1,000**

BER will continue to fund the Human Frontiers Science Program, an international program of collaborative research to understand brain function and biological function at the molecular level supported by the U.S. government through the DOE, the National Institutes of Health, the National Science Foundation, and the National Aeronautics and Space Administration. In FY 2002, DOE expects to explore the possibility of other agencies with stronger interests in brain function continuing the program allowing DOE to refocus its efforts on more mission relevant science.

	FY 2000	FY 2001	FY 2002
Low Dose Radiation Research Program	**14,175**	**18,458**	**12,655**

The goal of the Low Dose Radiation Research program is to support research that will help determine health risks from exposures to low levels of radiation, information that is critical to adequately and appropriately protect people and to make the most effective use of our national resources.

In FY 2002, BER will emphasize the use of new tools such as microbeam irradiators developed in the program in prior years, the characterization of individual susceptibility to radiation, and the forging of closer, more productive linkages between experimentalists and risk modelers, a relationship that lies at the critical interface between experimental science and the development of risk policy. In particular, research will focus on:

Bystander effect – is the response of cells that are not directly traversed by radiation but respond with gene induction and/or production of potential genetic and carcinogenic changes. It is important to know if bystander effects can be induced by exposure to low LET (linear energy transfer) radiation delivered at low total doses or dose-rates. This bystander effect potentially "amplifies" the biological effects (and the effective radiation dose) of a low dose exposure by effectively increasing the number of cells that experience adverse effects to a number greater than the number of cells directly exposed to radiation.

Genomic instability – is the loss of genetic stability, a key event in the development of cancer, induced by radiation and expressed as genetic damage many cell divisions after the insult is administered. Current evidence suggests that DNA repair and processing of radiation damage can lead to instability in the progeny of irradiated cells and that susceptibility to instability is under genetic control but there is virtually no information on the underlying mechanisms. Its role in radiation-induced cancer remains to be determined experimentally.

Adaptive response – is the ability of a low dose of radiation to induce cellular changes that perturb the level of subsequent radiation-induced or spontaneous damage. If low doses of radiation regularly and predictably induce a protective response in cells to subsequent low doses of radiation or to spontaneous damage, this could have a substantial impact on estimates of adverse health risk from low dose radiation. The generality and the extent of this apparent adaptive response needs to be quantified.

Endogenous versus low dose radiation induced damage - A key element of the program will continue to understand the similarities and differences between endogenous oxidative damage and damage induced by low levels of ionizing radiation as well as an understanding of the health risks from both. This information was not previously attainable because critical resources and technologies were not available. Today, technologies and resources such as those developed as part of the human genome program have the potential to detect and characterize small differences in damage induced by normal oxidative processes and low doses of radiation.

Genetic factors that affect individual susceptibility to low dose radiation – Research is also focused on determining if genetic differences exist making some individuals more sensitive to radiation-induced damage since these differences could result in sensitive individuals or sub-populations that are at increased risk for radiation-induced cancer.

Mechanistic and risk models – Novel research is supported that involves innovative collaborations between experimentalists and modelers to model the mechanisms of key radiation-induced biological responses and to describe or identify strategies for developing biologically-based risk models that incorporate information on mechanisms of radiation-induced biological responses.

Information developed in this program will provide a better scientific basis for remediating contaminated DOE sites and achieving acceptable levels of human health protection, both for cleanup workers and the public, in a more cost-effective manner that could save billions of dollars. University scientists, competing for funds in response to requests for applications, conduct a substantial fraction of the research in this program.

Performance will be measured by BER issuing an interim progress report on the success of the Low Dose Radiation Research program in producing science that will be useful to policy makers. This interim report will be timely since all awards made during the first full year of funding in this program will have completed their 3-year cycle of funding.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

In FY 2000, the research was funded within both the Cellular Biology and Health Effects programs. In FY 2001, the research was consolidated into the Cellular Biology program. The decrease in FY 2002 enables the program to support research at a level consistent with previous requests (FY 2001, $11,682,000).

	FY 2000	FY 2001	FY 2002
Study of Avian Populations at the Nevada Test Site	**94**	**192**	**0**

Congressional direction in FY 2000 for a Study of Avian Populations at the Nevada Test Site.

	FY 2000	FY 2001	FY 2002
Hiroshima Neutron Dosimetry	**1,624**	**0**	**0**

Congressional direction in FY 2000 for a review of the Hiroshima neutron dosimetry.

	FY 2000	FY 2001	FY 2002
Human Genome	**87,499**	**86,438**	**88,238**
Joint Genome Institute	**64,400**	**60,000**	**57,200**

Status of the DOE Joint Genome Institute (JGI) - The Joint Genome Institute (JGI) and its Production Sequencing Facility (PSF) have been primarily focused on high-throughput sequencing of DNA as DOE's contribution to the international human genome project. The JGI, a virtual institute initially formed from the combined strengths and expertise of DOE Human Genome Centers at the Los Alamos, Lawrence Livermore, and Lawrence Berkeley National Laboratories, has expanded to include Oak Ridge, Pacific Northwest, and Brookhaven National Laboratories that diversify and strengthen its overall capabilities. Oak Ridge adds unique capabilities in bioinformatics, including DNA sequence analysis, that were key to the JGI's completion of the draft DNA sequence of human chromosomes 5, 16, and 19 in FY 2000. Pacific Northwest adds unique capabilities in the high-throughput proteome analysis using mass spectrometry, a capability that is key to identifying and understanding the function of the genes (and their protein products) identified by DNA sequencing. Brookhaven adds unique capabilities in development and use of novel approaches for determining the DNA sequence of difficult-to-sequence regions of the genome.

Scientific needs of the JGI - FY 2001 is the fourth year of a major five-year scale-up of DNA sequencing capacity at the PSF. The PSF has completed the draft sequence of its three human chromosomes 5, 16, and 19. In FY 2002 the PSF will complete the high quality sequence of these three human chromosomes to international "Bermuda" quality standards. Scientists at Stanford University and LANL, working with the JGI, play a key role in completing DOE's share of determining the human DNA sequence. The PSF will also complete draft sequencing of regions of the mouse genome that are comparable to these three human chromosomes. This comparative information is critical to understanding gene function, networks, and regulation.

The need for DNA sequencing does not end with the completion of the reference human DNA sequence. Sequencing the reference human genome gives us a complete set of instructions for human biology, but it does not give us the key for understanding what all those instructions mean or how they work together to make a fully functional biological system--a human. To help scientists decipher the new wealth of human genomic information, the biological instruction set for humans, information is needed on the biological function of the more than 50,000 newly identified genes, information on how these genes work together to make us who we are and how we are different, and information on the genetic variation that predisposes us to good health or to disease. In short, the goal is to not only know the human DNA sequence--the instruction set--but to understand what it is telling us, i.e., how it actually works. Much of this understanding will come from additional DNA sequencing, comparative sequencing, in which portions of the reference human DNA sequence are compared to fragments of other human DNA sequence or to the sequence of model organisms such as the mouse and Fugu fish. These comparisons will help us define genetic differences between people and understand the functions and regulation of all human genes. These comparisons will also require the generation of as much as ten times more DNA sequence data than will be contained in the reference human DNA sequence.

As an example of the research challenge that still lies ahead, less than 3 percent of human DNA actually contains the instructions for the approximately 30,000 genes that make up our genomes. The remaining DNA, erroneously referred to as "junk DNA," is far from junk for it contains the instructions for making all of these 30,000 genes work at the right times and places throughout our lives – from development to good health and disease to death. Today, scientists are not able to recognize or identify these genetic instructions, or regulatory elements, using computational methods like we can for the genes themselves. Experimental approaches are needed to identify these elements and to define their roles in making our genes work together. The only way to currently find these sequences is by comparatively sequencing the DNA from other, distantly related animals. By comparing the DNA sequences from different species, scientists can identify, in human DNA, the essential regulatory elements by their common association with related genes from different species. The JGI and PSF will continue to use their substantial resources and capabilities for comparative sequencing of the DNA from several different organisms to identify and catalog the regulatory elements associated with the thousands of genes that have already been identified from the initial sequencing effort on human chromosomes 5, 16, and 19.

DOE continues to coordinate its human genome research activities with the activities at the National Human Genome Research Institute and the other partners in the International Human Genome Consortium.

The decrease in funding for the Joint Genome Institute is due to a programmatic shift to increase development of DNA sequencing technology research needed to meet the growing demand for cheaper, faster, and more accurate high-throughput DNA sequencing as a basic research tool in biology.

Performance of the JGI will be measured by the successful achievement of three DNA sequencing goals:

(1) The DOE JGI will complete the high quality DNA sequencing of the vast majority of regions of greatest biological interest of human chromosomes 5, 16, and 19 and will submit the data to GenBank, the public DNA sequence database.

		(dollars in thousands)	
	FY 2000	FY 2001	FY 2002

(2) The JGI will also complete the DNA sequence of the most difficult to sequence regions at the ends (telomeres) and middles (centromeres) of human chromosomes 5, 16, and 19 and submit the data to GenBank.

(3) The JGI's PSF will produce approximately 6 billion base pairs of DNA sequence from model organisms (in addition to its human DNA sequencing) needed to interpret and understand human DNA sequence information. This comparative DNA sequencing is currently the only efficient and cost-effective way to identify and characterize the regulatory elements (the biological on/off switches and the rheostats) that control the expression of human genes.

	FY 2000	FY 2001	FY 2002
Tools for DNA Sequencing and Sequence Analysis.................	**20,432**	**23,950**	**28,547**

BER continues to develop the tools and resources needed by the scientific, medical, and private sector communities to fully exploit the information contained in the first complete human DNA sequence. Unimaginable amounts of DNA sequencing, at dramatically increased speed and reduced cost, will be required in the future for medical and commercial purposes and to understand the information in the DNA sequence that has already been determined. BER continues to support research to further improve the reagents used in DNA sequencing and analysis; to decrease the costs of sequencing; to increase the speed of DNA sequencing; and to improve strategies for sequencing the "difficult regions" at the ends and middle of chromosomes and new computational tools for genome-wide data analysis. Novel sequencing strategies such as microchannel capillary electrophoresis offer great promise for the sequencing needs of the future.

Use of sequence information to understand human biology and disease will also require new strategies and tools capable of high-throughput, genome-wide experimental and analytic approaches. In FY 2002, BER will increase efforts to develop high-throughput approaches for analyzing gene regulation and function.

DNA sequencing technology research increases to meet growing demand for cheaper, faster, and more accurate high-throughput DNA sequencing as a basic research tool in biology.

	FY 2000	FY 2001	FY 2002
Ethical Legal and Societal Issues (ELSI).................................	**2,667**	**2,488**	**2,491**

The DOE and NIH human genome programs agreed at the outset to dedicate a fraction of their human genome program funding to understanding the ELSI issues associated with the genome program. DOE's ELSI research program represents 3 percent of the DOE human genome program. The DOE ELSI program supports research focus on issues of: (1) the use and collection of genetic information in the workplace especially as it relates to genetic privacy; (2) the storage of genetic information and tissue samples especially as it relates to privacy and intellectual property; (3) genetics and ELSI education; and (4) the ELSI implications of advances in the scientific understanding of complex or multi-genic characteristics and conditions.

A table follows displaying both DOE and NIH genome funding.

U.S. Human Genome Project Funding

	(dollars in millions)			
	Prior Years	FY 2000	FY 2001	FY 2002
DOE Total Funding (FY 87-99)	691.5	87.5	86.4	88.2
NIH Funding (FY 88-99)	1,524.1	335.1	382.4	426.7[a]
Total U.S. Funding	2,215.6	422.6	468.8	514.9

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Health Effects	**17,108**	**15,409**	**14,251**
Low Dose Radiation Research	**2,321**	**0**	**0**

Low dose radiation research (consolidated in Cellular Biology in FY 2001) was also funded in Health Effects in FY 2000.

Functional Genomics Research	**10,860**	**12,210**	**14,251**

Scientific needs for functional genomics research - Functional genomics research capitalizes on our understanding and the manipulability of the genomes of model organisms, including yeast, nematode, fruit fly, Zebra fish, and mouse, to speed understanding of human genome organization, regulation, and function. This research is a key link between human genomic sequencing, which provides a complete parts list for the human genome, and the development of information (a high-tech owner's manual) that is useful in understanding normal human development and disease processes. The mouse continues to be a major focus of our efforts. It is an integral part of our functional genomics research effort. BER creates and genetically characterizes new mutant strains of mice that serve both as important models of human genetic diseases. It develops high-throughput tools and strategies to characterize these mutant strains of mice. This mouse genetics research provides tools useful to the entire scientific community for decoding the functionality of the human genome as human DNA sequence becomes available.

Research to develop new strategies for using model organisms such as the mouse and Fugu fish to understand the function of human genes is increased in FY 2002 ($2,041,000). These funds will take advantage of the newly available DNA sequence of the Fugu fish and for mouse chromosomes homologous to human chromosome 5, 16, and 19.

[a] Estimate from NIH.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Technology Development Research	**3,927**	**3,199**	**0**

Technology development research ends as technology development needs are met with the initiation of the Genomes to Life program at DOE described here and the Structural Genomics program at the National Institutes of Health.

SBIR/STTR increased with Life Sciences program increase	**0**	**4,589**	**4,678**

In FY 2000, $4,259,000 and $264,000 were transferred to the SBIR and STTR programs, respectively. FY 2001 and FY 2002 amounts are the estimated requirements for the continuation of these programs.

Total, Life Sciences	**161,338**	**192,472**	**186,205**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Structural Biology	
Decrease in basic structural biology research to support increases for structural biology user facilities.	-1,168
Decrease in one-time GPP funding of user facility at the Advanced Photon Source and the MIE beamline development at the Advanced Light Source (-$7,084,000). However, there is an increase in support for structural biology user facilities at synchrotron sources and neutron sources (+$1,340,000).	-5,744
Total, Structural Biology	-6,912
Molecular and Cellular Biology	
Reduced emphasis on microbial DNA sequencing and increased support for Genomes to Life.	-3,981
Continue carbon sequestration at near FY 2001 level	+11
Redirected program, Genomes to Life, includes Microbial Cell Project and focuses on understanding cellular processes and multicellular systems so well that predictive simulation models can be developed to guide the use or development of microbial systems to solve DOE mission needs for energy use and production, waste cleanup, or carbon sequestration.	+9,879

	FY 2002 vs. FY 2001 ($000)
Continue Low Dose Radiation Research at about previously requested levels (FY 2001, $11,682,000).	-5,803
Decrease due to Congressional Direction for the study of biological effects of low level radioactivity at University of Nevada in FY 2001.	-192
Total, Molecular and Cellular Biology	-86
Human Genome	
Decrease in funding for the Joint Genome Institute is due to a programmatic shift to increase development of DNA sequencing technology research needed to meet the growing demand for cheaper, faster, and more accurate high-throughput DNA sequencing as a basic research tool in biology.	-2,800
DNA sequencing technology research increases to meet growing demand for cheaper, faster, and more accurate high-throughput DNA sequencing as a basic research tool in biology	+4,597
Ethical Legal and Societal Issues program continues at approximately same level.	+3
Total, Human Genome	+1,800
Health Effects	
Increase research to understand the function of human genes that could lead to better understanding of the causes of disease or to preventions or cures.	+2,041
Decrease research for high-throughput approaches that determine protein structure as NIH begins to make large investments in this area.	-3,199
Total, Health Effects	-1,158
SBIR/STTR	
■ Increase in SBIR/STTR due to increase in research funding for the Life Sciences program.	+89
Total Funding Change, Life Sciences	-6,267

Environmental Processes

Mission Supporting Goals and Objectives

The Environmental Processes subprogram supports four contributing areas of research: Climate and Hydrology; Atmospheric Chemistry and Carbon Cycle; Ecological Processes; and Human Interactions. The research is focused on understanding the physical, chemical, and biological processes affecting the Earth's atmosphere, land, and oceans and how these processes may be affected, either directly or indirectly, by energy production and energy use, primarily the emission of carbon dioxide from fossil fuel combustion. BER has designed and planned the research program to provide the data that will enable objective assessments of the potential for, and consequences of, global warming. The BER Environmental Processes subprogram (minus the carbon sequestration element) represents DOE's contribution to the U.S. Global Change Research Program proposed by President Bush in 1989 and codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606). The National Institute for Global Environmental Change (NIGEC) is integrated throughout the subprogram ($8,763,000).

The Environmental Processes subprogram is comprehensive with a major emphasis on understanding the radiation balance from the surface of the Earth to the top of the atmosphere and how changes in this balance due to increases in the concentration of greenhouse gases in the atmosphere may alter the climate. Much of the research is focused on improving the quantitative models necessary to predict possible climate change at the global and regional scales. Research in the Atmospheric Radiation Measurement (ARM) program will continue to focus on resolving the greatest scientific uncertainty in climate change prediction – the role of clouds and solar radiation. ARM includes developing a better quantitative understanding of how atmospheric properties, including the extent and type of cloud cover and changes in aerosols and greenhouse gas concentrations affect the solar and infrared radiation balance that drives the climate system. BER's Climate Modeling program uses massively parallel supercomputers to simulate and predict climate and climate change, including evaluating uncertainties in climate models due to changes in atmospheric levels of greenhouse gases on decade to century time scales.

The Atmospheric Science program is focused on acquiring the data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter emitted to the atmosphere. BER is emphasizing research on processes relating to new air quality standards for tropospheric ozone and particulate matter and relationships between air quality and climate change.

Research on the carbon cycle explores the movement of carbon on a global scale starting from natural and anthropogenic emissions to ultimate sinks in the terrestrial biosphere and the oceans. Experimental and modeling efforts address the net exchange of carbon among major types of terrestrial ecosystems and the atmosphere. Research is also conducted to determine the effects of atmospheric and climate changes on terrestrial organisms, ecosystems, and resources.

The BER carbon sequestration research funds basic research that seeks to exploit the biosphere's natural processes to enhance the sequestration of atmospheric carbon dioxide in terrestrial and marine ecosystems. It also seeks the understanding needed to assess the potential environmental implications of purposeful enhancement and/or disposal of carbon in the terrestrial biosphere and at the surface or deep ocean. The carbon sequestration activities include research to identify and understand the environmental and biological factors or processes that limit carbon sequestration in these systems and to develop approaches for overcoming such limitations to enhance sequestration. The research includes studies on the role of ocean and terrestrial microorganisms in carbon sequestration.

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
Climate and Hydrology	67,496	70,326	70,775	+449	+0.6%
Atmospheric Chemistry and Carbon Cycle	33,837	35,579	34,844	-735	-2.1%
Ecological Processes	11,858	12,431	12,437	+6	-
Human Interaction	9,369	8,020	8,084	+64	+0.8%
SBIR/STTR	0	3,348	3,329	-19	-0.6%
Total, Environmental Processes	122,560	129,704	129,469	-235	-0.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Climate and Hydrology	**67,496**	**70,326**	**70,775**
Climate Modeling	**24,151**	**27,103**	**27,181**

Model based climate prediction provides the most scientifically valid way of predicting the impact of human activities on climate for decades to centuries in the future. BER will continue to develop, improve, evaluate, and apply the best coupled atmosphere-ocean general circulation models (GCMs) that simulate climate variability and climate change over these time scales. The goal is to achieve statistically accurate forecasts of future climate over regions as small as river basins using ensembles of model simulations. The ensembles will accurately incorporate the dynamic and thermodynamic feedback processes that influence climate, including clouds, aerosols, and greenhouse gas forcing. Current predictions are limited by the inadequacy of computational resources and uncertainties in the model representations of key small-scale physical processes, especially those involving clouds, evaporation, precipitation, and surface energy exchange. BER will address both the computational and scientific shortcomings through an integrated effort. Support will continue to be provided to acquire the high-end computational resources to complete ensembles of climate simulations using present and future models. BER will emphasize research to

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

develop and employ information technologies that can quickly and efficiently work with large and distributed data sets of both observations and model predictions to produce quantitative information suitable for the study of regional climate changes. BER will continue to fund the multi-institutional research consortia established in FY 2001 to further the development of comprehensive coupled GCMs for climate prediction that are of higher resolution and contain accurate and verified representations of clouds and other important processes. **Performance will be measured** by how BER will successfully develop and test a fully coupled atmosphere-ocean-land-sea ice climate model of higher spatial resolution than is presently available. BER will support multi-disciplinary teams of scientists at multiple institutions using DOE supercomputers to perform model simulations, diagnostics, and testing. BER efforts will include ensembles of long-term (decade to century) coupled model simulations that will be made available to the broader climate research and assessment communities to enable probability-based assessments of climate change and variability at regional resolution.

In FY 2002, BER will continue to enhance the partnership with the Advanced Scientific Computing Research program and increase the computing resources for climate simulation and accelerate climate model development and application through the use of collaboratory technologies. Additionally, BER will increase the emphasis on data assimilation methods so as to quickly make use of the high quality observational data streams provided by ARM, satellite and other USGCRP climate data programs to evaluate model performance.

NIGEC will support research to evaluate the reliability of using isotopic signatures of trace gases in ice cores for interpreting climate variation and change in the past and the relationship between greenhouse gas concentrations and climate change ($2,191,000).

Performance will be measured by developing and testing a fully coupled atmosphere-ocean-land-sea climate model of higher spatial resolution than is presently available. Support multi-disciplinary teams of scientists at multiple institutions using DOE supercomputers to perform model simulations, diagnostics, and testing. These efforts will include ensembles of long-term (decade to century) couples model simulations that will be made available to the broader climate research and assessment communities to enable probability based assessment of climate change and variability at regional resolution.

Atmospheric Radiation Measurement (ARM) Research	**13,020**	**13,124**	**13,486**

ARM research supports about 50 principal investigators involved in studies of cloud physics and the interactions of solar and infrared radiation with water vapor and aerosols. University scientists form the core of the ARM science team that networks with the broader academic community as well as with the scientists at the DOE National Laboratories and with federal scientists at NASA, NOAA, and DOD. ARM scientists pursue research as individuals and as members of teams and contribute both to the production of ARM data, e.g., as designers of cutting-edge remote sensing instrumentation, as well as consumers of the data produced at the three ARM sites. The principal goal of the ARM scientific enterprise is to develop an improved understanding of the radiative transfer processes in the atmosphere and to formulate better parameterizations of these processes in

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

climate prediction models, referred to as General Circulation Models (GCMs). To facilitate the knowledge transfer from the ARM Program to the premier modeling centers, the ARM program supports scientific "Fellows" at NSF's National Center for Atmospheric Research and at the European Center for Medium-Range Weather Forecasting in the U.K. In FY 2002, the ARM program will continue at approximately the FY 2001 level.

Performance will be measured by improving the radioactive flux calculations and associated heating rates in climate models using ARM data and science by 10 percent.

	FY 2000	FY 2001	FY 2002
Atmospheric Radiation Measurement (ARM) Infrastructure .	**27,653**	**27,371**	**27,371**

The Atmospheric Radiation Measurement (ARM) infrastructure program develops, supports, and maintains the three ARM sites and associated instrumentation. BER will continue to operate over two hundred instruments (e.g., multifilter shadowband radiometers for aerosol measurements, Raman Lidar for aerosol and cloud measurements, radar wind profiler systems, radar cloud measurement systems, sky imaging systems, arrays of pyranometers, pygeometers, and pyrheliometers for atmospheric and solar radiation measurements, and standard meteorological measurement systems for characterization of the atmosphere) at the Southern Great Plains site and will continue limited operations at the Tropical Western Pacific station and at the North Slope site in Alaska. The ARM program will continue to provide data to the scientific community through the ARM Archive.

The ARM data streams are enhanced periodically by additional measurements during intensive field campaigns referred to as Intensive Operation Periods (IOP). Ranging from two weeks to two months, the campaigns bring together teams of scientists testing cutting edge remote sensing instruments and coordinate measurements with airborne and satellite observations. The ARM sites have become major testbeds of research in atmospheric processes serving as scientific user facilities for hundreds of scientists from universities and government laboratories. For example, both DoD and NASA have used the ARM sites to "ground truth" their satellite instruments.

Performance will be measured in FY 2002 by less than 5 percent downtime of the principal ARM instruments and by the successful conduct of five IOPs across the three ARM sites.

	FY 2000	FY 2001	FY 2002
Atmospheric Radiation Measurement (ARM)/Unmanned Aerial Vehicles (UAV)	**2,672**	**2,728**	**2,737**
Atmospheric Chemistry and Carbon Cycle	**33,837**	**35,579**	**34,844**
Atmospheric Science programs	**12,688**	**12,571**	**12,571**

The Atmospheric Science programs acquire data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter. Emphasis is placed on processes relating to new air quality standards for tropospheric ozone and particulate matter and relationships between air quality and climate change. Field and laboratory studies will continue to be conducted in both atmospheric chemistry and environmental meteorology and acquired data will be used to develop and validate predictive models of atmospheric processes. The research will include studies of chemical and physical processes affecting air pollutants such as

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

sulfur and nitrogen oxides, tropospheric ozone, gas-to-particle conversion processes, and the deposition and resuspension of associated aerosols, and studies to improve understanding of the meteorological processes that control the dispersion of energy-related chemicals and particulates in the atmosphere. Much of this effort involves multi-agency collaboration, and university scientists play key roles. New information will document both the contribution of energy production to regional haze in the U.S. and the relationship between urban and regional air pollution processes and continental, intercontinental, and global scale phenomena. The information is essential for assessing the effects of energy production on air quality and will contribute to the evaluation of science-based options for minimizing the impact of energy production on visibility.

In FY 2002 BER will continue the Tropospheric Aerosol Program (TAP) to quantify the impacts of energy-related aerosols on climate, air quality and human health. TAP will be closely coupled with other components of DOE's global change research, especially the Atmospheric Radiation Measurement (ARM) Program. TAP will also be broadly coordinated with the air quality and global change research communities, including collaborations with the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration and with the DOE Office of Fossil Energy's Airborne Fine Particulate Matter (PM) Research Program. Regional patterns of aerosol distribution will be related to sources and sinks and the information will feed the models that simulate the air quality and climate impacts of aerosols.

NIGEC will support research to quantify the effects of natural processes on atmospheric composition, including the exchange of energy-related trace gases between the atmosphere and the terrestrial biosphere ($2,191,000).

	FY 2000	FY 2001	FY 2002
Western States Visibility Study at New Mexico Tech	**0**	**1,246**	**0**

Congressional direction in FY 2001 for the Western States Visibility Study.

	FY 2000	FY 2001	FY 2002
Terrestrial Carbon Processes and Ocean Sciences...................	**12,958**	**12,731**	**13,716**

BER will continue supporting the successful AmeriFlux Program, including the measurements of carbon flux and water vapor exchange at approximately 25 sites across North America. These measurements will be linked to field measurement campaigns across North America that will test the representativeness of point measurements and allow the estimation of carbon sources and sinks on a regional basis. The fluxes of other greenhouse gases, e.g., methane and nitrous oxide, will be measured at several AmeriFlux sites.

In FY 2002, funding is increased to support the refinement and testing of carbon cycle models (based on mechanistic representations and simple carbon accounting). The models will be used to estimate potential carbon sequestration for a variety of biogeochemical cycles and climate variations.

	FY 2000	FY 2001	FY 2002

(dollars in thousands)

The focus of the ocean science element is on using microbiology tools to determine the linkages between the carbon and nitrogen cycles involving marine microbes. This research is conducted through partnerships between institutions with a tradition of research in oceanography (such as Skidaway Institute of Oceanography, U. of Washington, U. of Delaware, Rutgers University, U. of South Florida, Princeton University), and institutions traditionally serving minority students (such as Lincoln U., Howard U., Savannah State U., U. of Puerto Rico, and San Francisco State).

Performance will be measured by quantifying the net exchange of carbon dioxide in five additional ecosystems in the AmeriFlux network.

	FY 2000	FY 2001	FY 2002
National Energy Laboratory in Hawaii	**1,500**	**479**	**0**

Congressional direction in FY 2000 and FY 2001 for the National Energy Laboratory in Hawaii.

	FY 2000	FY 2001	FY 2002
Carbon Sequestration Research Centers	**6,691**	**8,552**	**8,557**

BER will continue support for two carbon sequestration research centers. One center, led by ORNL, PNNL, and ANL, and involving six collaboratory universities, focuses on terrestrial sequestration ($3,000,000). The other center, led by LBNL and LLNL, involves collaboration with six universities and research institutions, and focuses on ocean sequestration ($2,000,000). The centers develop the information to enhance the natural sequestration of carbon in terrestrial soils and vegetation and in the deep ocean. BER will continue research at universities and laboratories on cellular and biogeochemical processes that control the rate and magnitude of carbon sequestration in terrestrial and oceanic systems, including the identification of pathways and processes that could be modified to enhance the net flow of carbon from the atmosphere to both terrestrial plants and, ultimately, to soils, and to the ocean surface and, ultimately, to the deep ocean. Also, BER will support the research needed to assess the environmental implications of enhancing carbon sequestration and storage in the ocean and in terrestrial systems. BER research on carbon sequestration in terrestrial ecosystems will improve the scientific understanding of mechanisms of sequestration and how to alter them to enhance sequestration. The Carbon Sequestration in Terrestrial Ecosystems (CSiTE) activity will conduct research at universities and laboratories that specifically examine those plant and soil processes that capture and retain carbon in chemical and physical forms that are resistant to decay. The data will inform new models for estimating carbon sequestration in terrestrial ecosystems. New technologies will be successfully developed by the DOE Ocean Carbon Sequestration Center to facilitate the export of carbon to the deep ocean and for re-mineralization of organic carbon at depth. Such technologies are vital to assessing accurately the potential of ocean carbon sequestration. Initial in situ experiments will be designed to determine the feasibility and potential environmental impacts of deep ocean injection of CO_2. Associated research will include determination of chemical reactions at depth, stability of products, and effects of those products on marine organisms.

Performance will be measured by developing and testing the feasibility of soil, microbial manipulation, and ecosystem management approaches for enhancing the magnitude of net annual carbon sequestration.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

In FY 2002 university scientists will continue research on the effects of iron fertilization on plankton communities in the ocean and begin field experiments. The Southern Ocean is the largest high-nutrient, low-chlorophyll region in the world. The joint DOE-NSF Southern Ocean Iron Enrichment Experiment (SoFEX) will help scientists understand the potential to enhance ocean carbon sequestration through iron enrichment.

Ecological Processes	**11,858**	**12,431**	**12,437**

BER will continue the six Free-Air Carbon Dioxide Enrichment (FACE) experiments to improve understanding of the direct effects of elevated carbon dioxide and other atmospheric changes on the structure and functioning of various types of terrestrial ecosystems, including coniferous and deciduous forests, grasslands, and desert. Increasing emphasis will be on evidence of differential responses of plant species that may impact plant competition and succession in terrestrial ecosystems. Research will explore changes, over time, in the elevated productivity of terrestrial plants exposed to elevated atmospheric carbon dioxide (CO_2) concentrations.

The long-term experimental investigation at the Walker Branch Watershed in Tennessee will continue to improve the understanding of the direct and indirect effects of alterations in the annual average precipitation on the functioning and structure of a southeastern deciduous forest ecosystem.

Both the FACE network and the Walker Branch Watershed represent scientific user facilities that have attracted scientists from both the academic community and government laboratories who use the facilities to develop new instrument methodologies and test scientific hypotheses related to ecosystem responses to climate change and to carbon sequestration.

NIGEC will support experimental studies to document how climate warming and increasing CO_2 levels in the atmosphere affect biophysical processes in terrestrial ecosystems ($2,629,000).

Performance will be measured by exposing plants at least 95% of the time during the growing season to elevated CO_2 to test for long-term physiological responses to CO_2 enrichment.

Human Interactions	**9,369**	**8,020**	**8,084**
Human Interactions	**7,964**	**8,020**	**8,084**

The Integrated Assessment program, with a strong academic involvement, will continue to support research that will lead to better estimates of the costs and benefits of possible actions to mitigate global climate change. The new emphasis will be to improve the integrated assessment models to include other greenhouse gases as well as carbon dioxide, carbon sequestration, and international trade of emission permits. The models will better represent the efficiency gains and losses of alternate emission reduction plans, including market adjustments to inter-regional differences among relative energy prices, regulations, and production possibilities in the international arena. Integrated assessment models will be modified to include carbon sequestration as an alternative mitigation option. This representation will include both options to enhance natural carbon storage in the terrestrial biosphere, as well as engineering options, such as the capture of carbon dioxide and storage in geologic formations.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

NIGEC will support research to develop and test new methods involving the use of large regional databases and coupled climate-impact-economic models to conduct integrated assessments of the effects of climate change on regionally important resources in the U.S. ($1,752,000).

The Information and Integration element stores, evaluates, and quality-assures a broad range of global environmental change data, and disseminates these to the broad research community. BER will continue the Quality Systems Science Center for the tri-lateral (Mexico, United States, and Canada) North American Strategy for Tropospheric Ozone (NARSTO), a public partnership for atmospheric research in support of air quality management. The Center serves a diverse set of users, including academic and laboratory scientists and policy makers across North America.

The Global Change Education program supports DOE-related research in global environmental change for both undergraduate and graduate students, through the DOE Summer Undergraduate Research Experience (SURE), the DOE Graduate Research Environmental Fellowships (GREF), and collaboration with the NSF Significant Opportunities in Atmospheric Research and Science (SOARS) Program. **Performance will be measured** by how well the Global Change Education program will continue to support both undergraduate and graduate students in DOE-related global change research. Over 30 DOE-sponsored students participate in the program, including the DOE Summer Undergraduate Research Experience (SURE), the DOE Graduate Research Environmental Fellowships (GREF), and the NSF Significant Opportunities in Atmospheric Research and Science (SOARS) Program.

Utton Transboundary Center..	**1,405**	**0**	**0**

Congressional direction in FY 2000 for the Utton Transboundary Center.

SBIR/STTR..	**0**	**3,348**	**3,329**

In FY 2000 $3,201,000 and $185,000 were transferred to the SBIR and STTR programs, respectively. FY 2001 and FY 2002 amounts are the estimated requirements for the continuation of these programs.

Total, Environmental Processes..	**122,560**	**129,704**	**129,469**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Climate and Hydrology	
Climate Modeling program will continue at approximately the FY 2001 level.	+78
Atmospheric Radiation Measurement (ARM) program will continue at approximately the FY 2001 level.	+362
Atmospheric Radiation Measurement (ARM) Unmanned Aerial Vehicles (UAV) program will continue at FY 2001 level.	+9
Total, Climate and Hydrology	+449
Atmospheric Chemistry and Carbon Cycle	
Atmospheric Sciences research continues at approximately FY 2001 levels with the decrease due to Congressional Direction for the Western Visibility Study at New Mexico Tech	-1,246
Terrestrial Carbon is increased to support expanded studies of carbon cycling processes of Ameri Flux sites.	+985
Decrease due to Congressional Direction for the National Energy Laboratory in Hawaii	-479
Carbon Sequestration continues at FY 2001 levels	+5
Total, Atmospheric Chemistry and Carbon Cycle	-735
Ecological Processes	
Ecological Processes programs continue at approximately FY 2001 level.	+6
Human Interactions	
Integrated Assessment program will continue at FY 2001 level.	+64
SBIR/STTR	
SBIR/STTR decrease due to decrease in research funding for environmental processes	-19
Total Funding Change, Environmental Processes	-235

Environmental Remediation

Mission Supporting Goals and Objectives

BER's research in environmental remediation is primarily focused on gaining improved understanding of the fundamental biological, chemical, geological, and physical processes that must be marshaled for the development and advancement of new, effective, and efficient processes for the remediation and restoration of the Nation's nuclear weapons production sites. Research priorities are on bioremediation and operation of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL).

Bioremediation activities are centered on the Natural and Accelerated Bioremediation Research (NABIR) program, a basic research program focused on determining how and where bioremediation may be applicable as a reliable, efficient, and cost-effective technique for cleaning up or containing metals and radionuclides in contaminated subsurface environments. In this subprogram, BER also includes basic research in support of pollution prevention, sustainable technology development and other fundamental research to address problems of environmental contamination.

In the NABIR program, research advances will continue to be made from pore to field scales in the Biogeochemical Dynamics element; on genes and proteins used in bioremediation through the Biomolecular Science and Engineering element; in non-destructive, real-time measurement techniques in the Assessment element; in overcoming physico-chemical impediments to bacterial mobility in the Acceleration element; on species interaction and response of microbial ecology to contamination in the Community Dynamics and Microbial Ecology element; and in understanding microbial processes for altering the chemical state of metallic and radionuclide contaminants through the Biotransformation and Biodegradation element. In analogy with the Ethical, Legal, and Social Implications component of the Human Genome program, the Bioremediation and its Societal Implications and Concerns component of NABIR is exploring societal issues surrounding bioremediation research and promoting open and two-way communication with affected stakeholders to help ensure understanding and acceptance of proposed solutions to remediating contaminants. The research in the Systems Integration, Prediction, and Optimization element is focused on defining and developing an integrative model to aid collaboration and direction across research teams within the NABIR program. All NABIR elements and EMSL activities have a substantial involvement of academic scientists.

Within Facility Operations, support of the operation of the EMSL national user facility is provided for basic research that will underpin safe and cost-effective environmental remediation methods and technologies and other environmental science endeavors. Unique EMSL facilities, such as the Molecular Science Computing Facility, the High-Field Mass Spectrometry Facility, and the High-Field Magnetic Resonance Facility, are used by the external scientific community and EMSL scientists to conduct a wide variety of molecular-level environmental science research, including improved understanding of chemical reactions in DOE's underground storage tanks, transport of contaminants in subsurface groundwater and vadose zone sediments, and atmospheric chemical reactions that contribute to changes in the atmospheric radiative balance.

BER's William R. Wiley Environmental Molecular Sciences Laboratory will use its capabilities to expand its collaborations in the areas of structural biology and functional genomics. The number of users undertaking structural biology research also will increase.

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
Bioremediation Research	31,908	26,338	26,911	+573	+2.2%
Clean Up Research............................	1,846	1,556	2,463	+907	+58.3%
Facility Operations	28,816	31,054	34,054	+3,000	+9.7%
Waste Management	1,200	1,197	1,200	+3	+0.3%
SBIR/STTR	0	1,316	1,509	+193	+14.7%
Total, Environmental Remediation	63,770	61,461	66,137	+4,676	+7.6%

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Bioremediation Research...	**31,908**	**26,338**	**26,911**
NABIR and Bioremediation Research	**25,952**	**20,371**	**20,931**

NABIR will increase the understanding of the intrinsic bioremediation (natural attenuation) of DOE relevant metal and radionuclide contaminants, as well as of manipulated, accelerated bioremediation using chemical amendments. Laboratory and field experiments will be conducted to understand the fundamental mechanisms underlying chemical processes, complexation/transformation of contaminants, and microbial transport. The Field Research Center is in operation at the Oak Ridge National Laboratory. Field site characterization of the first NABIR Field Research Center and distribution of research samples to investigators will continue. In FY 2002, funding will increase support focused field research at the NABIR Field Research Center. Science elements in the NABIR program include fundamental research in the following subjects: (1) Biotransformation and Biodegradation (microbiology to elucidate the mechanisms of biotransformation and biodegradation of complex contaminant mixtures); (2) Community Dynamics and Microbial Ecology (ecological processes and interactions of biotic and abiotic components of ecosystems to understand their influence on the degradation, persistence, mobility, and toxicity of mixed contaminants); (3) Biomolecular Science and Engineering (molecular and structural biology to enhance the understanding of bioremediation and improve the efficacy of bioremedial organisms and identify novel remedial genes); (4) Biogeochemical Dynamics (dynamic relationships among *in situ* geochemical, geological, hydrological, and microbial processes); (5) Assessment (measuring and validating the biological and geochemical processes of bioremediation); (6) Acceleration (flow and transport of nutrients and microorganisms, focused on developing effective methods for accelerating

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

and optimizing bioremediation rates); and (7) System Engineering, Integration, Prediction, and Optimization, (conceptual and quantitative methods for describing community dynamics, biotransformation, biodegradation, and biogeochemical processes in complex geologic systems). University scientists continue to form the core of the NABIR science team that networks with the broader academic community as well as with scientists at the National Laboratories and at other agencies.

The NABIR Field Research Center at Oak Ridge was started in FY 2000. To make the Center operational, initial activities will address laboratory and logistical infrastructure, characterize the subsurface water flow and contaminant transport, and model the flow, transport, and biogeochemistry so that appropriate sites and procedures can be selected for the initial experiments. Initial results will be published in FY 2002 and will help determine the efficacy of removing nitrate and injecting electron donors to precipitate and, therefore, immobilize uranium. The NABIR program will take advantage of the newly completed genomic sequence of three important metal and radionuclide-reducing microorganisms to understand the regulation and expression of genes that are important in bioremediation. Knowledge of the regulation of genes involved in metal-reduction, such as the cytochromes, will determine the effect of co-contaminants, such as nitrate or other metals and radionuclides on the ability of microorganisms to immobilize the metals and radionuclides. Researchers working on *Geobacter sulfurreducens*, *Desulfovibrio vulgaris,* and *Shewanella oneidiensis* will be able to use the genetic sequence and laboratory techniques such as micro-arrays to determine the enzymatic pathways for the reduction of uranium.

Performance will be measured by demonstrating that uranium concentrations in groundwater can be measurably decreased using bioremediation at the Field Research Center.

General Plant Projects (GPP)	**4,692**	**4,800**	**4,811**

The General Plant Projects (GPP) funding is for minor new construction, other capital alterations and additions, and for buildings and utility systems such as replacing piping in 30 to 40-year old buildings, modifying and replacing roofs, and HVAC upgrades and replacements. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. This subprogram includes landlord GPP funding for Pacific Northwest National Laboratory (PNNL) and for Oak Ridge Institute for Science and Education (ORISE). The total estimated cost of each GPP project will not exceed $5,000,000.

The enhanced effort will accelerate rehabilitation and upgrade research facilities in the 300 area of the PNNL, including beginning the replacement of sanitary water piping in a 40 year old building used for research, refurbishing 20-year old laboratory space, and reconfiguring space in a 45 year old building to better accommodate current scientific research projects.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
General Purpose Equipment (GPE)	**1,264**	**1,167**	**1,169**

The General Purpose Equipment (GPE) funding will continue to provide general purpose equipment for PNNL and ORISE such as updated radiation detection monitors, information system computers and networks, and instrumentation that supports multi-purpose research.

Clean Up Research	**1,846**	**1,556**	**2,463**

The modest program in clean up research will be restored to characterize the geologic, chemical, and physical properties that affect the rate and effectiveness of a variety of environmental remediation and waste-stream cleanup methods, including bioremediation.

New research will support laboratory and field studies at universities and DOE laboratories to identify and characterize the biophysical and chemical properties of environmental pollutants in contaminated environments and waste streams, especially how those properties influence the efficacy of various remediation and waste-stream cleanup methods. In FY 2002, research in in-situ approaches is enhanced to focus on challenging problems of mixed wastes containing complex mixtures of organic wastes, metals, and radionuclides.

Much of this research will be conducted in collaboration with efforts undertaken by the Science and Technology element of the DOE Office of Environmental Management (EM) including the Environmental Management Science Program (EMSP) that is jointly managed by EM and SC.

Facility Operations: William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)	**28,816**	**31,054**	**34,054**
Operating Expenses	**26,835**	**26,604**	**32,065**

The EMSL is a scientific user facility focused on conducting interdisciplinary, collaborative research in molecular-level environmental science. Operating funds are essential to allow the EMSL to operate as a user facility, and are used for maintenance of buildings and instruments, utilities, staff support for users, environment, safety and health compliance activities, and communications. With over 100 leading-edge instruments and computer systems, the EMSL annually supports approximately 1000 users. University scientists form the core of the EMSL science team that networks with the broader academic community as well as with scientists at other agencies. EMSL users have access to unique instrumentation for environmental research, including the 512-processor, high performance computer system, a suite of nuclear magnetic resonance spectrometers ranging from 300 MHz to 800 MHz, a suite of mass spectrometers, including an 11.5 Tesla high performance mass spectrometer, laser desorption and ablation instrumentation, ultra-high vacuum scanning tunneling and atomic force microscopes, and controlled atmosphere environmental chambers.

Increased funding in FY 2002 ($5,461,000) will be used to lease and operate a 2 to 3 teraflop high performance computer for the EMSL to replace its current ¼ teraflop computer, which is no longer effective for leading edge computation studies in the environmental molecular sciences. The new high performance computer will be used for theoretical studies, model code development in molecular geochemistry and biogeochemistry, and numerical modeling of reactive transport in the subsurface, chemical processing and catalysis, aerosol formation and chemical transformations and

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

climate modeling and simulation. The computer will also greatly assist the EMSL focus on structural genomics.

Performance will be measured by (1) an expansion of the EMSL's collaboratory capabilities to two additional instruments, and (2) unscheduled operational downtime on EMSL instrumentation and computational resources will not exceed 10 percent.

	FY 2000	FY 2001	FY 2002
Capital Equipment	**1,981**	**4,450**	**1,989**

Capital equipment support for the EMSL enables instrument modifications needed by collaborators and external users of the facility as well as the purchase of state-of-the-art instrumentation to keep EMSL capabilities at the leading edge of molecular-level scientific research. Increased capital equipment funding ($3,000,000) in FY 2001 supported the upgrade of user capabilities through the acquisition of additional mass spectrometers and Nuclear Magnetic Resonance (NMR) spectrometers for structural biology research.

	FY 2000	FY 2001	FY 2002
Waste Management	**1,200**	**1,197**	**1,200**

Provides for packaging, shipping, and disposition of hazardous, radioactive, or mixed waste generated at Pacific Northwest National Laboratory in the course of normal operations. These activities were funded by Environmental Management prior to FY 2001.

	FY 2000	FY 2001	FY 2002
SBIR/STTR	**0**	**1,316**	**1,509**

In FY 2000 $1,430,000 and $86,000 were transferred to the SBIR and STTR programs, respectively. FY 2001 and FY 2002 amounts are the estimated requirements for the continuation of these programs.

	FY 2000	FY 2001	FY 2002
Total, Environmental Remediation	**63,770**	**61,461**	**66,137**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Bioremediation Research	
Increase in support for focused field research at the NABIR Field Research Center. .	+560
Continue GPP funding at FY 2001 level.	+11
Continue GPE funding at FY 2001 level.	+2
Total, Bioremediation Research	+573
Clean Up Research	
Clean up research on in-situ approaches is being enhanced to focus on challenging problems of in situ cleanup of mixed wastes containing complex mixtures of organic wastes, metals, and radionuclides	+907
Facility Operations	
Increase will support the lease and operation of a 2 to 3 teraflop computer ($5,461,000) for the EMSL to play a significant role in molecular modeling and structural genomics	+5,461
Decrease due to one-time FY 2001 Capital Equipment funding for mass spectrometers and Nuclear Magnetic Resonance (NMR) spectrometers at EMSL.	-2,461
Total, Facility Operations	+3,000
Waste Management	
Continue Waste Management program at FY 2001 level.	+3
SBIR/STTR	
SBIR/STTR increases due to increase in research funding for cleanup research.	+193
Total Funding Change, Environmental Remediation	+4,676

Medical Applications and Measurement Science

Mission Supporting Goals and Objectives

The modern era of nuclear medicine is an outgrowth of the original charge of the Atomic Energy Commission (AEC), "to exploit nuclear energy to promote human health." From the production of a few medically important radioisotopes in 1947, to the development of production methods for radiopharmaceuticals used in standard diagnostic tests in millions of patients throughout the world, to the development of ultra-sensitive diagnostic instruments, e.g. the PET (positron emission tomography) scanner, the medical applications program has led and continues to lead the field of nuclear medicine.

Today the program seeks to develop new applications of radiotracers in diagnosis and treatment in light of the latest concepts and developments in genomic sciences, structural and molecular biology, computational biology and instrumentation. Using non-invasive technologies and highly specific radiopharmaceuticals, BER is ushering in a new era of brain mapping, and highly specific disease diagnostics. New tools will enable the real-time imaging of gene expression in a developing organism.

Research capitalizes on the national laboratories' unique resources and expertise in biological, chemical, physical, and computational sciences for technological advances related to human health. The national laboratories have highly sophisticated instrumentation (neutron and light sources, mass spectroscopy, high field magnets), lasers and supercomputers, to name a few, that directly impact research on human health. Research is directed to fundamental studies in medical imaging, biological and chemical sensors, laser medicine and informatics. This research is highly complementary to and coordinated with clinical research at the National Institutes of Health (NIH) and to basic research in the NIH intramural and extramural programs.

Measurement Science research emphasizes new sensor instrumentation for cleanup efforts and new imaging instrumentation for the life sciences, including Genomes to Life, and having broad medical applications.

The Medical Applications and the Measurement Science subprogram continues a substantial involvement of academic scientists along with the scientists in the national laboratories.

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
Medical Applications	63,104	88,138	43,872	-44,266	-50.2%
Measurement Science	5,265	5,626	5,961	+335	+6.0%
SBIR/STTR	0	2,624	1,326	-1,298	-49.5%
Total, Medical Applications and Measurement Science	68,369	96,388	51,159	-45,229	-46.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Medical Applications	**63,104**	**88,138**	**43,872**
Boron Neutron Capture Therapy (BNCT)	**9,662**	**10,454**	**10,041**

In FY 2002, funding is decreased as the followup of all patients treated in the human clinical trials of boron neutron capture therapy (BNCT) at Brookhaven National Laboratory and the Massachusetts Institute of Technology is completed. These analyses will complete BER's assessment of the maximum safe dosages of boron compounds and neutron radiation.

Working with the National Institutes of Health and the National Cancer Institute, basic research on BNCT will evolve into a new program of innovative approaches to cell-targeted ablation therapy for cancer with in-vivo radiation techniques. Success of the program will depend on key partnerships with scientists from the national laboratories and academia. The emphasis of this new program will be on the therapeutic use of ionizing radiation that may be achieved with radionuclide therapy or techniques such as boron neutron capture therapy. The specific goals include the development of novel ligands and delivery techniques to target and treat cancer at the cellular level. Research will address such complex challenges as chemical ligand synthesis, tumor targeting, and dosimetry.

Overall program objectives include: (1) techniques to ensure highly selective tumor targeting by the proposed ligands; (2) efficient screening techniques for selecting candidate ligands for in-vivo testing; (3) research suggesting a reasonable likelihood of success for in-vivo targeting of primary tumors and their metastases in pre-clinical animal trials; (4) reliable approaches for dosimetry calculations to normal tissues and to tumor sites based on 3-dimensional modeling; (5) measurement techniques for accurately assessing the success of tumor targeting in vivo; and (6) measurement techniques for assessing therapy effects in vivo at the molecular, cellular and metabolic levels.

Performance will be measured by the number of tumor ligands that perform sufficiently well in pre-clinical evaluations to deserve consideration for clinical trials by NIH and/or private industry.

Radiopharmaceutical Design and Synthesis..................................	**20,753**	**26,637**	**24,445**

BER will support research on radiopharmaceutical design and synthesis using concepts from genomics as well as computational biology and structural biology. BER will continue research into radiolabeling of monoclonal antibodies for cancer diagnosis and new radiotracers for the study of brain and heart function. Molecules directing or affected by homeostatic controls always interact and, thus, are targets for specific molecular substrates. The substrate molecules can be tailored to fulfill a specific need and labeled with appropriate radioisotopes to become measurable in real time in the body on their way to, and in interaction with their targets, allowing the analysis of molecular functions in the homeostatic control in health and disease. The function of radiopharmaceuticals at various sites in the body is imaged by nuclear medical instruments, such as, gamma ray cameras and positron emission tomographs (PET). This type of imaging refines diagnostic differentiation between health and disease at the molecular/metabolic levels, and among various diseases, such as of the heart, brain and cancer, often leading to more effective therapy. If labeled with high energy-emitting radioisotopes, the substrate molecules, carrying the radiation dose may be powerful tools for targeted

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

molecular therapy especially of cancer. **Performance will be measured** by the successful development of unique radiopharmaceutical tracers that will enable PET medical imaging to more precisely diagnose neuro-psychiatric illnesses (Alzheimer's Disease, Parkinson's Disease, multiple sclerosis, and others) and cancer in humans. This research is closely coordinated with the NIH Institutes of Drug Abuse, of Mental Health and of Neurological Disorders and Stroke.

BER will also develop nuclear medicine driven technologies to image mRNA transcripts in real time in tissue culture and whole animals. Currently the expression of endogenous genes in animals (including humans) cannot be imaged, at least not directly. However, given the astounding pace of biotechnology development, such imaging may be highly challenging but not an unattainable goal. This research includes an emphasis on nucleic acid biochemistry, radioligand synthesis and macromolecular interactions. It addresses the functional consequences of gene expression by targeting and perturbing the activity of a particular gene in living cells or animals. It also develops biological applications of optical and radionuclide imaging devices, all contributing to the goal of imaging specific gene expression in real time in both animals and humans. Methods such as combinatorial chemistry techniques will be used to develop antisense radiopharmaceuticals that hybridize DNA probes to RNA transcripts in highly specific ways to block their activity or function. Molecular signal amplification methods that work in vivo at the mRNA level will be developed. Drug targeting technology will be developed to such an extent that the various biological barriers can be safely surmounted in vivo. The research will evaluate the clinical potential of real-time imaging of genes at work in cells, tissues, and whole organisms, including people. This information will have applications ranging from understanding the development of a disease to the efficacy of treatments for the disease and will strongly impact developmental biology and genome research, including the Genomes to Life program, and medical sciences. **Performance will be measured** by the successful development of innovative methods and instrumentation to image gene expression in real time in cells, tissues and whole organisms.

In FY 2001, Congressional Direction provided a one-time increase for molecular nuclear medicine. The increase provided infrastructure support for molecular biology and molecular nuclear medicine.

Multimodal Imaging Systems and Medical Photonics	**5,043**	**9,922**	**9,386**

In FY 2002, BER will decrease support in multimodal imaging systems for study of human brain function and explore the combination of nuclear medicine imaging systems with magnetic resonance imaging. The research will continue to develop innovative imaging instrumentation and will transfer the relevant technology into clinical medicine. Capital equipment funds will develop new instrumentation such as a PET camera for small animal imaging. The program will continue to support research in brain imaging including substance abuse, mental illness, Parkinson's disease, Alzheimer's disease, and studies of neurochemical metabolism. **Performance will be measured** by the enhancement of micro-PET and micro-CT scanners so that these unique and powerful tools can be used to enhance basic biomedical research in medical centers, leading to improved human health care.

(dollars in thousands)

FY 2000	FY 2001	FY 2002

BER will also expand its research program at the national laboratories in capitalizing on their unique resources and expertise in the biological, physical, chemical, and computational, sciences to develop new research opportunities for technological advancement related to human health. Due to the medical nature of the program, all research activities are partnerships between national laboratories and medical research centers. The program emphasizes biomedical imaging, novel sensing devices, spectroscopy, and related informatics systems. It will advance fundamental concepts, create knowledge from the molecular to the organ systems level, and develop innovative processes, instruments, and informatics systems to be used for the prevention, diagnosis, and treatment of disease and for improving health care in the Nation. An emphasis is placed on:

Biomedical Imaging – is the development of novel medical imaging systems. Emphasis is placed on combining optical imaging with other traditional medical imaging systems such as MRI, PET, and SPECT and on the development of small imaging systems that image in real-time under natural physiological conditions. A major objective is improvement of the reliability and cost-effectiveness of medical imaging technologies. The BER program has played a leading role in the development of new positron emission tomography (PET) instrumentation as well as new chemistries for applying PET to diagnosis of cancer and other diseases. A high priority is placed on transfer of the new PET technologies into clinical research and practice.

Medical Photonics – is the development of advanced optical systems, including lasers, that will enhance the monitoring, detection, and treatment of disease.

Smart Medical Instrumentation – is the development and fabrication of “smart” medical instruments that can operate within the body either remotely or independently to monitor, detect, and treat various medical dysfunctions. This includes the development and fabrication of biological sensors that can be used to detect or monitor various physiological functions and disease in situ in real-time.

The ultimate goal of the program is to support basic research and technology development that will ultimately lead to the development of technology that can be transferred to the National Institutes of Health for clinical testing or to industry for further commercial development. This research is highly complementary to and coordinated with clinical research at the National Institutes of Health (NIH) and to basic research in the NIH intramural and extramural programs

Performance will be measured as follows: in close partnership with NIH, develop novel technology and instrumentation to image single molecules, genes, cells, organs, and whole organisms in real time under natural physiological conditions with a high degree of precision, including MIR, PET, and SPECT. Technology and detector systems will be developed to capitalize on recent findings of the human genome project that will enable imaging of gene expression in real time which will have a critical impact on biomedical research and medical diagnosis.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Congressional Direction	**27,646**	**41,125**	**0**

Congressional direction in FY 2000 for Gallo Institute of the Cancer Institute of New Jersey; City of Hope National Medical Center; National Foundation for Brain Imaging; University of Missouri Research Reactor; North Shore Long Island Jewish Health System; Burbank Hospital Regional Center; Midwest Proton Radiation Institute; Medical University of South Carolina Cancer Research Center; Center for Research on Aging at Rush Presbyterian St. Lukes Medical Center; University of Nevada Las Vegas Cancer Complex; Science Center at Creighton University; and the West Virginia National Education and Technology Center. Congressional direction in FY 2001 for School of Public Health, University of South Carolina; Nuclear Medicine and Cancer Research Capital Program, University of Missouri-Columbia; Discovery Science Center in Orange County, California; Children's Hospital Emergency Power Plant in San Diego; Center for Science and Education at the University of San Diego; Bone Marrow Transplant Program at Children's Hospital Medical Center Foundation in Oakland, CA; North Shore Long Island Jewish Health System, New York; Museum of Science and Industry, Chicago; Livingston Digital Millenium Center, Tulane University; Center for Nuclear Magnetic Resonance, University of Alabama-Birmingham; Nanotechnology Engineering Center at the University of Notre Dame of South Bend, Indiana; National Center for Musculoskeletal Research, Hospital for Special Surgery, New York; High Temperature Super Conducting Research and Development, Boston College; Positron Emission Tomography Facility, West Virginia University; Advanced Medical Imaging Center, Hampton University; Child Health Institute of New Brunswick, New Jersey; Linear Accelerator for University Medical Center of Southern Nevada; Medical University of South Carolina Oncology Center; National Foundation for Brain Imaging; Science and Technology Facility at New Mexico Highlands University; and Inland Northwest Natural Resources Research Center at Gonzaga University.

Measurement Science	**5,265**	**5,626**	**5,961**

BER will continue research on new sensor instrumentation for characterizing the chemical composition of contaminated subsurface environments in support of the Department's environmental cleanup efforts of highly radioactive chemical wastes. **Performance will be measured** by the development of new environmental sensors that are better, faster, and cheaper than existing laboratory techniques. New field-based sensors that take advantage of novel biotechnologies will be ready for deployment. The new sensors will include antibody and nucleic acid approaches that have precedence in other applications but will be new to bioremediation at DOE legacy sites.

Research into new imaging instrumentation for life sciences and biomedical sensor applications will be continued. Capital equipment funds will be increased in FY 2002 for research to develop new instrumentation for the life sciences, including Genomes to Life and having broad medical applications. BER will continue research on medical applications of laser technology at the national laboratories and at universities.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
SBIR/STTR	**0**	**2,624**	**1,326**

In FY 2000, $1,533,000 and $90,000 were transferred to the SBIR and STTR programs, respectively. FY 2001 and FY 2002 amounts are the estimated requirements for the continuation of these programs.

Total, Medical Applications and Measurement Science	**68,369**	**96,388**	**51,159**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Medical Applications	
Boron Neutron Therapy (BNCT) program is decreased	-413
The infrastructure support for molecular biology and molecular nuclear medicine has been successfully completed	-2,192
Decrease in Multimodal Imaging Systems is a result of a redirection in the Nuclear Medicine program	-536
Decrease due to Congressional Direction in FY 2001.	-41,125
Total Funding Change, Medical Applications	-44,266
Measurement Science	
Measurement Science will increase capital equipment funding to develop new instrumentation for the life sciences, including Genomes to Life and having broad medical applications..	+335
SBIR/STTR	
Decrease in SBIR/STTR as overall research program decreased with completion of Congressional direction.	-1,298
Total Funding Change, Medical Applications and Measurement Science	-45,229

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Construction

Mission Supporting Goals and Objectives

Construction is needed to support the research under the Biological and Environmental Research Program (BER) program. Cutting-edge basic research requires that state-of-the-art facilities be built or existing facilities modified to meet unique BER requirements.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Construction	0	2,495	10,000	+7,505	+300.8%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Construction	**0**	**2,495**	**10,000**

The Laboratory for Comparative and Functional Genomics at Oak Ridge National Laboratory will provide a modern gene function research facility to help understand the function of newly discovered human genes, to support DOE research programs and to provide protection for the genetic mutant mouse lines created during the past 50 years. This new facility will replace a 50-year old animal facility with rapidly escalating maintenance costs still in use at Oak Ridge. **Performance will be measured** by BER successfully managing the development and upgrade of the Laboratory for Comparative and Functional Genomics at ORNL on schedule and within cost.

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Construction	
Continue construction of the Laboratory for Comparative and Functional Genomics at the approved funding profile level.	+7,505

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	4,692	7,794	4,811	-2,983	-38.3%
Capital Equipment	13,960	22,702	17,633	-5,069	-22.3%
Total Capital Operating Expenses	18,652	30,496	22,444	-8,052	-26.4%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Unapprop-riated Balance
01-E-300, Laboratory for Comparative and Functional Genomics, ORNL	13,900	0	0	2,495	10,000	1,405
Total, Construction		0	0	2,495	10,000	1,405

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	Acceptance Date
DNA Repair Protein Complex Beamline, ALS	4,490	0	0	4,490	0	FY 2001
Total, Major Items of Equipment		0	0	4,490	0	

01-E-300, Laboratory for Comparative and Functional Genomics, Oak Ridge National Laboratory, Oak Ridge, Tennessee

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 2001 Budget Request *(Preliminary Estimate)*	1Q2001	3Q2001	3Q2001	1Q2004	13,900	14,420

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2001	2,495	2,495	2,175
2002	10,000	10,000	6,980
2003	1,405	1,405	4,550
2004	0	0	195

3. Project Description, Justification and Scope

The Laboratory for Comparative and Functional Genomics (LCFG) will provide a modern gene function research facility to support Department of Energy research programs and provide protection for the genetic mutant mouse lines created during the past 50 years. The LCFG will replace the deteriorated mouse housing-facility located at the Y-12 Weapons Plant on the Oak Ridge Reservation to meet these programmatic needs.

The current Biology facilities are fifty years old and the buildings and building systems are in need of major upgrades which include asbestos abatement, roof replacement, HVAC replacement, underground utility system replacement, electrical systems upgrade, and exterior repairs to the building. Animal care accreditation depends on improving the housing conditions. The LCFG will provide cost-effective housing for the experimental animals that are vital to the next phase of the Genome program. It will be designed for efficient utilization of space and will be energy efficient and easy to maintain. It will accommodate the entire DOE live mutant mouse colony in Oak Ridge, which will be reduced in size by utilizing cryogenic preservation technology. The facility will be designed to permit the establishment of specific pathogen free colonies of mice.

The facility will be a single story building of approximately 32,000 sq.ft. comprised of four functional areas: support, animal housing, quarantine and laboratory support. The heating, ventilation and air-conditioning system will utilize 100% fresh air to achieve 10-15 air changes per hour and maintain temperatures between 68EF and 74EF with humidity levels of 40% to 60%. The system will be capable of maintaining +/- 2EF control in each animal housing room including the quarantine area. The lighting system will be timer controlled with variable intensity level between 130-325 lux. Sound levels will be maintained below 85 decibels. The internal water system will use reverse osmosis or special chlorination treatment to ensure adequate water chemistry. Floor, walls and ceilings will be constructed of durable, moisture-proof, fire-resistant, seamless materials to allow the highest possible levels of sanitation. Non-toxic paints and glazes will be used within the facility. The building will be equipped with silent fire alarm systems.

The building will be equipped with two tunnel washers, two rack washers, two pass-through autoclaves and two bulk autoclaves, a bedding dispenser, bedding disposal system and ventilated animal cage systems equipped with automatic watering. The HVAC system will include a 24-hour monitoring system. Other equipment includes slotted hood vents, down draft tables and surgical lighting in the laboratory support area to support animal procedures.

Site preparation will consist of clearing, grading, and excavating for the new structure; extension of access streets to the site; and landscaping and seeding. Outside utilities will consist of extending the required utilities from the building to the closest, and an adequately sized supply source. Utilities will include steam, sanitary sewers, potable and fire protection water, natural gas, and electricity.

Obligations for FY 2001 will be used to award the Engineer/Procure/Construct Contract (EPCC) with sufficient funds to accomplish the detail design, initiate construction, and to order long-lead items. First year funding will also support project management and inspection of construction.

The researchers and animals are currently housed in facilities at the East end of the Y-12 Weapons Plant. Most of the buildings that have been used for biology were constructed in the late 1940s or early 1950s for other purposes. The building housing the animals has deteriorated with age and cannot be maintained cost effectively and the building systems need to be upgraded to assure continued compliance with accreditation standards for animal research facilities. In addition to being expensive to operate and maintain, the existing facility does not provide a barrier maintenance facility for maintaining immune deficit and other lines of mice that require a pathogen-free environment.

The principle programmatic reasons for constructing the new facility are to ensure adequate, cost effective housing for the national resource embodied in the mutant mouse colony to support the next phase of the Genome Program - the identification of gene function.

In addition, benefits include:

- Enabling the DOE Mammalian Genetics User Facility to more effectively support the national research community and DOE researchers at other institutions.
- Providing substantially more effective collaboration between the Life Sciences Division and other Oak Ridge National Laboratory (ORNL) facilities and Divisions such as Environmental Sciences, Chemical and Analytical Sciences, Solid State, and Computing and Mathematical Sciences Divisions as well as the Center for Computational Sciences.
- Enhancing ORNL's ability to attract first rate young scientists to facilities that represent state-of-the-art laboratories that are cost effective in operation and efficient in the conduct of biological research.
- Facilitating the access for visiting scientists worldwide by eliminating the restrictions stemming from the close proximity of a high-security weapons plant.
- Developing facilities that offer unique resources of the organization and the world-class capabilities of the staff.
- Continuing the contribution to higher education via administration of and participation in the University of Tennessee - Oak Ridge Graduate School of Biomedical Sciences.

4. Details of Cost Estimate [a]

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design Costs (Design, Drawings, and Specifications)	465	N/A
Design Management Costs (0.3% of TEC)	40	N/A
Project Management Costs (0.2% of TEC)	30	N/A
Total, Design Costs (3.8% of TEC)	535	
Construction Phase		
Buildings	7,815	N/A
Utilities	140	N/A
Standard Equipment	3,530	N/A
Inspection, design and project liaison, testing, checkouts and Acceptance	250	N/A
Construction Management (0.6% of TEC)	80	N/A
Project Management (1.2% of TEC)	160	N/A
Total, Construction Costs	11,975	
Contingencies (10% of TEC)		
Design Phase	45	N/A
Construction Phase	1,345	N/A
Total, Contingencies (10% of TEC)	1,390	
Total Line Item Costs (TEC)	13,900	N/A

5. Method of Performance

Detail design, procurement and construction will be accomplished by a fixed price Engineer/Procure/ Construct Contractor (EPCC).

[a] The cost estimate is based on a conceptual design completed in April 1998. The DOE Headquarters escalation rates were used as appropriate over the project life.

6. Schedule of Project Funding

	Prior Years	FY 2000	FY 2001	FY 2002	Outyears	Total
Project Cost						
Facility Cost						
Design	0	0	580	0	0	580
Construction	0	0	1,595	6,980	4,745	13,320
Total, Line item TEC	0	0	2,175	6,980	4,745	13,900
Other project costs						
Conceptual design costs [a]	20	0	0	0	0	20
NEPA documentation costs [b]	0	15	0	0	0	15
Other project related costs [c]	0	485	0	0	0	485
Total, Other Project Costs	20	500	0	0	0	520
Total Project Cost (TPC)	20	500	2,175	6,980	4,745	14,420

[a] A conceptual design report (CDR) was completed in April 1998 at a cost of $20,000.

[b] NEPA for this project is expected to require a NEPA Categorical Exclusion Determination (CXD). Estimated cost is $15,000.

[c] Soil borings and other sampling and documentation associated with site characterization to be completed in FY 2000 at an estimated cost of $60,000. A detailed requirements document (including Design Criteria) and Engineer/ Procure/Construct Contractor (EPCC) selection activities will be completed in FY 2000 at an estimated cost of $340,000. Technical and project management support through FY 2000 are estimated at a cost of $85,000.

7. Related Annual Funding Requirements

	(FY 2004 dollars in thousands)	
	Current Estimate	Previous Estimate
Annual facility operating costs[a]	675	N/A
Facility maintenance and repair costs[b]	130	N/A
Programmatic operating expenses directly related to the facility[c]	740	N/A
Capital equipment not related to construction but related to the programmatic effort in the facility[d]	205	N/A
Utility costs	510	N/A
Other costs[e]	205	N/A
Total related annual funding	2,465	N/A

[a] This includes janitorial and other miscellaneous support services. Approximately five staff years of effort will be required to provide these services. This is approximately $360,000 less than the cost for operating the existing facility. The savings result from having a modern facility with a more functional design.

[b] The FY 1998 facility maintenance and utility cost for the existing ORNL animal housing facilities totaled approximately $1,350,000. Based on experience with functionally comparable buildings at the ORNL site with energy conservation features incorporated in the construction, the estimated maintenance and utilities cost for the proposed facility are approximately $130,000 for maintenance and $510,000 for utilities. Thus, the savings in operating funds is estimated to be nearly $710,000, per year.

[c] The FY 1998 programmatic operating expenses of the existing animal housing facilities were approximately $740,000. This includes funding for animal care support personnel. This level of funding will not increase as a result of the proposed relocation of facilities.

[d] The conduct of modern biological research by the LCFG such as that involved in the Human Genome Project and Structural Biology requires the periodic purchase of capital scientific equipment. Recurring annual cost of capital equipment is approximately $205,000.

[e] The estimated expenditures for programmatic related maintenance are approximately $205,000 per year. This includes funding for three maintenance personnel to perform programmatic related maintenance. The relocation to the proposed facility will result in an estimated savings of approximately $50,000 per year. The new animal support equipment will require a smaller portion of the operating budget for maintenance.

8. Design and Construction of Federal Facilities

All DOE facilities are designed and constructed in accordance with applicable Public Laws, Executive Orders, OMB Circulars, Federal Property Management Regulations, and DOE Orders. The total estimated cost of the project includes the cost of measures necessary to assure compliance with Executive Order 12088, "Federal Compliance with Pollution Control Standards"; section 19 of the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, and the related Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); and the Architectural Barriers Act, Public Law 90-480, and implementing instructions in 41 CFR 101-19.6. This project includes the construction of new buildings and/or building additions; therefore, a review of the GSA Inventory of Federal Scientific Laboratories is required. The project will be located in an area not subject to flooding determined in accordance with the Executive Order 11988.

Basic Energy Sciences

Program Mission

The mission of the Basic Energy Sciences (BES) program – a multipurpose, scientific research effort – is to foster and support fundamental research in materials sciences and engineering, chemical sciences, biosciences, and geosciences to provide the foundations for new and improved energy technologies and for understanding and mitigating the environmental impacts of energy use. As part of its mission, the BES program plans, constructs, and operates major scientific user facilities to serve researchers at universities, national laboratories, and industrial laboratories.

The Research Portfolio

The BES program is one of the Nation's largest sponsors of fundamental research. In FY 2000, the program funded research in more than 150 academic institutions located in 48 states and in 13 Department of Energy (DOE) laboratories located in 9 states. BES supports a large extramural research program, with approximately 40% of the program's research activities sited at academic institutions. This investment in academic research has been a constant fraction of the BES research portfolio for more than a decade.

The BES program also supports outstanding scientific user facilities, providing world-class capabilities for imaging and characterizing materials. Experiments at these facilities are conducted on a host of different samples, including ceramics, metals, and alloys; polymers and soft materials; gases and liquids; and fragile biological specimens and crystals. The BES synchrotron radiation light sources, the neutron scattering facilities, and the electron beam characterization centers represent the largest collection of such facilities supported by a single organization in the world. Annually, 8,000 researchers from universities, national laboratories, and industrial laboratories perform experiments at these facilities. The BES program also supports the vast majority of the federally funded research in the physical sciences at these facilities.

Activities supported by the BES program are a significant part of the national research effort, providing particular strength to the Nation's science enterprise in the physical sciences and in facilities planning, construction, and operation.

DOE's history and mission have played an important role in BES's current position as the Nation's steward and primary user of neutron and x-ray facilities. Historically, neutron sources descended from neutron reactors that were constructed in the early 1940's as part of the U.S. Manhattan Project, an early predecessor of DOE. Similarly, synchrotron facilities stemmed from particle accelerators that were developed for DOE high-energy physics research. Originally constructed for materials sciences research, the BES facilities are now used by a wide variety of scientific disciplines, some far removed from the original vision. Notably about 30% of the users at the synchrotron radiation light sources are structural biologists, a significant increase from only a few percent two decades ago.

Today, spurred by results from the physical sciences and by innovations in accelerator physics, the BES program continues its pioneering role in the development of new instrument concepts and next-generation facilities for "materials science and related disciplines" -- the original motivation for virtually all the BES facilities. A decade or two from now, we expect once again to be surprised by the breadth of disciplines and applications that will thrive at these new facilities.

BES Subprograms

The BES program has four subprograms to address its mission. Research activities within each of the subprograms are strongly coupled to those in the other BES subprograms.

Materials Sciences

The Materials Sciences subprogram supports basic research in condensed matter physics, metal and ceramic sciences, and materials chemistry. This research seeks to understand the atomistic basis of materials properties and behavior and how to make materials perform better at acceptable cost through new methods of synthesis and processing. Basic research is supported in magnetic materials, semiconductors, superconductors, metals, ceramics, alloys, polymers, metallic glasses, ceramic matrix composites, catalytic materials, surface science, corrosion, neutron and x-ray scattering, chemical and physical properties, and new instrumentation. Ultimately the research leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and use. This subprogram is the premier sponsor of condensed matter and materials physics in the U.S., is the primary supporter of the BES user facilities, and is responsible for the construction of the Spallation Neutron Source.

Chemical Sciences

The Chemical Sciences subprogram supports basic research in atomic, molecular and optical science; chemical physics; photochemistry; radiation chemistry; physical chemistry; inorganic chemistry; organic chemistry; analytical chemistry; separation science; and heavy element chemistry. This research seeks to understand chemical reactivity through studies of the interactions of atoms, molecules, and ions with photons and electrons; the making and breaking of chemical bonds in the gas phase, in solutions, at interfaces, and on surfaces; and energy transfer processes within and between molecules. Ultimately, this research leads to the development of such advances as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improved catalysts for the production of fuels and chemicals; and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. This subprogram provides support equal to that of the National Science Foundation for basic research in chemistry. It provides the Nation's primary support for homogeneous and heterogeneous catalysis, photochemistry, radiation chemistry, gas-phase chemical dynamics, and separations and analysis. It is the Nation's sole support for fundamental research in heavy element chemistry.

Engineering and Geosciences

The geosciences activity in the Engineering and Geosciences subprogram supports basic research to understand the Earth's crust, including mineral-fluid interactions; rock, fluid, and fracture physical properties; and new methods and techniques for geosciences imaging from the atomic scale to the kilometer scale. The activity contributes to the solution of problems in multiple DOE mission areas, including reactive fluid flow studies to understand contaminant remediation; seismic imaging for reservoir definition; and coupled hydrologic-thermal-mechanical-reactive transport modeling to predict repository performance. This activity provides one third of the total federal support for individual investigator basic research in solid earth sciences. The engineering activity in the Engineering and Geosciences subprogram is integrated with activities in the materials sciences subprogram and focuses on nanotechnology and microsystems, multicomponent fluid dynamics and heat transfer in materials, and nonlinear systems.

Energy Biosciences

The Energy Biosciences subprogram supports basic research in the molecular and cellular mechanisms to understand the capture and conversion of solar energy via natural photosynthesis. The research defines -- at the molecular level -- the structure, synthesis, and assembly of cellular components involved in the light-driven production of chemical energy. Ultimately, this research will aid the development of renewable biomass resources. This subprogram is the prime provider for molecular research on plants not focussed on traditional crop and agricultural interests and a major supporter of research on microbial systems that have broader importance than the model systems used in the biomedical community. This subprogram is one of the Nation's prime interfaces between bio- and physical sciences, promoting multi- and cross-disciplinary research activities jointly with all of the other BES subprograms.

Program Goal

Maintain U.S. world leadership in areas of materials sciences and engineering, chemical sciences, biosciences, and geosciences relevant to energy efficiency, renewable energy resources, fossil fuels, reduced environmental impacts of energy production and use, science-based stockpile stewardship, and future energy sources.

Program Objectives

- Foster and support world-class, peer-reviewed research in the scientific disciplines encompassed by the BES mission areas, cognizant of DOE needs as well as the needs of the broad national science agenda.
- Provide national and international leadership in select areas of materials sciences and engineering, chemical sciences, biosciences, and geosciences.
- Plan, construct, and operate premier national scientific user facilities for materials research and related disciplines to serve researchers at universities, national laboratories, and industrial laboratories. Operate facilities to the highest standards for scientific productivity, efficiency, user needs, and safety.
- Establish and steward stable, essential research communities and institutions, particularly those for which BES is the Nation's primary or sole support.
- Continue the advanced education and training activities of young scientists to maintain and renew research communities and institutions.
- Manage the operations of the Basic Energy Sciences program to high standards by ensuring that the processes for planning, reviewing, selecting, and managing science projects and programs are sound and based on peer review and merit evaluation.

Evaluation of Objectives

BES evaluates the progress being made toward 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 on a similar process for the laboratory programs and scientific user facilities. New projects are selected by peer review and merit evaluation. In addition, BES regularly conducts external reviews of its construction projects to ensure that they are on time and within budget. Beginning in FY 2001, the Basic Energy Sciences Advisory Committee (BESAC) will evaluate the proposal review and selection process and provide advice on subprogram portfolios on a rotating basis, completing the entire BES program portfolio approximately every three to five years. High-level performance measures are given below; specific performances measures are included within the detailed program justification narratives, as appropriate.

- The overall quality of the research in the BES program will be judged excellent and relevant by external evaluation by peers, and through various forms of external recognition.
- Leadership in key BES 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 BES will be peer reviewed and competitively selected, and will undergo regular peer review merit evaluation.
- BES will keep within 10%, on average, of cost and schedule milestones for upgrades and construction of scientific user facilities, including the construction of the Spallation Neutron Source.
- The BES scientific user facilities will be operated and maintained so that unscheduled operational downtime will be less than 10% of total operating time, allowing nearly 8,000 scientists to conduct experiments on an annual basis.
- BES 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

FY 2000 Honors and Awards

Each year, principal investigators funded by BES win dozens of major prizes and awards sponsored by professional societies and by others. In addition, many are elected to fellowship in organizations such as the National Academy of Sciences, the National Academy of Engineering, and the major scientific professional societies. Paramount among the honors are four Nobel Prizes awarded to BES principal investigators during the 1990s. Selected major prizes and awards for FY 2000 include:

- *From ASM International* — the Materials Science Research Silver Medal
- *From the Alexander von Humbolt Foundation* — the Senior Research Award; the Senior Scientist Award
- *From the American Academy of Microbiology* — Procter and Gamble Award in Applied and Environmental Microbiology
- *From the American Ceramic Society* — the George W. Morey Award; the First-in-Class Award for Ceramographic Competition; Norbert J. Kreidl Award for Young Scholars
- *From the American Chemical Society* — the Arthur C. Cope Scholar Award; Award in Inorganic Chemistry; Award in Chemistry of Materials; Award in Colloid or Surface Chemistry; the George

A. Olah Award in Hydrocarbon or Petroleum; F. A. Cotton Medal; Award for Creative Research in Homogeneous or Heterogeneous Catalysis; Distinguished Service Award in Analytical Chemistry

- *From the American Institute of Chemical Engineers* — the Warren K. Lewis Award; the William H. Walker Award for Excellence in Contributions to Chemical Engineering Literature; the Clarence G. Gerhold Award
- *From the American Physical Society* — the Frank Isakson Prize; two recipients of the Herbert P. Broida Prize; the Oliver E. Buckley Prize for Condensed Matter Physics; James C. McGroddy Prize; and the Wheatley Award
- *From the American Society of Plant Physiologists* — Steven Hales Prize
- *From the American Welding Society* — two recipients of the Davis Silver Medal
- *From the Electrochemical Society* — the David C. Graham Award; the Carl Wagner Award
- *From the Institute for Physical and Chemical Research, Tokyo, Japan* — the Eminent Scientist Award
- *From the International Society for Measurement and Control* — the Arnold O. Beckerman Founder Award
- *From the Materials Research Society* — the Gold Award; the Materials Research Society Medal; the MRS Turnbull Award; the Woody Award; the Von Hippel Award
- *From the Minerals, Metals and Materials Society* — the Young Leader Program; the Acta Metallurgica Gold Medal; the John Bardeen Award
- *From the National Institute for Materials Center* — the Center for Excellence Award
- *From R&D Magazine* — R&D 100 Awards for:

  X-ray scanning microprobe, which focuses hard x-rays to a spot size of less than 150 nanometers.

  Differentially deposited x-ray microfocus mirrors, which efficiently focus monochromatic and broad-bandpass x-rays to a submicron spot.

  Combinatorial Synthesis, which permits the acceleration of the discovery of new materials with improved properties.

  ANDE-Advances Nondestructive Evaluation System, which uses ultrasonic interferometry for examining the contents of sealed containers.

- *From the Society of Automotive Engineers* — the Lloyd L. Withrow Distinguished Speaker Award

Three principal investigators were elected to the National Academy of Sciences, and four were elected to the National Academy of Engineering. Two principal investigators were advanced to fellowship in the American Association for the Advancement of Science; two in the American Ceramic Society; seventeen in the American Physical Society; one in the American Welding Society; two in the ASM International; and two in the American Vacuum Society.

Finally, principal investigators served in numerous elected offices including: President-elect, American Ceramic Society; Director, Microbeam Analysis Society; Vice Chair, Division of Materials Physics, American Physical Society; Council, Materials Research Society; Council of Fellow, ASM International; Chair, Materials Research Society; National Program Chair, American Chemical Society; Vice Chair, Fellows Selection Panel of the American Welding Society; Secretary, Vacuum Metallurgy Division, IUVSTA; and Foreign Member, Royal Academy of Engineering.

SELECTED SCIENCE ACCOMPLISHMENTS

Materials Sciences

- **Magnetism at the atomic scale.** When information is written to a computer hard drive, local magnetic moments associated with atoms in a small region of the surface reverse direction like sub-microscopic compass needles. A new theory has helped explain these dynamical processes. This work recently received the Gordon Bell Award for the fastest real supercomputing application and was named to the Computerworld Smithsonian 2000 collection for being the first supercomputing application to surpass one teraflop.
- **Functional nanostructured materials that replicate natural processes.** A newly developed class of nanostructured materials can selectively filter molecules by their size and chemical identity. These remarkable materials are made from a solution of molecular building blocks that spontaneously arrange themselves into a porous solid as the solvent evaporates. This achievement involved creating the self-organizing precursors, controlling the pore size, and employing a novel evaporation process that promotes self-assembly. These materials hold the promise for significant applications. For example, in the future we may wear "breathing" fabrics that block hazardous chemicals while admitting benign species like oxygen.
- **The Library of Congress on a single disk?** The vision that information can be written and erased near the single molecule limit has been realized for the first time. Disordering and re-ordering tiny regions of a thin film show promise for storing a million times more information than with today's computer disks with no increase in space. The film is made of organic material and supported by graphite. It is so thin that 40,000 layers would be only as thick as a sheet of paper. By exposing the film to voltage pulses with a scanning tunneling microscope, nanometer-sized regions can be switched from crystalline to disordered, increasing their ability to conduct electricity by 10,000 times. Each tiny region is one bit of information, not much bigger than a single molecule of the film.
- **Analyses of nanocrystals using coherent (laser-like) synchrotron radiation.** A powerful new x-ray diffraction method for characterizing the structure of nanocrystalline solids has been developed. Tailoring nanocrystalline properties for specific applications depends critically on detailed knowledge of three-dimensional structure. Traditional x-ray diffraction methods are inadequate; however, coherent x-ray diffraction patterns of gold nanocrystals show surface facets, fringes due to interference among facets, nanocrystal lattice distortion, and, ultimately, equilibrium nanocrystal shape.
- **Ion-implantation for strong metal-ceramic bonds**. Ceramics are hard and corrosion resistant but fracture easily. Metals resist fracture but are not as wear or corrosion resistant as ceramics. Coating a metal with a ceramic is a way to improve both. However, current coating technologies can degrade the performance of metals. A new approach has been successfully developed that employs ion-beam intermixing of the coating with the metal from collision cascades, which are microscopic (nanometer-sized) "hot-zones" formed along the ion track. Since the heating in collision cascades is very short and localized, macroscopic heating of the metal does not occur. A patent has been filed using this new approach to improve hip, knee, and dental prosthetic devices. Ion implantation is used to coat the bone mineral (hydroxyapatite) on titanium starting with a high density layer bonded well to the

titanium and changing progressively toward a porous bone mineral outer surface that promotes bone growth and bonding to bone.

- **Long-term storage of plutonium.** Worldwide, nuclear energy production and defense programs have created 1,350 metric tons of plutonium. Because plutonium is radiotoxic and has a long half-life (24,500 years), a long-term storage solution must immobilize plutonium in materials that are resistant to radiation damage for millennia. Using heavy-ion irradiation, advanced characterization techniques, and computer simulation methods, researchers have discovered that highly durable gadolinium zirconate can lock plutonium into its structure while remaining resistant to radiation damage for millions of years.

- **Boron doping of silicon semiconductor devices -- faster, lower-power computing.** Boron doping of silicon improves electrical conductivity and other important aspects of silicon device performance. A fifty-fold increase in active boron doping -- far above nature's maximum of 0.01% -- has been achieved using a new process involving atomic hydrogen. Resulting ultra-highly doped silicon layers provide self-aligned "metallic" contacts, improve semiconductor devices, eliminate etching steps in device fabrication, reduce manufacturing costs, and minimize the use of toxic etching gases and chemicals.

- **Seeing electrons.** A novel, quantitative, and highly sensitive method has been developed to image and measure the distribution of valence electrons, which are responsible for chemical bonding and the transport of electrical charge in solids. This new technique, combining imaging and diffraction in the electron microscope, was used to reveal the spatial distribution of valence electrons in complex structures of high-temperature superconductors. The ability to directly observe and measure valence electron distributions with atomic scale resolution will greatly help in the search for better superconductors, ferroelectrics, and semiconductors.

- **Fluctuation microscopy.** Fluctuation microscopy, a new discovery, challenges the common perception that glassy materials have no organization. Fluctuation microscopy relies on the ability of the electron microscope to measure diffraction from tiny volumes (~1000 atoms). It is based on detailed computational simulations coupled with computer-assisted statistical analysis of multiple electron images. It has required development of advanced image-detection methods. In one of the first applications of this method, studies of amorphous silicon and germanium show that both are highly organized over distances of tens of atoms, even though other measurement techniques see these atoms as completely random. This finding is critical to improving the ability of amorphous solar cells.

- **A smart transistor.** A breakthrough in developing the world's smartest transistor has been accomplished. Germanium-based transistors using a new ferroelectric dielectric would be "smart" devices capable of remembering their state. The heart of this new scientific advance is the understanding of the relationship between polarization and microstructure and how to control it. This breakthrough offers enormous potential for energy savings in a myriad of electronic sensors and devices as no power is necessary to maintain a given on/off state. A low-power, gigabyte chip could thus serve as a computer hard drive.

- **Design of semiconductors with prescribed properties**. A theoretical method has been invented by which one can first specify the properties desired in a semiconductor and then work backward to predict the structure of the material that will show those properties. This work was featured in *Fortune Magazine*.

Chemical Sciences

- **Direct measurement of chemical reactions in turbulent flows.** Long known for their dramatic advancements in laser instrumentation for monitoring gas-phase reactions and chemically reacting flows, scientists at the Combustion Research Facility have for the first time monitored multiple flame species directly and simultaneously. These measurements provide a powerful test of combustion models that could lead to improved combustion efficiency.
- **Dynamics of single molecules.** Reactions of single molecules have been observed by monitoring molecular fluorescence using newly developed experimental methods, thus separating the effects of the motion of one molecule from the ensemble motion of the molecule in its environment. The dynamics of a single molecule have been shown to be significantly different from motion in an ensemble, and should lead to the development of new theories for predicting chemical reactivity.
- **Blinking quantum dots.** 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, has potential applications for optical logic and photonics and may one day lead to nano-scale computers and/or portable analytical instrumentation.
- **Generation of laser-like x-ray beams.** Combining state-of-the-art ultrafast laser systems with evolutionary computer algorithms has led to a dramatic new demonstration of the controlled generation of coherent x-rays. This represents an important new source of ultrafast, coherent soft x-rays for studies of materials properties and chemical physics.
- **Biomolecular photobatteries.** Voltages have been measured from a single photosynthetic reaction center -- the five nanometer wide molecular structure in green plants that captures solar energy and converts it into electrical energy. The reaction center may be thought of as a tiny photobattery. The reaction center functions as nanometer-sized diodes with possible applications to molecular scale logic devices and computers.
- **Radiation induced chemistry.** Solid particles have been found to enhance the effects of water radiolysis and the resulting production of hydrogen. Furthermore, gas bubbles form on the particles and that impedes the continuous, safe release of hydrogen from the suspension. These results may provide an explanation for the “burps” in storage tanks containing aqueous suspensions and radioactive material.
- **Plutonium chemistry in the environment**. Using newly constructed beamlines at the BES synchrotron radiation light sources, scientists are now able to study small quantities of radioactive materials. X-ray absorption studies on plutonium-containing soils from Rocky Flats revealed that the plutonium is predominantly present as the solid oxide, PuO_2, a form substantially less mobile in soil and ground water than other possible forms. This result demonstrates that the plutonium will remain stable and has led to substantial cleanup cost savings.
- **Actinide supramolecular complexes**. Researchers have for the first time built a supramolecular actinide complex. Supramolecular complexes are molecules that are built from smaller subunits, yet retain their own distinct molecular properties. While there may be future applications in separation science and catalysis, the current worldwide effort in supramolecular chemistry is to understand the principles that govern assembly of such molecules.
- **Molecular theory of liquids**. A molecular theory for the liquid state, which has eluded scientists for years, has now been developed. This provides new opportunities in one of the most important areas

for process engineering and one of its most perplexing problems - the prediction of liquid-gas equilibria based on the well-known properties of molecules.

Engineering and Geosciences

- **Engineering at the nanoscale.** Using nanoscale devices in real-world engineered systems is one of the greatest challenges facing nanoscale research. A portfolio of research activities explores how to engineer at the nanoscale. Recent activities include the development of physics-based models to represent crack initiation as a nanoscale phenomenon; studies of the frictional response of nanochains; electric charge transfer in semiconductor nanostructures; nanoscale quantum-dot self assembly using DNA templates; and the integration of nanoscale biomotors with mechanical devices. In this last activity, researchers constructed integrated nanoscale devices that are powered by biomolecular motors and fueled by light. In one such system, a protein from a photosynthetic bacterium generates an electrochemical gradient across an artificial membrane system. This system is chemically closed, enabling the motors to be continuously supplied with fuel using a total light collection area less than 400 square nanometers.

- **Geosciences imaging from the atomic scale to the kilometer scale.** Advances in geosciences imaging were demonstrated this year at a variety of disparate length scales. At the smallest length scale, the GeoCARS beamline at the Advanced Photon Source was used to examine the interaction of liquid water with alumina as a model for understanding aluminum containing minerals such as clays. Unlike other techniques used to characterize surfaces, the new beamline can study wet crystal surfaces. The result showed a significant change from the experiments using dry surfaces and will help researchers understand water-solid interactions in nature at the atomic level. At an intermediate length scale, researchers are using advanced laser scanning confocal microscopy to image, reconstruct, and characterize fluid flow through pores and cracks. Predicting the magnitudes and directions of flow in earth material is critical in performance assessment of oil and gas reservoirs. Finally, at the largest length scales, researchers are using specially instrumented regions in an earthquake zone to help model and improve geophysical imaging on the kilometer scale.

- **Biogeochemistry.** It is increasingly evident that living processes play a fundamental role in determining the geochemistry of groundwater, near-surface sediments, and deeper rocks. Microbes affect the weathering of rocks and minerals, and microbial metabolism affects the accumulation of heavy metals in soils or their release to groundwater. These and other processes determine how soils, sediments, and ore bodies form and how water quality is affected. Work identifying how microbes affect the fate of zinc released to groundwater percolating through lead-zinc mines and other biogeochemistry work recently led to the award of MacArthur Foundation Fellowship to a BES supported researcher. Biogeochemistry, which links three BES subprograms, is expected to play an increasingly important role in addressing DOE missions.

Energy Biosciences

- **Completion of the gene sequence of *Arabidopsis thaliana*, the first plant genome.** *Arabidopsis thaliana*, a small weed belonging the mustard family, became the world's "model" plant owing to its small physical size, small genome size, low level of junk and repetitive DNA, short life cycle, large number of mutations, and ease in genetic analysis. An international collaboration involving scientists from the U.S., Europe, and Japan announced the completion of the complete sequence of this plant genome in December 2000. The *Arabidopsis* genome is entirely in the public domain, making the results available to scientists worldwide. The Energy Biosciences subprogram has been a partner in this project since its inception; support for research on *Arabidopsis* dates to the early 1980s.

- **Snapshot of a light-driven pump.** Sunlight causes the bacteriorhodopsin protein to change shape, and in the process transport protons across a membrane to provide chemical energy. X-ray crystallographic structure determinations of this light-driven proton pump captured for the first time the molecule frozen mid-stroke of this shape modification. This novel view of the intermediate conformation enables us to see how biological nanostructures capture and transform energy.

SELECTED FACILITY ACCOMPLISHMENTS

The four BES synchrotron radiation light sources and three BES neutron scattering facilities served 6,533 users in FY 2000 by delivering a total of 30,249 operating hours to 218 beam lines at an average of 97.8% reliability (delivered hours/scheduled hours). Statistics for individual facilities are provided below. In two instances, less time was needed for maintenance activities than was scheduled, so more time was delivered to users than planned. The maximum number of total operating hours for these 7 facilities is estimated to be about 36,750 hours. Most of the BES facilities already operate close to the maximum number of hours possible for their facility. Significant reductions from the maximum in FY 2000 were a result of planned shutdowns for the installation of upgrades.

The first priority for utilizing the facilities optimally is to generate a highly reliable source of beam for the maximum number of operating hours possible. In addition, however, the beamlines and their instruments must be supported and maintained at the state-of-the-art, and the number of beam lines must be increased in order to achieve the full capacity of each of the facilities. Capacity at the light sources could increase by nearly a factor of two if all beamlines were fully instrumented.

BES defines "users" as researchers who conduct experiments at a facility (e.g., received a badge) or receive primary services from a facility. An individual is counted as one user per year regardless of how often he or she uses a given facility in a year. “Operating hours” are the total number of hours the facility delivers beam time to its users during the Fiscal Year. Facility operating hours are the total number of hours in the year (e.g., 365 days times 24 hour/day = 8,760 hours) minus time for machine research, operator training, accelerator physics, and shutdowns (due to maintenance, lack of budget, faults, safety issues, holidays, etc.).

- **The Advanced Light Source (ALS)** served 1,036 users in FY 2000 by delivering 5,367 operating hours to 34 beam lines at 95.0% reliability (delivered hours/scheduled hours). The ALS is supported by the Materials Sciences subprogram.

  New technique for improved storage-ring stability. The electron beam parameters in the storage ring determine x-ray beam lifetime and stability. Using a mathematical technique, accelerator physicists have understood the strength and location of harmful resonances that cause irregular, chaotic electron behavior leading to loss of electrons from the beam.

  Third-harmonic cavities enhance beam lifetime. The electron beam lifetime in a synchrotron-radiation source determines how long users can record data before being interrupted when accelerator operators replenish the train of short bunches that make up the beam. A desirable way to increase the lifetime is to lengthen the bunches. Five new third-harmonic cavities accomplish the bunch lengthening and have increased electron beam lifetime increased by about 50%.

  X-ray science possible at femtosecond speeds. X-ray experiments to study physical, chemical, and biological processes that occur on a time scale of one molecular vibration (typically 100 femtoseconds) are an emerging area of research. Three developments at the ALS brought x-ray science into the femtosecond realm. First, researchers developed a high-speed x-ray detector (a streak camera) with a picosecond time resolution. Second, researchers showed how to use a femtosecond laser to "slice" tiny slivers from the circulating electron bunches in the storage ring and use them to produce pulses of synchrotron radiation lasting just 300 femtoseconds, which is 100 times shorter than the x-ray pulse normally produced. Finally, accelerator physicists devised an arrangement of magnets that allow a narrow-gap undulator optimized for the production of femtosecond x rays to be installed in the storage ring.

Undulator has complete polarization control. The elliptically polarizing undulator (EPU) in the ALS is now in full user operation with a high-resolution beamline to provide state-of-the-art performance. This capability opens up many new experimental possibilities in polymer, biophysics, and magnetism research all without rotation of the sample.

Upgrades improve photoemission electron microscopy. By imaging the photoelectrons emitted from a sample with high spatial resolution, the photoemission electron microscope is an ideal tool for combining spectroscopy with variable polarization microscopy in the study of materials ranging from magnetic materials to polymers. The performance and sample-preparation facility of this instrument have been upgraded, making possible new experiments, such as probing the magnetic roles of the different elements in multilayer structures of the type under development for magnetic memory and data storage.

A facility for sub-micron x-ray diffraction developed. Many properties depend on behavior within individual grains and on the details of grain-to-grain interactions. The ALS has pioneered the technology needed for x-ray micro-diffraction and its application to thin-film stress analysis. The system is capable of measuring structural parameters from grains as small as 0.7 micron. The technique is starting to play a major role in many materials projects, from stress-induced cracking of indented high-strength materials to stress in magnetic thin films.

- **The Advanced Photon Source (APS)** served 1,527 users in FY 2000 by delivering 4,724 operating hours to 34 beam lines at 93.6% reliability (delivered hours/scheduled hours). The APS is supported by the Materials Sciences subprogram.

3-D imaging in real time. A real-time, three-dimensional x-ray microtomography imaging system that can acquire, reconstruct, and interactively display rendered 3-D images of a sample at micrometer-scale resolution within minutes has been developed. This system could bring better understanding of an array of physical processes, ranging from failure in microelectronic devices to growth and depletion processes in medical samples.

Novel x-ray microprobe developed. The magnetic contribution to the cross section for x-ray scattering is of significant interest. A technique has been developed that combines microfocusing x-ray optics with Bragg-diffracting phase retarders to produce a circularly polarized x-ray microprobe. This will enable a wide variety of magnetic scattering experiments in applied fields like magnetic materials and superconducting compounds.

New beam chopper improves time-resolved experiments. A new beam chopper has been developed for time-resolved experiments. The time window of 10 nanoseconds enables time-resolved experiments in condensed-matter physics, atomic physics, and biological science.

Beam-position monitor improvements started. Significant upgrades have been made to the particle beam and x-ray beam position measurement systems. Further progress is expected when these changes are incorporated in all of the beamlines at the APS. This state-of-the-art improvement in beam stability will provide the APS users with more efficient beamlines and the capability of working with smaller samples and increased measurement resolution.

Storage-ring "top-up" operations developed. The APS is the first facility to implement "top-up" filling of the storage with electrons during normal operations. During 136 hours of top-up operation, the stored current was held constant to about two parts per thousand by injecting a pulse of electrons once every two minutes. This resulted in improvements in x-ray beam stability. Ultimately, top-up filling will be the routine operating mode of the APS.

Record FEL SASE achieved. Using the Low-Energy Undulator Test Line (LEUTL) and the injector linac, an experimental verification was obtained of the self-amplified spontaneous emission (SASE) process for 530 nm light. More recently, saturation of the SASE process at a power level 10,000,000 times higher than the light produced by a single undulator insertion device was verified. These experiments are viewed as necessary experimental milestones for achieving an x-ray free-electron laser.

- **The National Synchrotron Light Source (NSLS)** served 2,551 users in FY 2000 by delivering 5,620 operating hours to 90 beam lines at 112.9% reliability (delivered hours/scheduled hours). The NSLS is supported by the Materials Sciences subprogram and the Chemical Sciences subprogram.

New optical polarizer. A newly developed quadruple-reflector optical polarizer efficiently converts VUV light from linear to either left-circular or right-circular polarization. This polarizer expands the capability the U5UA beamline in the area of ultra-thin magnetic films.

High-resolution photoelectron spectrometer. A new photoelectron spectrometer was installed on the U13UB beamline, and has already produced new physical insights into the electronic structure of high temperature superconductors.

Infrared beamlines revitalized. The 10 year-old infrared microspectrometer at U10B beamline was replaced with a state-of-the-art continuum microscope and advanced Fourier transform infrared spectrometer. The system has been used for the study of interplanetary materials, biological tissues, corrosion, and materials formed at high pressure. Also, the beam delivery optics for the U12IR beamline were rebuilt to provide infrared radiation to a new high-resolution spectrometer. This spectrometer will be used for magnetospectroscopy studies of materials such as $LaMnO_3$.

Fluorescence microscopy. For the first time, an infrared microscope has been modified such that fluorescence sample visualization and infrared microspectroscopic analysis can be performed simultaneously. This unique combination is a valuable analysis tool for probing the chemical composition of materials.

Advanced x-ray detector array enables study of trace elements. X-ray absorption spectroscopy of trace elements in samples poses a serious detection problem. The detector technology developed for high-energy physics applications was used to produce a 100-element energy-resolving detector array for use on an NSLS beamline.

Advanced x-ray detector system developed. One of the ways in which diffraction experiments can be made more efficient is to detect the entire diffraction pattern with high resolution. In order to accomplish this, a novel curved cylindrical detector was developed. In addition, a highly-parallel readout system was developed that is capable of processing events 10 times faster than before.

Low-cost monochromator, low-maintenance spectrometer. A simple device that consists of a monolithic silicon diffracting element is near-zero maintenance and almost adjustment free. It is now used on five NSLS beamlines; several more such detectors will be installed at NSLS and at other facilities. The new device removes need for ultra-fine mechanisms that contribute to most of the cost of such an instrument and makes x-ray monochromators difficult to control.

Digital feedback system improves storage ring stability. Meeting the needs of the large population of NSLS users for high quality photon beams requires an extremely stable electron orbit. To that end, digital orbit feedback systems to replace the original analog ones were designed in both the VUV and the X-ray rings. The main advantage of switching to a digital architecture is the ability to use a higher number of beam position monitors to achieve a better match between disturbances on the beam and corrective action by the feedback system. The digital global orbit feedback system was put into operations in the VUV ring in August 2000. Implementation of the digital orbit feedback system on the X-ray ring is expected in FY 2001.

- **The Stanford Synchrotron Radiation Laboratory (SSRL)** served 895 users in FY 2000 by delivering 4,143 operating hours to 26 beam lines at 96.8% reliability (delivered hours/scheduled hours). The SSRL is supported by Materials Sciences subprogram and the Chemical Sciences subprogram.

Reliability of SPEAR improved. The reliability of the injector was improved by rebuilding the regulation of power supplies in the beam transport line. This contributed to shorter filling times, and, consequently, to longer beam times available to the users.

Quality of the photon beam enhanced. Stable photon beam intensity is one of the requirements for performing demanding synchrotron radiation experiments. Accelerator physics studies determined that one type of beam noise was due to the excitation of high order electro-magnetic modes in the accelerating cavities. To alleviate this problem, waveguide dampers were installed in the radio-frequency accelerating system. As a consequence, SPEAR operates more reliably and the beam stability is improved.

SSRL beam line systems modernized. Six beam line stations were upgraded to the SSRL standard data acquisition system and control software. This greatly increases reliability while reducing user training time, spares requirements, and staff support requirements.

High magnetic field x-ray scattering station commissioned. A new high magnetic field end station incorporating a 13 Tesla superconducting magnet was constructed and commissioned on SSRL's premiere x-ray scattering beam line, BL7-2. This facility is one of the few facilities in the world that enable state-of-the-art x-ray scattering experiments in high field environments. The unique matching of a versatile, high-field magnet with an intense synchrotron x-ray source allows scientists to unravel the properties of these new materials. Eventually, the fundamental understanding that will be derived from this research will lead to higher performance sensors and magnetic storage devices.

Photoemission beamline improved for higher throughput and resolution. The high-resolution angle resolved photoemission beam line station 5-4 has been used to study the fundamental mechanisms of high temperature superconductivity and improvements in FY 2000 have brought the station to new levels of performance. The upgrades include a new primary focusing mirror and an angle mode option to the photoelectron energy analyzer greatly improving throughput.

Molecular environmental science facility commissioned. The importance of molecular based research in the environmental area is increasing in importance due to the emergence problems ranging from environmental remediation at the DOE weapons labs, to long term storage of nuclear waste, to basic questions concerning molecular interactions of pollutants at the surfaces of soils. Beam line station 11-2 has been optimized for x-ray absorption studies of samples in a variety of states and under dilute field conditions. The station also includes capabilities for small spot analysis as well as specialized facilities for the safe handling and analysis of radioactive materials such as soils contaminated with actinides or wastes from nuclear storage sites.

New research and training gateway program initiated. A Gateway pilot program involving SSRL and the University of Texas at El Paso (UTEP) is providing training and research opportunities targeted toward Mexican and Mexican American students. In FY 2000, a group of 16 UTEP students and staff underwent training and carried out experiments on four separate beam lines.

- **The Intense Pulsed Neutron Source (IPNS)** served 230 users in FY 2000 by delivering 3,842 operating hours to 15 beam lines at 101.6% reliability (delivered hours/scheduled hours). The IPNS is supported by the Materials Sciences subprogram.

Upgrade of QENS instrument. The quasielastic neutron scattering (QENS) instrument was completely upgraded. This instrument is used for measurements that determine the diffusion rates of both molecular rotation and translation on the typical time-scales of simple liquids, adsorbates etc. QENS is also capable of measuring vibrational excitations up to a few hundred meV, providing access to both external and internal vibrational modes for hydrogenous systems.

IPNS hosts second National Neutron and X-Ray Scattering School. During the two-week period of August 14-26, 2000, Argonne National Laboratory once again hosted the National School on Neutron and X-Ray Scattering. The success of the previous year was so overwhelming that additional funds were provided by BES to increase the size of the school from 48 to 60 graduate students. Funding was also provided by the National Science Foundation. This school fulfills a continuing need for training graduate students in the utilization of national user facilities. The formal program included 32 hours of lectures given by an internationally known group of scientists recruited from universities, national laboratories and industry.

- **The Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center** LANSCE served 25 users in FY 2000 by delivering 736 operating hours to 7 beam lines at 78.8% reliability (delivered hours/scheduled hours). LANSCE was down for installation of upgrades and safety shutdowns in FY 2000. The Lujan Center is supported by the Materials Sciences subprogram.

Neutron flux increased. The Lujan Center is the first spallation neutron source to exploit the increased neutron flux provided by coupled moderators. A new coupled liquid-hydrogen moderator provides an increase of approximately 2.5 times over the previous decoupled moderator. Both the small-angle diffractometer and the Surface Profile Analysis Reflectometer benefit from this increased flux.

- **The High Flux Isotope Reactor (HFIR)** served 269 users in FY 2000 by delivering 5,817 operating hours to 12 beam lines at 92.9% reliability (delivered hours/scheduled hours). The HFIR is supported by the Materials Sciences subprogram and the Chemical Sciences subprogram.

Cold source progress. Work continues on the development of the nation's highest-intensity cold neutron source. This cold source, which will be comparable in intensity to the world's best at the Institut Laue–Langevin (ILL) in Grenoble, France, will support four neutron guides and instruments. The cold source building and refrigeration plant have been completed, and the guides and cold-source moderator vessel are in fabrication.

- **The Combustion Research Facility (CRF)** is supported by the Chemical Sciences subprogram.

  New capabilities brought on line. The CRF provides a primary interface for the integration of BES programs with those of DOE's Office of Energy Efficiency and Renewable Energy and Office of Fossil Energy related to combustion by collocating basic and applied research at one facility. Phase II of the CRF more than doubled the laboratory floor space to 37,000 square feet, increasing the number of labs to 37. The new wing houses unique instruments, such as picosecond lasers for diagnosing molecular energy transfer. The turbulent flame diagnostics laboratory, which has become an international standard, has been expanded to accommodate two simultaneous and independent experimental stations for visitors. The new laser-imaging laboratory has also been expanded to include several flame geometries with controlled, reproducible flow structures. New staff members have been or are being hired in theoretical chemistry, computer science, and experimental chemical dynamics.

PROGRAM SHIFTS

Materials Sciences

- **Initiation of programs in complex systems, the precursor to activities in nanoscale science, engineering, and technology.** An FY 2000 laboratory solicitation in complex systems began two new programs. The first, at Ames Laboratory, is on extraordinary responsive magnetic rare earth materials and will focus on new materials with enhanced magnetostriction, magnetoresistance, and magnetocaloric effects, i.e., on materials whose properties can change dramatically and reversibly with very small changes in temperature, pressure, or magnetic field. The research will focus on a fundamental understanding of the electronic and structural mechanisms for the changes. There is great potential for future use of these materials to control a variety of devices. The second project, at Argonne National Laboratory, is on laterally confined nanomagnetic materials. The goal is to understand how the physics changes and the ultimate limits of miniaturization and structural perfection are approached. Interactions between nanoscale elements and within the nanoscale elements will be studied. This work will provide the basis for new classes of electronic devices and ultimately, quantum computing.

Chemical Sciences

- **Initiation of programs in complex systems, the precursor to activities in nanoscale science, engineering, and technology.** An FY 2000 laboratory solicitation in complex systems began two new programs. The first, at Lawrence Berkeley National Laboratory, is a collaboration between chemists and bioscientists to understand the molecular origins of photosynthetic light capture and energy conversion mechanisms through the study of time-dependent spectroscopy of genetically modified algae and plants having altered light harvesting molecular complexes and pigment compositions. The second, at Oak Ridge National Laboratory in collaboration with partners at universities and other national laboratories, is a collaboration between chemists and geoscientists to understand the water-oxide interface through the study of specific interfaces and surfaces. This work is fundamental to advancing our knowledge of contaminant migration in the environmental, energy production, energy storage, and catalysis areas.

Scientific Facilities Utilization

The BES program request includes $310,279,000 to maintain support of the scientific user facilities. Research communities that have benefited from these facilities include materials sciences, condensed matter physics, chemical sciences, earth and geosciences, environmental sciences, structural biology, superconductor technology, medical research, and industrial technology development. The level of operations will be maintained as close to that in FY 2001 as feasible. More detailed descriptions of the specific facilities and their funding are given in the subprogram narratives and in the sections entitled Site Description and Major User Facilities.

Spallation Neutron Source (SNS) Project

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

Neutrons enable scientists studying the physical, chemical, and biological properties of materials to determine how atoms and molecules are arranged and how they move -- knowledge needed to understand and "engineer" materials at the atomic level so that they have improved macroscopic properties and perform better in new applications. Neutron scattering will play a role in all forms of materials research and design, including the development of smaller and faster electronic devices; lightweight alloys, plastics, and polymers for transportation and other applications; magnetic materials for more efficient motors and for improved magnetic storage capacity; and new drugs for medical care. The high neutron flux (i.e., high neutron intensity) from the SNS will enable broad classes of experiments that cannot be done with today's low-flux sources. For example, high flux enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions.

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

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

Significant progress has been made on the Spallation Neutron Source project. The funding conditions stipulated in the House Report (Report 106-253, pages 113-114) accompanying the FY 2000 Energy and Water Development Appropriations Act were fulfilled, and FY 2000 construction funds were released at the end of February 2000. The Department approved the start of construction in November 1999 and site preparation began at Oak Ridge the following month. Site excavation and grading work has been completed, moving about 1.3 million cubic yards of earth. FY 2001 budget authority has been provided for conducting detailed design and for starting fabrication of the ion source, low-energy beam transport, linac structures and magnet systems, target assemblies, experimental instruments, and global control systems. Construction work will begin on several conventional facilities (buildings and accelerator tunnels).

FY 2002 funding of $291,400,000 (includes construction and other project costs) is requested to complete the ion source and continue component procurements for and fabrication of the linac structures and magnet systems, target assemblies, and the global controls. The assembly and testing of technical components will continue. Installation efforts will begin in the front end and the low energy sections of the linac. Title II design will continue for the target and experimental instruments. Work on conventional facilities will continue; some will reach completion and be turned over for equipment installation, such as the front end building, and portions of the klystron hall and linac tunnel.

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

Workforce Development

The BES program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. In addition, the BES scientific user facilities provide outstanding hands-on research experience to many young scientists. Thousands of students and post-doctoral investigators are among the 8,000 researchers who conduct experiments at BES-supported facilities each year. The work that these young investigators perform at BES facilities is supported by a wide variety of sponsors including BES, other Departmental research programs, other federal agencies, and private institutions. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research and also provides talent for a wide variety of technical and industrial areas that require the problem solving abilities, computing skills, and technical skills developed through an education and experience in fundamental research.

This program supported 2,900 graduate students and postdoctoral investigators in FY 2000 through grants or contracts; 3,680 graduate students and postdoctoral investigators used the BES science user facilities in FY 2000.

Funding Profile

	(dollars in thousands)				
	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Basic Energy Sciences					
Research					
Materials Sciences	388,602	456,111	-12,869	443,242	434,353
Chemical Sciences	197,940	223,229	-6,703	216,526	218,714
Engineering and Geosciences	35,639	40,816	-1,050	39,766	38,938
Energy Biosciences	29,850	33,714	-498	33,216	32,400
Subtotal, Research	652,031	753,870	-21,120	732,750	724,405
Construction	100,000	259,500	-571	258,929	280,300
Subtotal, Basic Energy Sciences	752,031[a]	1,013,370	-21,691	991,679	1,004,705
General Reduction	0	-7,655	7,655	0	0
General Reduction for Safeguards and Security	0	-11,850	11,850	0	0
Omnibus Rescission	0	-2,186	2,186	0	0
Total, Basic Energy Sciences	752,031[b c]	991,679	0	991,679	1,004,705

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 $15,083,000 which has been transferred to the SBIR program and $905,000 which has been transferred to the STTR program.

[b] Includes $8,201,000 for Waste Management activities at Ames Laboratory and Argonne National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $11,743,000 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	23,696	22,721	22,927	+206	+0.9%
National Renewable Energy Laboratory ..	5,177	4,873	4,535	-338	-6.9%
Sandia National Laboratories	23,740	22,967	22,843	-124	-0.5%
Total, Albuquerque Operations Office	52,613	50,561	50,305	-256	-0.5%
Chicago Operations Office					
Ames Laboratory	18,105	16,967	16,753	-214	-1.3%
Argonne National Laboratory – East........	151,026	155,902	159,149	+3,247	+2.1%
Brookhaven National Laboratory	73,569	72,005	57,089	-14,916	-20.7%
Chicago Operations Office.....................	93,708	84,792	84,173	-619	-0.7%
Princeton Plasma Physics Laboratory	561	0	0	--	--
Total, Chicago Operations Office...............	336,969	329,666	317,164	-12,502	-3.8%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	2,748	2,220	1,710	-510	-23.0%
Oakland Operations Office					
Lawrence Berkeley National Laboratory ..	65,048	70,760	72,586	+1,826	+2.6%
Lawrence Livermore National Laboratory	5,966	5,316	4,628	-688	-12.9%
Stanford Linear Accelerator Facility (SSRL)..	24,098	33,691	33,991	+300	+0.9%
Oakland Operations Office	37,334	34,693	34,588	-105	-0.3%
Total, Oakland Operations Office	132,446	144,460	145,793	+1,333	+0.9%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science and Education	1,366	866	852	-14	-1.6%
Oak Ridge National Laboratory	212,663	370,312	384,317	+14,005	+3.8%
Total, Oak Ridge Operations Office	214,029	371,178	385,169	+13,991	+3.8%
Richland Operations Office					
Pacific Northwest National Laboratory	12,072	11,846	11,398	-448	-3.8%
Washington Headquarters	1,154	81,748	93,166	+11,418	+14.0%
Total, Basic Energy Sciences....................	752,031[abc]	991,679	1,004,705	+13,026	+1.3%

[a] Excludes $15,083,000 which has been transferred to the SBIR program and $905,000 which has been transferred to the STTR program.

[b] Includes $8,201,000 for Waste Management activities at Ames Laboratory and Argonne National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $11,743,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. The laboratory was built on the campus of Iowa State University during World War II to emphasize the purification and science of rare earth materials. This emphasis continues today. The BES Materials Sciences subprogram supports experimental and theoretical research on rare earth elements in novel mechanical, magnetic, and superconducting materials. Ames scientists are experts on magnets, superconductors, and quasicrystals that incorporate rare earth elements. The BES Chemical Sciences subprogram supports studies of ultrafast spectroscopic techniques to examine energy transfer processes and studies of molecular beams to obtain highly accurate and precise thermochemical information for small molecules and radicals. Ames Laboratory provides leadership in analytical and separations chemistry with strength in catalysis.

Ames Laboratory is home to the **Materials Preparation Center** (MPC), which is dedicated to the preparation, purification, and characterization of rare-earth, alkaline-earth, and refractory metal materials. Established in 1981, the MPC is a one-of-a-kind resource that provides scientists at university, industrial, and government laboratories with research and developmental quantities of high-purity materials and unique analytical and characterization services that are not available from commercial suppliers. The MPC is renowned for its technical expertise in alloy design and for creating materials that exhibit ultrafine microstructures, high strength, and high conductivity. The MPC also operates the Materials Referral System and Hotline, where users may obtain free information from a database of over 2,500 expert sources for the preparation and characterization of a wide variety of commercial materials and research samples.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on 1,700 acres in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. ANL is home to one of the largest BES research efforts, with research activities in broad areas of materials and chemical sciences. It is also the site of three BES supported user facilities -- the Advanced Photon Source (APS), the Intense Pulsed Neutron Source (IPNS), and the Electron Microscopy Center for Materials Research (EMC).

The Materials Sciences subprogram supports research in high-temperature superconductivity; polymeric superconductors; thin-film magnetism; surface science; the synthesis, characterization, and atomistic computer simulation of interfaces in advanced ceramic thin-films; the investigation of the effects of neutron, gamma, and ion-irradiation of solids; tribological investigation of the boundary films on aluminum and aluminum alloys; and synthesis and electronic and structural characterization of oxide ceramic materials, including high-temperature superconductors. The Chemical Sciences subprogram supports research in actinide separations; fundamental physical and chemical properties of actinide compounds; structural aspects fundamental to advanced electrochemical energy storage concepts and the chemistry of complex hydrocarbons; experimental and theoretical studies of metal clusters of catalytically active transition metals; molecular dynamics of gas-phase chemical reactions of small molecules and radicals; photosynthesis mechanisms; and atomic, molecular, and optical physics. ANL has one of three pulsed radiolysis activities that together form a national research program in this area. The other two are at Brookhaven National Laboratory and Notre Dame University. The Engineering and

Geosciences subprogram supports geosciences research in computational microtomography of porous earth materials and in organic geochemistry related to hydrocarbon formation.

The **Advanced Photon Source** is one of only three third-generation, hard x-ray synchrotron radiation light sources in the world, and it is the only one in the Americas. It is a world-class facility. Dedicated in 1996, the construction project was completed five months ahead of schedule and for less than the budget. The 7 GeV hard x-ray light source has since met or exceeded all technical specifications. For example, the APS is 10 times more brilliant than its original specifications and the vertical stability of the particle beam is three times better than its design goal. The 1,104-meter circumference facility -- large enough to house a baseball park in its center -- includes 34 bending magnets and 34 insertion devices, which generate a capacity of 68 independently controlled beamlines for experimental research. Beamlines are assigned to user groups in Collaborative Access Teams (CATs), whose proposals are reviewed and approved based on their scientific program and the criticality of high-brilliance x-rays to the work. The CATs, groups of primarily industrial and university researchers, provided approximately $160 million to fund fabrication of the first 40 beamlines at the APS. These instruments attracted 1,527 users in FY 2000 to study the structure and properties of materials in a variety of disciplines, including condensed matter physics, materials sciences, chemistry, geosciences, structural biology, medical imaging, and environmental sciences. The APS is considering proposals for the remaining beamline ports, and it is expected that the facility will accommodate over 3,000 users annually when it fully matures. The high-quality, reliable x-ray beams at the APS have already brought about new discoveries in materials structure, encompassing a variety of technological applications including micromachining, lithography, medical insights and even new archaeological information.

The **Intense Pulsed Neutron Source** is a 30 Hz short-pulsed spallation neutron source that first operated all instruments in the user mode in 1981. Twelve neutron beam lines serve 14 instruments, one of which is a test station for instrument development. Distinguishing characteristics of IPNS include its innovative instrumentation and source technology and its dedication to serving the users. The first generation of virtually every pulsed source neutron scattering instrument was developed at IPNS. In addition, the source and moderator technologies developed at IPNS, including uranium targets, liquid hydrogen and methane moderators, solid methane moderators, and decoupled reflectors, have impacted spallation sources worldwide. A recent BESAC review of this facility described it as a “reservoir of expertise with a track record of seminal developments in source and pulsed source instruments second to none” and noted that ANL is “fully committed from top to bottom to supporting the user program.” This is reflected by a large group of loyal, devoted users. Research at IPNS is conducted on the structure of high-temperature superconductors, alloys, composites, polymers, catalysts, liquids and non-crystalline materials, materials for advanced energy technologies, and biological materials. The staff of the IPNS is taking a leadership role in the design and construction of instrumentation for the Spallation Neutron Source at Oak Ridge National Laboratory.

The **Electron Microscopy Center for Materials Research** provides in-situ, high-voltage and intermediate voltage, high-spatial resolution electron microscope capabilities for direct observation of ion-solid interactions during irradiation of samples with high-energy ion beams. The EMC employs a tandem accelerator for simultaneous ion irradiation and electron beam microcharacterization. It is the only instrumentation of its type in the Western Hemisphere. The unique combination of two ion accelerators and two microscopes permits direct, real-time, in-situ observation of the effects of ion and/or electron bombardment of materials and consequently attracts users from around the world.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on 5,200 acres in Upton, New York. BNL is home to BES major research efforts in materials and chemical sciences as well as to efforts in geosciences and biosciences. BNL is also the site of the National Synchrotron Light Source (NSLS).

The Materials Sciences subprogram emphasizes experiments that make use of the NSLS. BNL scientists are among the world leaders in neutron and x-ray scattering applied to a wide variety of research problems such as high-temperature superconductivity, magnetism, structural and phase transformations in solids, and polymeric conductors. BNL has strong research programs in the structure and composition of grain boundaries and interfaces in high temperature superconductors, in aqueous and galvanic corrosion studies, and in the theory of alloy phases.

The Chemical Sciences subprogram supports one of three national activities for pulsed radiolysis research at BNL. The innovative short-pulse radiation chemistry facility contributes to radiation sciences research across broad areas of chemistry. There is also research on the spectroscopy of reactive combustion intermediates and an active research effort on studies of the mechanisms of electron transfer related to artificial photosynthesis. Other Chemical Sciences research at BNL is focused around the unique capabilities of the NSLS in obtaining time dependant structural data of reacting systems, the structural changes accompanying catalytic and electrochemical reactions, and the formation of atmospheric aerosols and their reactivity.

The Energy Biosciences subprogram supports activities in the plant sciences, which include mechanistic and molecular-based studies on photosynthesis, lipid metabolism, and genetic systems. The studies on lipid biosynthesis may lead to exciting prospects for engineering new pathways for the synthesis of alternative fuels and petroleum-replacing chemicals. The Engineering and Geosciences subprogram supports synchrotron-based studies of rock-fluid interactions, particularly for investigations of diagenetic processes and synchrotron computed microtomography of porosity of reservoir rocks.

The **National Synchrotron Light Source** (NSLS) is among the largest and most diverse scientific user facilities in the world. The NSLS, commissioned in 1982, has consistently operated at 97% reliability 24 hours a day, seven days a week, with scheduled periods for maintenance and machine studies. In FY 2000, the NSLS served 2,551 researchers from universities, industry, and national laboratories. Adding to its breadth is the fact that the NSLS consists of two distinct electron storage rings. The x-ray storage ring is 170 meters in circumference and can accommodate 60 beamlines or experimental stations, and the VUV storage ring can provide 25 additional beamlines around its circumference of 51 meters. Synchrotron light from the x-ray ring is used to determine the atomic structure of materials using diffraction, absorption, and imaging techniques. Experiments at the VUV ring help solve the atomic and electronic structure as well as the magnetic properties of a wide array of materials. These data are fundamentally important to virtually all of the physical and life sciences as well as providing immensely useful information for practical applications. The petroleum industry, for example, uses the NSLS to develop new catalysts for refining crude oil and making by-products like plastics. The electronics industry does R&D on semiconductors and develops x-ray lithography processes to produce future generations of computer chips with even smaller features than those presently produced using optical lithographic techniques.

The **High Flux Beam Reactor**, commissioned in 1965, was a research reactor designed to produce neutrons for scattering. During its three decades of operation, the HFBR was a premier gathering spot for neutron scientists involved in a broad array of studies, including phonons in rare gases; ferromagnets and antiferromagnets; critical phenomena in magnetic transitions; structure and dynamics of molecules adsorbed on surfaces; direct measure of electron-phonon interaction in 'old' superconductors; structure determination of small sub-unit of ribosomes; critical phenomena in one- and two-dimensional magnets; impurity effects on phase transitions; incommensurate systems in metals and insulators; magnetic correlations in heavy fermions; magnetic superconductors; hydrogen location in amino acids and carbohydrate building blocks; static and dynamic correlations in high temperature superconductors; exotic behavior of one-dimensional magnets; shape memory materials; anomalous correlation lengths in phase transitions; and the structure of ceramics with negative thermal expansion. In December 1996, a plume of tritiated water was discovered emanating from a leak in the HFBR spent fuel pool, which contaminated the groundwater south of the reactor. The facility remained on standby until Secretary of Energy Bill Richardson announced on November 16, 1999, that the reactor would be permanently closed. Activities to place the reactor in a safe state awaiting full decommissioning by DOE's Office of Environmental Management will be completed in FY 2001. The permanent shut down of the HFBR has been a significant loss to the scientific community, and it increases the importance of the remaining neutron sources in the U.S.

Idaho National Engineering and Environmental Laboratory

Idaho National Environmental and Engineering Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. The Materials Sciences subprogram supports research in the modeling, growth, and properties of functionally gradient materials as an effective means of joining ceramic and metallic materials, on the microstructural evolution of rapidly solidified materials, and on high strength magnetic materials. The Chemical Sciences subprogram focuses on fundamental understanding of negative ion mass spectrometry, studies of secondary ion mass spectrometry, and computer simulation of ion motion and configuration of electromagnetic fields crucial to the design of ion optics. The Engineering and Geosciences subprogram supports studies to establish controls of biologically based engineering systems, to understand and improve the life expectancy of material systems used in engineering such as welded systems, to improve controls of nonlinear systems, and to develop new diagnostic techniques for engineering systems.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory (LBNL) is a Multiprogram Laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. LBNL is home to BES major research efforts in materials and chemical sciences as well as to efforts in geosciences, engineering, and biosciences. Collocated with the University of California at Berkeley, the Laboratory benefits from regular collaborations and joint appointments with numerous outstanding faculty members. The Laboratory is the home to the research of many students and postdoctoral appointees. LBNL is also the site of two BES supported user facilities -- the Advanced Light Source (ALS) and the National Center for Electron Microscopy (NCEM).

The Materials Sciences subprogram supports research in laser spectroscopy, superconductivity, thin films, femtosecond processes, x-ray optics, biopolymers, polymers and composites, surface science, and theory. Research is carried out on the fundamental features of evolving microstructures in solids; alloy-phase stability; structure and properties of transforming interfaces; the structures of magnetic, optical, and electrical thin films and coatings; processing, mechanical fatigue, and high-temperature corrosion of structure ceramics and ceramic coatings; and the synthesis, structure, and properties of advanced semiconductor and semiconductor-metal systems. The Chemical Sciences subprogram supports fundamental, chemical dynamics research using molecular-beam techniques. Femtosecond spectroscopy studies of energy transfer on surfaces has also been developed. LBNL is recognized for its work in radiochemistry, the chemistry of the actinides, inorganic chemistry, and both homogeneous and heterogeneous chemical catalysis. The Engineering and Geosciences subprogram supports a broad spectrum of experimental and computational geosciences research on coupled reactive fluid flow and transport properties and processes in the subsurface, and how to track and image them. In particular, geochemical studies focus on experimental and modeling studies on critical shallow earth mineral systems, improving analytical precision in synchrotron x-ray studies, and improving our understanding of how isotopic distributions act as tracers for geologic processes and their rates. Engineering research is concerned with the development of modern nonlinear dynamics with applications to problems in engineering sciences. The Energy Biosciences subprogram focuses on the physics of the photosynthetic apparatus and on the genesis of subcellular organelles.

The **Advanced Light Source** (ALS) began operations in October 1993 and now serves over 1,000 users as one of the world's brightest sources of high-quality, reliable vacuum-ultraviolet (VUV) light and long-wavelength (soft) x-rays. Soft x-rays and VUV light are used by the researchers at the ALS as high-resolution tools for probing the electronic and magnetic structure of atoms, molecules, and solids, such as those for high-temperature superconductors. The high brightness and coherence of the ALS light are particularly suited for soft x-ray imaging of biological structures, environmental samples, polymers, magnetic nanostructures, and other inhomogeneous materials. Other uses of the ALS include holography, interferometry and the study of molecules adsorbed on solid surfaces. The pulsed nature of the ALS light offers special opportunities for time resolved research, such as the dynamics of chemical reactions. Shorter wavelength (intermediate-energy) x-rays are also used at structural biology experimental stations for x-ray crystallography and x-ray spectroscopy of proteins and other important biological macromolecules. The ALS is a growing facility with a lengthening portfolio of beamlines that have already been applied to make important discoveries in a wide variety of scientific disciplines.

The **National Center for Electron Microscopy** provides instrumentation for high-resolution, electron-optical microcharacterization of atomic structure and composition of metals, ceramics, semiconductors, superconductors, and magnetic materials. The facility is home to the Nation’s highest voltage microscope, one that specializes in high-resolution studies.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on 821 acres in Livermore, California. This laboratory was built in Livermore as a weapons laboratory 42 miles from the campus of the University of California at Berkeley to take advantage of the expertise of the university in the physical sciences. The Materials Sciences subprogram supports research in metals and alloys, ceramics, materials for lasers, superplasticity in alloys, and intermetallic metals. The Engineering and Geosciences subprogram supports geosciences research on the source(s) of electromagnetic responses in crustal rocks, seismology theory and modeling, the mechanisms and kinetics of low-temperature geochemical processes and the relationships among reactive fluid flow, geochemical transport and fracture permeability. The Chemical Sciences subprogram supports plasma assisted catalysis for environmental control of pollutants.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a Multiprogram Laboratory located on 27,000 acres in Los Alamos, New Mexico. LANL is home to BES major research efforts in materials sciences with other efforts in chemical sciences, geosciences, and engineering. LANL is also the site of the Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE).

The Materials Sciences subprogram supports research on strongly correlated electronic materials; the theory of evolving microstructures; and plasma immersion processes for ion-beam processing of surfaces for improved hardness, corrosion resistance, and wear resistance. The Chemical Sciences subprogram supports research to understand the electronic structure and reactivity of actinides through the study of organometallic compounds. Also supported is work to understand the chemistry of plutonium and other light actinides in both near-neutral pH conditions and under strongly alkaline conditions relevant to radioactive wastes and research in physical electrochemistry fundamental to energy storage systems. The BES Engineering and Geosciences subprogram supports experimental and theoretical geosciences research on rock physics, seismic imaging and the physics of the earth's magnetic field. It also supports fundamental geochemical studies of isotopic equilibrium/disequilibrium and mineral-fluid-microbial interactions in natural and anthropogenically perturbed systems. Engineering research supports work to study the viscosity of mixtures of particles in liquids.

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

National Renewable Energy Laboratory

National Renewable Energy Laboratory (NREL) is a program-dedicated laboratory (Solar) located on 300 acres in Golden, Colorado. NREL was built to emphasize renewable energy technologies such as photovoltaics and other means of exploiting solar energy. The Materials Sciences subprogram supports basic research efforts that underpin this technological emphasis at the Laboratory, for example on theoretical and experimental studies of properties of advanced semiconductor alloys for prototype solar cells. The Chemical Sciences subprogram supports research addressing the fundamental understanding of solid-state, artificial photosynthetic systems. This research includes the preparation and study of novel dye-sensitized semiconductor electrodes, characterization of the photophysical and chemical properties of quantum dots, and study of charge carrier dynamics in semiconductors.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on 150 acres in Oak Ridge, Tennessee. The BES program provides funding to ORISE for support of a consortium of university and industry scientists to share the ORNL research station at NSLS to study the atomic and molecular structure of matter (known as ORSOAR, the Oak Ridge Synchrotron Organization for Advanced Research). The BES program also funds ORISE to provide support for expert panel reviews of major new proposal competitions, external peer review of DOE laboratory programs, technical review of proposals for DOE's EPSCoR program, and EPSCoR site reviews and the evaluation of program needs and impacts. ORISE also assists in the compilation of annual BES subprogram summary books, the administration of topical scientific workshops, and provides support for other activities such as for the reviews of BES construction projects. ORISE manages the **Shared Research Equipment Program** (SHaRE) at ORNL. The SHaRE Program makes available state-of-the-art electron beam microcharacterization facilities for collaboration with researchers from universities, industry and other government laboratories.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on 24,000 acres in Oak Ridge, Tennessee. ORNL is home to major research efforts in materials and chemical sciences with additional programs in engineering and geosciences. It is the site of the High Flux Isotope Reactor (HFIR) and the Radiochemical Engineering Development Center (REDC). ORNL also leads the six-laboratory collaboration that is designing and constructing the Spallation Neutron Source (SNS).

ORNL has perhaps the most comprehensive materials research program in the country. The Materials Sciences subprogram supports basic research that underpins technological efforts such as those supported by the energy efficiency program. Research is conducted in superconductivity, magnetic materials, neutron scattering and x-ray scattering, electron microscopy, pulsed laser ablation, thin films, lithium battery materials, thermoelectric materials, surfaces, polymers, structural ceramics, alloys; and intermetallics. Research is carried out on the fundamentals of welding and joining and on welding strategies for a new generation of automobiles. The subprogram emphasizes experiments at HFIR and other specialized research facilities that include the High Temperature Materials Laboratory, the Shared Research Equipment (SHaRE) Program, and the Surface Modification and Characterization (SMAC) facility. The SMAC facility is equipped with ion implantation accelerators that can be used to change the physical, electrical, and chemical properties of solids to create unique new materials not possible with conventional processing techniques. Surface modification research has led to important practical applications of materials with improved friction, wear, catalytic, corrosion, and other properties.

The Chemical Sciences subprogram supports research in analytical chemistry, particularly in the area of mass spectrometry, separation chemistry, and thermo-physical properties. Examples of the science include solvation in supercritical fluids, electric field-assisted separations, speciation of actinide elements, ion-imprinted sol-gels for actinide separations, ligand design, stability of macromolecules and ion fragmentation, imaging of organic and biological materials with secondary ion mass spectrometry, and the physics of highly charged species. The subprogram also supports research on the collision physics of highly charged ions and their interactions with surfaces.

The Engineering and Geosciences subprogram investigates experimental and analytical geochemistry with innovative technical approaches for understanding low-temperature geochemical processes and rates in mineral-fluid systems. Engineering research provides support for computational nonlinear sciences such as advanced use of neural nets and sensor fusion, stochastic approximations, and global optimization of cooperating autonomous systems such as cooperating, auto-learning robots.

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

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

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The BES Chemical Sciences subprogram supports research in interfacial chemistry of water-oxide systems, near-field optical microscopy of single molecules on surfaces, inorganic molecular clusters, and direct photon and/or electron excitation of surfaces and surface species. Programs in analytical chemistry and in applications of theoretical chemistry to understanding surface catalysis are also supported by the Chemical Sciences subprogram. Included among these studies are high-resolution laser spectroscopy for analysis of trace metals on ultra small samples; understanding of the fundamental inter- and intra-molecular effects unique to solvation in supercritical fluids; and interfacing theoretical chemistry with experimental methods to address complex questions in catalysis. Theoretical, ab-initio quantum molecular calculations are integrated with modeling and experiment. The Materials Sciences subprogram supports research on stress corrosion cracking of metals and alloys, high temperature corrosion fatigue of ceramic materials, and irradiation effects in ceramic materials relevant to radioactive waste containment. The Engineering and Geosciences program supports research on basic theoretical and experimental geochemical research that underpins technologies important for the Department's environmental missions and research to improve our understanding of the phase change phenomena in microchannels.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a Multiprogram Laboratory located on 3,700 acres in Albuquerque, New Mexico (SNL/NM), with sites in Livermore, California (SNL/CA), and Tonopah, Nevada. SNL is home to significant research efforts in materials and chemical sciences with additional programs in engineering and geosciences. SNL/CA is also the site of the Combustion Research Facility (CRF). SNL has a historic emphasis on electronic components needed for Defense Programs. The laboratory has very modern facilities in which unusual microcircuits and structures can be fabricated out of various semiconductors. The Materials Sciences subprogram supports projects on the sol-gel processing and properties of ceramics; the development of nanocrystalline materials through the use of inverse micelles; adhesion and wetting of surfaces of metals, glass, and ceramic materials; theoretical and experimental research of defects; and interfaces in metals and alloys. The Engineering and Geosciences subprogram supports geosciences research on fundamental laboratory and theoretical studies on mineral-fluid reactivity, rock mechanics, reactive fluid flow and particulate flow through fractured and porous media, and seismic and electromagnetic imaging and inversion studies. Engineering research addresses the viscosity of mixtures of particles in liquids.

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

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. It is the home of the **Stanford Synchrotron Radiation Laboratory** (SSRL) and peer-reviewed research projects associated with SSRL. The Stanford Synchrotron Radiation Laboratory was built in 1974 to take and use for synchrotron studies the intense x-ray beams from the SPEAR storage ring that was built for particle physics by the SLAC laboratory. Over the years, the SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third-generation synchrotron sources. In FY 2000, the facility was comprised of 32 experimental stations and was used by nearly 900 researchers from industry, government laboratories and universities. These include astronomers, biologists, chemical engineers, chemists, electrical engineers, environmental scientists, geologists, materials scientists, and physicists. The Materials Sciences subprogram supports a research program at SSRL with emphasis in both the x-ray and ultraviolet regions of the spectrum. SSRL scientists are experts in photoemission studies of high-temperature superconductors and in x-ray scattering. The SPEAR 3 upgrade at SSRL will provide major improvements that will increase the brightness of the ring for all experimental stations.

All Other Sites

The BES program funds research at 157 colleges/universities located in 48 states. Also included are funds for research awaiting distribution pending completion of peer review results.

Materials Sciences

Mission Supporting Goals and Objectives

The Materials Sciences subprogram supports basic research in condensed matter physics, metal and ceramic sciences, and materials chemistry. This basic research seeks to understand the atomistic basis of materials properties and behavior and how to make materials perform better at acceptable cost through new methods of synthesis and processing. Basic research is supported in metals, alloys, metallic glasses, ceramics, ceramic matrix composites, semiconductors, superconductors, magnetic materials, catalytic materials, polymers, surface science, neutron and x-ray scattering, chemical and physical properties, corrosion, non-destructive evaluation, and new instrumentation. Ultimately the research leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and use. These material studies affect developments in numerous areas, such as the efficiency of electric motors and generators; solar energy conversion; batteries and fuel cells; stronger, lighter materials for vehicles; welding and joining of materials; plastics; and petroleum refining.

The Materials Sciences subprogram supports leading institutions and individuals. In particular, the large DOE laboratory programs consistently rank among the top materials sciences institutions worldwide. For example, Argonne National Laboratory, Lawrence Berkeley National Laboratory, University of Illinois (site of the Materials Research Laboratory), and Oak Ridge National Laboratory rank among the top 25 institutions *in the world* in the area of materials sciences based on citations of high-impact papers published (*Science Watch*, 1995). These international studies of high-impact papers from scientific journals typically survey more than 1,000 institutions, including universities, government laboratories, private research institutions, and industries.

Performance will be measured by continuing the new directions in the areas of nanoscale science, engineering, and technology research initiated in FY 2001, and explore concepts and designs for nanoscale science research centers.

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
Materials Sciences Research	175,796	202,977	208,984	+6,007	+3.0%
Waste Management	8,201	8,056	8,056	0	0%
Facilities Operations	204,605	221,963	207,454	-14,509	-6.5%
SBIR/STTR	0	10,246	9,859	-387	-3.8%
Total, Materials Sciences	388,602	443,242	434,353	-8,889	-2.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Materials Sciences Research	**175,796**	**202,977**	**208,984**
▪ **Structure and Composition of Materials**	**26,092**	**28,236**	**28,236**

This activity supports basic research in the structure and characterization of materials; the relationship of structure to the behavior and performance of materials; predictive theory and modeling; and new materials such as bulk metallic glasses and "nanophase" materials.

This activity also supports four world-class electron beam microcharacterization user centers: the Center for Microanalysis of Materials at the University of Illinois, the Electron Microscopy Center for Materials Research at Argonne National Laboratory, the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory, and the Shared Research Equipment Program at Oak Ridge National Laboratory. These network-interfaced centers contain a variety of highly specialized instruments to characterize localized atomic positions and configurations, chemical gradients, interatomic bonding forces, etc.

In FY 2002, major activities will be responsive to the need for advanced instruments with capabilities to characterize and interpret atomic configurations and packing arrangements at the nanoscale with improved resolution and accuracy, including the ability to determine composition, bonding, and physical properties of materials. To be at the cutting edge, instruments are needed for the determination of single-atom sensitivity to impurities, 3-dimensional shape with atomic accuracy, functional sites and the origin of the function, and optical absorption and emission from individual elements. Many of these advanced tools will come from the further development of current microscopies including scanning tunneling microscopy, confocal and near-field optical microscopy, atomic resolution transmission and scanning transmission electron microscopy, electron energy loss spectroscopy, cathodeluminescence and electron–beam–induced current imaging. However, new instruments are needed as well to image and characterize buried interfaces with nanoscale resolution; these new instruments must operate over a wide range of temperatures and environments.

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

▪ **Mechanical Behavior and Radiation Effects**	**16,200**	**14,617**	**14,617**

This activity supports basic research to understand the mechanical behavior of materials under static and dynamic stresses and the effects of radiation on materials properties. The objective is to understand at the atomic level the relationship between physical properties and defects in materials, including defect formation, growth, migration, and propagation. In the area of mechanical behavior, the research aims to build on this atomic level understanding in order to develop predictive models for the design of materials having prescribed mechanical behavior. In the areas of radiation effects, the research aims to advance atomic level understanding of amorphization mechanisms (transition from crystalline to a non-crystalline phase) to predict and suppress radiation damage, develop radiation-tolerant materials, and modify surfaces by such techniques as ion implantation.

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

This research helps understand load-bearing capability, failure and fatigue resistance, fracture toughness and impact resistance, high-temperature strength and dimensional stability, ductility or deformability of materials that is critical to their ease of fabrication, and radiation effects including understanding and modeling of radiation damage and surface modification using ion implantation. This activity relates to energy production and conversion through the need for failure resistant materials that perform reliably in the hostile and demanding environments of energy production and use. The scientific results of this program contribute to DOE missions in the areas of fossil energy, fusion energy, and radioactive waste storage.

In FY 2002, major activities will include continued development of experimental techniques and methods for the characterization of mechanical behavior, the development of a universal model for mechanical behavior that includes all length scales from atomic to bulk dimensions, and advancement of computer simulations for modeling behavior and radiation induced degradation.

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

	FY 2000	FY 2001	FY 2002
▪ **Physical Behavior of Materials**..	**14,667**	**15,832**	**15,832**

This activity supports basic research at the atomic and molecular level to understand, predict, and control physical behavior of materials by developing rigorous models for the response of materials to environmental stimuli such as temperature, electromagnetic field, chemical environment, and proximity of surfaces or interfaces. Included within the activity are research in aqueous, galvanic, and high-temperature gaseous corrosion and their prevention; photovoltaics and photovoltaic junctions and interfaces for solar energy conversion; the relationship of crystal defects to the superconducting properties for high-temperature superconductors; phase equilibria and kinetics of reactions in materials in hostile environments, such as in the very high temperatures encountered in energy conversion processes; diffusion and the transport of ions in ceramic electrolytes for improved performance batteries and fuel cells.

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

In FY 2002, major activities will continue fundamental studies of corrosion resistance and surface degradation; semiconductor performance; high-temperature superconductors; and the interactions, and transport of defects in crystalline matter.

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

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Synthesis and Processing Science**	**13,820**	**14,781**	**14,781**

This activity supports basic research on understanding and developing innovative ways to make materials with desired structure, properties, or behavior. Examples include materials synthesis and processing to achieve new or improved behavior, for minimization of waste, and for hard and wear resistant surfaces; high-rate, superplastic forming of light-weight metallic alloys for fuel efficient vehicles; high-temperature structural ceramics and ceramic matrix composites for high-speed cutting tools and fuel efficient and low-pollutant engines; non-destructive analysis for early warning of impending failure and flaw detection during production; response of magnetic materials to applied static and cyclical stress; plasma, laser, charged particle beam surface modification to increase corrosion resistance; and processing of high-temperature, intermetallic alloys.

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

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

In FY 2002, major activities will include work on thermally unstable systems and large-scale deformation and fracture phenomena. This research will include nanoscale films using epitaxial growth; synthesis of nanoparticles; patterned deposition of nanoparticles and clusters; processing of three-dimensional nanoscale structures and composites; and ion implanted nanostructures. The strength of structural elements and modes of failure also will change as the scale of devices and machines decreases toward the nanoscale. The causes of these changes include different mechanical properties that will modify fracture characteristics; the increased importance of surface tension; and, the enhanced role of diffusion and corrosion at the large surface-to-volume ratios that will occur.

Capital equipment includes furnaces, lasers, processing equipment, plasma and ion sources, and deposition equipment.

▪ **Neutron and X-ray Scattering**	**22,076**	**31,211**	**36,293**

This activity supports basic research in condensed matter physics using neutron and x-ray scattering capabilities primarily at major BES-supported user facilities. Research seeks to achieve a fundamental understanding of the atomic, electronic, and magnetic structures and excitations of materials, and the relationship of these structures and excitations to the physical properties of materials. Both ordered and disordered materials are of interest as are strongly correlated electron systems, surface and interface phenomena and behavior under environmental variables such as temperature, pressure, and magnetic field. Also included in this activity is the development of neutron and x-ray instrumentation for next generation sources.

The type of information derived from neutron and x-ray scattering is very diverse with inelastic scattering allowing measurements of elastic, magnetic, and charge excitations (phonons, magnons, crystal field energies) and elastic scattering affording structural information. X-ray scattering allows researchers to “see” where the atoms are since x-ray wavelengths are commensurate with interatomic distances. The dramatic increase in brilliance of synchrotron radiation sources has directly improved the available photon flux to probe a limited sample volume over a small time domain making in-situ experiments on nanoscale samples a reality. Neutron scattering can provide information concerning the positions, motions, and magnetic properties of solids. Neutrons possess unique properties such as sensitivity to light elements which has made the technique invaluable to polymer and biological sciences. Neutrons have magnetic moments and are thus uniquely sensitive probes of magnetic interactions. Taken together, neutron and x-ray scattering cover an enormous range of energies and allow multiple length scales and associated phenomena to be probed.

Included within this request are funds to increase neutron science activities in the U.S. based on three recent BESAC reviews that addressed: (1) the current status of research activities using neutron scattering in the U.S. and strategies needed to take full advantage of the SNS upon its completion; (2) the scientific output, the operational effectiveness, and the user programs at the three operating BES neutron scattering facilities; and (3) the impacts resulting from the permanent shutdown of the High Flux Beam Reactor and the strategies to address those impacts. The studies presented several common findings and recommendations, including the importance of establishing a large and well-trained user community by the time the SNS is fully operational in the 2008-2010 timeframe. In FY 2002, funding is increased by $5,802,000 for academic scientists to participate in the development of neutron scattering instruments and for the neutron science/scattering programs at the host institutions of the BES facilities, where historically the interplay between science programs and instrument design and fabrication has produced advances in instrumentation and seminal scientific results.

Capital equipment is provided for items such as detectors, monochromators, mirrors, and beamline instrumentation at all of the facilities, including university proposals for instruments at the SNS in the range of $4,000,000 pending review.

	FY 2000	FY 2001	FY 2002
▪ **Experimental Condensed Matter Physics**	**30,785**	**34,326**	**34,326**

This activity supports a broad-based experimental program in condensed matter and materials physics with selected emphasis in the areas of electronic structure, surfaces/interfaces, and new materials. Research includes measurements of the properties of solids, liquids, glasses, surfaces, thin films, artificially structured materials, self-organized structures, and nanoscale structures. The materials examined include magnetic materials, superconductors, semiconductors and photovoltaics, liquid metals and alloys, and complex fluids. The development of new techniques and instruments including magnetic force microscopy, electron microscopic techniques, and innovative applications of laser spectroscopy is a major component of this activity. Measurements will be made under extreme conditions of temperature, pressure, and magnetic field - especially with the availability of the 100 Tesla pulsed field magnet at LANL.

This research is aimed at a fundamental understanding of the behavior of materials that underpin DOE technologies. Presently, the portfolio includes specific research thrusts in magnetism, semiconductors, superconductivity, materials synthesis and crystal growth, and photoemission spectroscopy. The portfolio addresses well-recognized needs, including understanding magnetism and superconductivity; the control of electrons and photons in solids; understanding materials at reduced dimensionality; the physical properties of large, interacting systems; and the properties of materials under extreme

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

conditions. The combined projects in superconductivity comprise a concerted and comprehensive energy-related research program. The DOE laboratories anchor the BES multi-disciplinary basic research efforts and maintain integration with the EE applied and developmental efforts. Research on magnetism and magnetic materials has more emphasis and direction than in other federally supported programs, focussing on hard magnet materials, such as those used for permanent magnets and in motors.

Major efforts in FY 2002 will include continued support for investigations of materials with increasingly complex behavior, composition, and structures. Extremely high quality crystals of transition metal oxides will be grown and subsequent high precision measurements of various physical properties will be made. There will be continued research on ferromagnetism, ferroelectricity, and superconductivity, because these have long been expected to demonstrate substantial changes when structures contain a small number of the relevant particles or when the system size is comparable to the particle size or the coherence length for collective behavior.

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

	FY 2000	FY 2001	FY 2002
▪ **Condensed Matter Theory**	**14,888**	**18,116**	**18,116**

This activity supports basic research in theory, modeling, and simulations, and it complements the experimental work. The links between the electronic, optical, mechanical, and magnetic properties of nanostructures and their size, shape, topology, and composition are not well understood. For the simplest semiconductor systems, carbon nanotubes, and similar "elementary" systems, there has been considerable progress though many unanswered questions remain. However, for more complex materials and hybrid structures, even the basic outlines of a theory describing these connections remains to be made. Stochastic simulation methods, as well as computational models incorporating quantum and semiclassical methods, are required to evaluate the performance of nanoscale devices. Consequently, computer simulations -- both electronic-structure-based and atomistic -- play a major role in understanding materials at the nanometer scale and in the development "by design" of new nanoscale materials and devices. The greatest challenges and opportunities are in those transition regions where nanoscale phenomena are just beginning to emerge from the macroscopic and microscale regimes, which may be described by bulk properties plus the effects of interfaces and lattice defects.

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

In FY 2002, this activity will provide support for theory, modeling and large-scale computer simulation to explore new nanoscale phenomena and the nanoscale regime. Also supported is the Computational Materials Sciences Network for studies of such topics as polymers at interfaces; fracture mechanics - understanding ductile and brittle behavior; microstructural evolution and microstructural effects on mechanics of materials, magnetic materials, modelling oxidation processes at surfaces and interfaces, and excited state electronic structure and response functions.

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

	FY 2000	FY 2001	FY 2002
▪ **Materials Chemistry**	**25,353**	**27,823**	**27,823**

This activity supports basic research on the chemical properties of materials to understand the effect of chemical reactivity on the behavior of materials and to synthesize new chemical compounds and structures from which better materials can be made, including research in solid state chemistry, surface chemistry, polymer chemistry, crystallography, synthetic chemistry, and colloid chemistry. Also supported are investigations of novel materials such as low-dimensional, self-assembled monolayers; polymeric conductors; organic superconductors and magnets; complex fluids; and biomolecular materials. The research employs a wide variety of experimental techniques to characterize these materials, including x-ray photoemission and other spectroscopies, scanning tunneling and atomic force microscopies, nuclear magnetic resonance (NMR), and x-ray and neutron reflectometry. The activity also supports the development of new experimental techniques, such as high-resolution magnetic resonance imaging (MRI) without magnets, neutron reflectometry, and atomic force microscopy of liquids.

The research underpins many technological areas, such as batteries and fuel cells, catalysis, friction and lubrication, membranes, electronics, and environmental chemistry. New techniques for fabrication of nanocrystals, such as a unique inverse micellar process, make possible the efficient elimination of dangerous chlorinated organic and phenolic pollutants (e.g., PCPs). Research on solid electrolytes has led to very thin rechargeable batteries that can be recharged many more times than existing commercial cells. Research on chemical vapor deposition (CVD) continues to impact the electronics industry. The development of synthetic membranes using biological synthesis may yield materials for separations and energy storage, and research on polymers may lead to light-weight structural materials which can be used in automobiles and thereby providing substantial savings in energy efficiency.

In FY 2002, the patterning of matter on the nanometer scale will continue to receive support. The controlled positioning of atoms within small molecules is of course routinely achieved by chemical synthesis. Nanometer-size objects are much larger entities, containing thousands or even millions of atoms. There are many powerful new approaches to patterning on the nanoscale that are fundamentally serial in nature, for instance atom manipulation using scanning probe tips or electron beam lithography. The research in this activity focuses on methods to prepare macroscopic quantities of nanoscale components in complex, designed patterns, using techniques of self-assembly.

Capital equipment is provided for such items as chambers to synthesize and grow new materials, nuclear magnetic resonance and electron spin resonance spectrometers, lasers, neutron reflectometers, x-ray beamlines, and atomic force microscopes.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Experimental Program to Stimulate Competitive Research** ...	**6,815**	**7,685**	**7,685**

This activity supports basic research spanning the complete range of activities within the Department in states that have historically received relatively less Federal research funding. The EPSCoR states are Alabama, Alaska, Arkansas, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, North Dakota, Oklahoma, South Carolina, South Dakota, Vermont, West Virginia, and Wyoming, and the Commonwealth of Puerto Rico. In FY 2002, Hawaii and New Mexico will be included among the DOE EPSCoR states. The work supported by the EPSCoR program includes research in materials sciences, chemical sciences, biological and environmental sciences, high energy and nuclear physics, fusion energy sciences, fossil energy sciences, and energy efficiency and renewable energy sciences. In FY 2001, an increase was provided to develop scientific manpower in the EPSCoR states through collaborative activities between faculty and students in EPSCoR states and staff in the extensive network of research laboratories and facilities in the Office of Science.

EPSCoR Distribution of Funds by State

	(dollars in thousands)		
	FY 2000	FY 2001 Estimate	FY 2002 Estimate
Alabama	225	425	375
Alaska[a]	0	0	0
Arkansas	90	110	65
Hawaii[b]	0	0	0
Idaho	162	113	60
Kansas	747	710	615
Kentucky	515	468	471
Louisiana	152	130	130
Maine	0	0	0
Mississippi	585	585	535
Montana	125	540	465
Nebraska	300	300	300
Nevada	466	370	325
New Mexico[b]	0	0	0
North Dakota	46	113	55
Oklahoma	100	165	65
Puerto Rico	65	435	435
South Carolina	855	870	120
South Dakota	50	0	0
Vermont	610	585	585
West Virginia	575	525	525
Wyoming	860	60	65
Technical Support	287	400	400
Other	0	781[c]	2,094[c]
Total	6,815	7,685	7,685

[a] Alaska becomes eligible for funding in FY 2001.

[b] Hawaii and New Mexico become eligible for funding in FY 2002.

[c] Uncommitted funds in FY 2001 and FY 2002 will be competed among all EPSCoR states.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Los Alamos Neutron Science Center (LANSCE) instrumentation enhancement at the Manuel Lujan Jr. Neutron Scattering Center (Lujan Center)**	**3,500**	**0**	**0**

This project is a major item of equipment with a revised total estimated cost of $12,500,000 -- down from the previous TEC of $20,500,000 -- to provide enhanced instrumentation at the Lujan Center. Instrument fabrication was implemented concurrently with an accelerator upgrade funded by the Office of Defense Programs. Two new neutron scattering instruments have been completed and are in different stages of assembly and commissioning. An Office of Science project review of the instrument project concluded that the two new instruments are "best in class." However, the recent BESAC review of the IPNS and the Lujan Center as well as the Office of Science project review of the instrument project concluded that the Lujan Center staff and LANSCE staff are seriously over committed. Based on these reviews, BES and LANL management agreed that the fabrication of the remaining two instruments originally planned for the Lujan Center should be stopped. As a result, the scope of this major item of equipment has been reduced. In order to maintain the communities of scientists who have come together to build these instruments, these instruments will be fabricated and located at the Intense Pulsed Neutron Source or other existing neutron scattering facilities. The Lujan Center remains a critical component of the Nation's neutron scattering capabilities, both in the short term and in the long-term. This change in instrument fabrication strategy does not change the BES or LANL commitment to this facility. Instrument upgrades and new instruments will be incorporated into future plans for this facility.

▪ **Extension of HB-2 Beam Tube at the High Flux Isotope Reactor**	**1,600**	**1,150**	**0**

This project is a major item of equipment with a total estimated cost of $5,550,000 that will provide beam access for six thermal neutron scattering instruments. Beam guides and optimized geometry will provide a neutron flux at the instrument positions 2-3 times higher than currently available. Completion of this MIE concludes the improvements that were undertaken at HFIR to improve neutron scattering capabilities during the reactor outage in FY 2000 and FY 2001 for the regularly scheduled (approximately every decade) replacement of the beryllium reflector. These improvements included installation of larger beam tubes and shutters for higher neutron flux on sample and fabrication and installation of a high-performance liquid hydrogen cold source to enable new classes of materials to be studied. **Performance will be measured** by maintaining cost and schedule within 10% of baselines.

▪ **Neutron Scattering Instrumentation at the High Flux Isotope Reactor**	**0**	**0**	**2,000**

Capital equipment funds are provided for new and upgraded instrumentation, such as spectrometers, defractometers, and detectors. **Performance will be measured** by maintaining cost and schedule within 10% of baselines.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **SPEAR3 Upgrade**	**0**	**8,300**	**8,300**

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade is being undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The technical goals are to increase injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decrease beam emittance by a factor of 7 to increase beam brightness; increase operating current from 100 mA to 200 mA to increase beam intensity; and maintain long beam life time (>25 hr). The increased photon flux will greatly improve performance in a variety of applications including powder and thin film diffraction, topographic studies, surface microcontamination studies, x-ray tomographic analysis, x-ray absorption studies, and protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring will be replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC is $29,000,000; DOE and NIH are equally funding the upgrade with a total Federal cost of $58,000,000. NIH has provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and is expected to provide $1,000,000 in FY 2001. The funding profile, but not the TEC, of this MIE has been modified based on an Office of Science construction project review, which recommended that some funds be shifted from later years to early years in order to reduce schedule risk by ensuring that critical components are available for installation when scheduled. That recommendation was accepted and is reflected in the current funding profile. **Performance will be measured** by continuing upgrades on the major components of the SPEAR3, maintaining cost and schedule within 10% of baselines. The increased brightness for all experimental stations at SSRL will greatly improve performance in a variety of applications and scientific studies.

▪ **Advanced Light Source Beamline**	**0**	**900**	**975**

This beamline is a major item of equipment with a total estimated cost of $6,000,000 that will provide capabilities for surface and interfacial science important to geosciences, environmental science, and aqueous corrosion science. It is being funded jointly by the Materials Sciences Subprogram and the Chemical Sciences Subprogram. **Performance will be measured** by maintaining cost and schedule within 10% of baselines.

Waste Management	**8,201**	**8,056**	**8,056**

These funds will be provided for disposal of wastes from current activities at ANL and Ames. This activity was funded by Environmental Management prior to FY 2001.

Facilities Operations	**204,605**	**221,963**	**207,454**
▪ **Operation of National User Facilities**	**185,727**	**206,622**	**207,454**

The facilities included in Materials Sciences are: Advanced Light Source, Advanced Photon Source, National Synchrotron Light Source, Stanford Synchrotron Radiation Laboratory, High Flux Isotope Reactor, Intense Pulsed Neutron Source, and Manuel Lujan, Jr. Neutron Scattering Center. Research and development in support of the construction of the Spallation Neutron Source is also included. The facility operations budget request, presented in a consolidated manner later in this budget, includes operating funds, capital equipment, and Accelerator and Reactor Improvements (AIP) funding under $5,000,000. AIP funding will support additions and modifications to accelerator and

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

reactor facilities that are supported in the Materials Sciences subprogram. Included in the AIP funding are funds for HFIR for the extension of the Neutron Sciences Support Building and for general infrastructure upgrades. Capital equipment is needed at the facilities for items such as beam monitors, interlock systems, vacuum systems, beamline front end components, monochromators, and power supplies. A summary of the funding for the facilities included in the Materials Sciences subprogram is provided below. Additional funds for facility operations for some of these facilities are included in the Chemical Sciences subprogram of this budget. **Performance will be measured** by maintaining and operating these user facilities so that the unscheduled downtime, on average, is less than 10% of the total scheduled operating time, as reported to Headquarters by facilities at the end of each fiscal year. For the Spallation Neutron Source, **performance will be measured** by maintaining cost and schedule of construction within 10% of baselines as reflected by regular independent reviews of the cost and schedule milestones. **Performance will be measured** by improving U.S. research in neutron science in preparation for the commissioning of the SNS by ensuring that BES neutron facilities are optimally available to the scientific community and by investing in instrumentation for the future.

- **High Flux Beam Reactor (HFBR)**.. **18,878** **15,341** **0**

The HFBR has been closed. Responsibility for the reactor has been transferred from SC to the Office of Environmental Management (EM) for surveillance and decommissioning. Surveillance will continue until the reactor is fully decommissioned and decontaminated by EM.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Facilities			
Advanced Light Source	30,652	35,605	37,605
Advanced Photon Source	84,783	90,314	90,314
National Synchrotron Light Source	23,174	26,907	26,907
Stanford Synchrotron Radiation Laboratory	3,992	3,858	3,858
High Flux Beam Reactor	18,878	15,341	0
High Flux Isotope Reactor	5,519	8,209	8,400
Intense Pulsed Neutron Source	12,739	13,480	16,080
Manuel Lujan, Jr. Neutron Scattering Center	6,968	9,190	9,190
Spallation Neutron Source	17,900	19,059	15,100
Total, Facilities	204,605	221,963	207,454

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
SBIR/STTR Funding	**0**	**10,246**	**9,859**

In FY 2000, $9,009,000 and $541,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.

	FY 2000	FY 2001	FY 2002
Total, Materials Sciences	**388,602**	**443,242**	**434,353**

Explanation of Funding Changes from FY 2000 to FY 2001

	FY 2002 vs. FY 2001 ($000)
Materials Sciences Research	
▪ Increase for neutron and x-ray scattering. This increase results from funds previously used for the support of the operations of the High Flux Beam Reactor. Funding is provided for a number of activities, including increased support for academic scientists to participate in the development of neutron scattering instruments and increased support for the neutron science/scattering programs at the host institutions of the BES facilities, where historically the interplay between science programs and instrument design and fabrication has produced advances in instrumentation and seminal scientific results.	+5,082
▪ Decrease in capital equipment funds for the Extension of HB-2 beam tube MIE at HFIR for thermal neutron scattering due to completion of project	-1,150
▪ Increase for neutron scattering instrumentation at HFIR, such as spectrometers, defractometers, and detectors	+2,000
▪ Increase in capital equipment funds for the ALS Beamline MIE per approved profile	+75
Total, Materials Sciences Research	+6,007
Facilities Operations	
▪ Increase support for HFIR. Includes a decrease for HFIR operations (-$1,619,000) which is offset by an increase of $1,316,000 for HFIR operations under the Chemical Sciences subprogram. Overall support for HFIR operations decreases by $303,000 due to decreased requirements associated with the tritium release. An increase in AIP for HFIR for extension of the Neutron Sciences Support Building, instrumentation and general infrastructure upgrades (+$2,210,000), and a decrease in GPP for the HFIR due to decreased needs (-$400,000).	+191

	FY 2002 vs. FY 2001 ($000)
▪ Increase for the Intense Pulsed Neutron Source for operations in response to a BESAC subpanel review recommendation to increase operating hours and user support.	+2,600
▪ Increase for the Advanced Light Source for equipment, such as spectrometers, defractometers, and improvements in insertion devices.	+2,000
▪ Termination of support for the operations of the HFBR. Responsibility has been transferred from SC to the Office of Environmental Management for surveillance and decommissioning.	-15,341
▪ Decrease in the Spallation Neutron Source research and development funds per FY 2002 project datasheet	-3,959
Total, Facilities Operations.	-14,509
SBIR/STTR	
▪ Decrease in SBIR/STTR funding because of decrease in operating expenses	-387
Total Funding Change, Materials Sciences	-8,889

Chemical Sciences

Mission Supporting Goals and Objectives

The Chemical Sciences subprogram supports a major portion of the Nation's fundamental research in the chemical sciences. The research covers a broad spectrum of the chemical sciences including atomic, molecular and optical (AMO) science; chemical physics; photo- and radiation chemistry; physical chemistry; inorganic chemistry; organic chemistry; analytical chemistry; separation science; heavy element chemistry; and aspects of chemical engineering sciences. This research provides a foundation for fundamental understanding of the interactions of atoms, molecules, and ions with photons and electrons; the making and breaking of chemical bonds in gas phase, in solutions, at interfaces, and on surfaces; and understanding the energy transfer processes within and between molecules. This work underpins our fundamental understanding of chemical reactivity. In turn, this enables the production of more efficient combustion systems with reduced emissions of pollutants. It also increases knowledge of solar photoconversion processes resulting in new, improved systems and production methods. This research has resulted in improvements to catalytic systems, new catalysts for the production of fuels and chemicals, and better analytical methods for a wide variety of applications in energy processes. It also provides new knowledge of actinide elements and separations important for environmental remediation and waste management. Finally, it provides better methods for describing turbulent combustion and predicting thermophysical properties of multicomponent systems.

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
Chemical Sciences Research	127,650	145,981	145,793	-188	-0.1%
Facilities Operations	70,290	65,595	67,911	+2,316	+3.5%
SBIR/STTR	0	4,950	5,010	+60	+1.2%
Total, Chemical Sciences	197,940	216,526	218,714	+2,188	+1.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Chemical Sciences Research	**127,650**	**145,981**	**145,793**
▪ **Atomic, Molecular, and Optical (AMO) Science**	**10,765**	**11,887**	**11,887**

This activity supports theory and experiment to understand the properties of and interactions among atoms, molecules, ions, electrons, and photons. Included among the research activities are studies to determine the quantum mechanical description of such properties and interactions; interactions of intense electromagnetic fields with atoms and molecules; development and application of novel x-ray light sources; and ultracold collisions and quantum condensates. This activity also supports the James R. MacDonald Laboratory at Kansas State University, a multi-investigator program and BES collaborative research center devoted to experimental and theoretical studies of collision processes involving highly charged ions.

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

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

Research priorities for FY 2002 include the interactions of atoms and molecules with intense electromagnetic fields that are produced by collisions with highly charged ions or short laser pulses; the use of optical fields to control quantum mechanical processes; atomic and molecular interactions at ultracold temperatures and the creation and utilization of quantum condensates, which provides strong linkages between atomic and condensed matter physics at the nanoscale; and the development and application of novel x-ray light sources based on table-top lasers and new utilization of third generation synchrotrons in advance of next-generation BES light sources.

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

▪ **Chemical Physics Research**	**25,019**	**32,647**	**33,488**

This activity supports experimental and theoretical investigations of gas phase chemistry and chemistry at surfaces. Gas phase chemistry emphasizes the dynamics and rates of chemical reactions at energies characteristic of combustion with the aim of developing validated theories and computational tools for predicting chemical reaction rates for use in combustion models and

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

experimental tools for validating these models. The study of chemistry at well characterized surfaces and the reactions of metal and metal oxide clusters leads to the development of theories on the molecular origins of surface mediated catalysis.

This activity also has oversight for the Combustion Research Facility (which is budgeted in Facilities Operations), a multi-investigator facility for the study of combustion science and technology. In-house BES-supported efforts combine theory, modeling, and experiment including diagnostic development, kinetics, and dynamics. Several innovative non-intrusive optical diagnostics such as degenerate four-wave mixing, cavity ring-down spectroscopies, high-resolution optical spectroscopy, and ion-imaging techniques have been developed to characterize gas phase processes. Other activities at the Combustion Research Facility involve BES interactions with the Office of Fossil Energy, the Office of Energy Efficiency and Renewable Energy, and industry.

This activity is the Nation's principal supporter of high temperature chemical kinetics and gas phase chemical physics. The Chemical Dynamics Beamline at the Advanced Light Source is run as a national resource. The Combustion Research Facility is home to the foremost fundamental research program on laser-based optical diagnostics for the measurement of chemical and fluid-mechanical parameters.

Work in FY 2002 will emphasize atomic and molecular clusters, which provide a basis for relating detailed, extended structures to the chemistry of molecules and molecular fragments with which they come into contact. Emerging capabilities for locating single molecules on metal surfaces and measuring their properties while on the surface open the way for developing detailed models for surface chemistry. The increased effort reflects a realignment of activities previously funded in chemical energy and chemical engineering that focused on modeling of heat transfer in combustion systems. These activities have developed in directions that incorporate an integrated molecular level focus. Shifting these activities to chemical physics reflects the coordination of theory and modeling that has developed in recent years.

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

▪ **Photochemistry and Radiation Research**................................	**23,731**	**26,167**	**26,167**

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

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

collaborative research center, which features cobalt-60 gamma irradiators, a van de Graaff-ESR and resonance Raman, and a linear accelerator for electron pulse radiolysis experiments.

Photochemistry research supports conversion of light energy to electrical or chemical energy, based on light-induced charge separation at semiconductor/liquid interfaces or in molecular biomimetic assemblies. Artificial photosynthesis can be coupled to chemical reactions for generation of fuels such as hydrogen, methane, or complex hydrocarbons found in gasoline. The fundamental concepts devised for highly efficient excited-state charge separation in molecule-based biomimetic assemblies should also be applicable in the future development of molecular optoelectronic devices. Radiation science research supports fundamental chemical effects produced by the absorption of energy from ionizing radiation. This research provides information on transients in solution and intermediates at liquid/solid interfaces for resolving important issues in solar energy conversion, environmental waste management and remediation; and intermediates relevant to nuclear energy production.

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

For FY 2002 research will continue to expand our knowledge of the semiconductor/liquid interface, colloidal semiconductors, and dye-sensitized solar cells; inorganic/organic donor-acceptor molecular assemblies and photocatalytic cycles; biophysical studies of photosynthetic antennae and the reaction center; and radiolytic processes at interfaces, radiolytic intermediates in supercritical fluids, and characterization of excited states by dual pulse radiolysis/photolysis experiments.

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

▪ **Catalysis and Chemical Transformation**	**23,125**	**24,929**	**24,929**

This activity supports basic research to understand the chemical aspects of catalysis, both heterogeneous and homogeneous; the chemistry of fossil resources; and the chemistry of the molecules used to create advanced materials. Catalysts are crucial to energy conservation in creating new, less-energy-demanding routes for the production of basic chemical feedstocks and value-added chemicals. Catalysts are also indispensable for processing and manufacturing fuels that are a primary means of energy storage. Results from a fundamental, molecular-level understanding of the syntheses of advanced catalytic materials have the potential of providing new chemicals or materials that can be fabricated with greater energy efficiency or function as energy-saving media themselves.

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

In FY 2002 research will continue to focus on understanding the unique catalytic properties of metal, as well as mixed metal and oxide particles and their role in surface catalyzed reactions enabled by nanoscience engineering and technology. Increased emphasis will also be placed on the properties of reactions within nanoscale cavities. Key to these efforts will be studies on the structure, function, and reactivity of metal clusters both in solution as well as dispersed supports. Other activities will include the synthesis of discrete nanomaterials created from a controlled assembly of molecular building blocks.

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

	FY 2000	FY 2001	FY 2002
▪ **Separations and Analyses**	**12,255**	**12,747**	**13,047**

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

Chemical separations are ubiquitous in Department missions and in industry. An analysis is an essential component of every chemical process from manufacture through safety and risk assessment and environmental protection. The goal of this activity is to obtain a thorough understanding of the basic chemical and physical principles involved in separations systems and analytical tools so that their utility can be realized. Work is closely coupled to the Department's stewardship responsibility for transuranic chemistry and for the clean-up mission; therefore, separation and analysis of transuranic isotopes and their radioactive decay products are important components of the portfolio.

Increased funding in FY 2002 will emphasize new opportunities in single-molecule detection for the study of molecule-molecule, molecule-membrane, and molecule-surface interactions.

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

	FY 2000	FY 2001	FY 2002
▪ **Heavy Element Chemistry**	**6,753**	**7,410**	**7,685**

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

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

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Approximately twenty undergraduate students chosen from universities and colleges throughout the U.S. are given introductory lectures in actinide and radiochemistry each summer.

This activity is closely coupled to the BES separations and analysis activity and to the actinide and fission product chemistry efforts in DOE's Environmental Management Science Program.

Increased funding will enable new opportunities for FY 2002 in the emerging areas of actinide molecular speciation and reactivity and in advanced theoretical and computational methods for prediction of electronic and molecular structure of actinide complexes.

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

	FY 2000	FY 2001	FY 2002
▪ **Chemical Energy and Chemical Engineering**	**9,891**	**11,989**	**11,020**

This activity supports research on electrochemistry, thermophysical and thermochemical properties, and physical and chemical rate processes. Emphasis is given to improving and/or developing the scientific base for engineering generalizations and their unifying theories. Also included is fundamental research in areas critical to understanding the underlying limitations in the performance of electrochemical energy storage and conversion systems including anode, cathode, and electrolyte systems and their interactions with emphasis on improvements in performance and lifetime. The program covers a broad spectrum of research including fundamental studies of composite electrode structures; failure and degradation of active electrode materials; thin film electrodes, electrolytes, and interfaces; and experimental and theoretical aspects of phase equilibria, especially of mixtures, including supercritical phenomena

There are strong links with related efforts within the Department and other federal agencies through the Interagency Power Working Group.

For FY 2002, decreased funding reflects the shift of combustion modeling efforts to the chemical physics activity. There will be continued emphasis on research to expand the ability to control electrode structures on the nanometer scale. Preliminary studies have shown that this has a great impact on the electrochemical efficiency of electrode processes and the rate at which they respond to electrochemical potentials.

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

	FY 2000	FY 2001	FY 2002
▪ **General Plant Projects (GPP)**	**10,275**	**11,550**	**11,840**

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

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **General Purpose Equipment (GPE)**	**5,086**	**4,055**	**4,055**

GPE funding is provided for Ames Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory as part of the Basic Energy Sciences stewardship responsibilities for these laboratories for general purpose equipment that supports multipurpose research. Increased infrastructure funding is requested to maintain, modernize, and upgrade ORNL, ANL, and Ames site and facilities to correct deficiencies due to aging, changing technology, and inadequate past investments.

▪ **SPEAR3 Upgrade**	**0**	**1,700**	**700**

Over the period FY 1999 - FY 2003, the SPEAR3 upgrade is being undertaken at SSRL to provide major improvements to all existing experimental stations served by this synchrotron radiation light source. The technical goals are to increase injection energy from 2.3 GeV to 3 GeV to improve the energy spectrum available to users; decrease beam emittance by a factor of 7 to increase beam brightness; increase operating current from 100 mA to 200 mA to increase beam intensity; and maintain long beam life time (>25 hr). The increased photon flux will greatly improve performance in a variety of applications including powder and thin film diffraction, topographic studies, surface microcontamination studies, x-ray tomographic analysis, x-ray absorption studies, and protein crystallography. The magnets and associated vacuum chambers of the existing SPEAR storage ring will be replaced in order to implement the revised lattice system. All components are housed within the existing buildings. The TEC is $29,000,000; DOE and NIH are equally funding the upgrade with a total Federal cost of $58,000,000. NIH has provided $14,000,000 in FY 1999, $14,000,000 in FY 2000, and is expected to provide $1,000,000 in FY 2001. The funding profile, but not the TEC, of this MIE has been modified based on an Office of Science construction project review, which recommended that some funds be shifted from later years to early years in order to reduce schedule risk by ensuring that critical components are available for installation when scheduled. That recommendation was accepted and is reflected in the current funding profile. **Performance will be measured** by continuing upgrades on the major components of the SPEAR3, maintaining cost and schedule within 10% of baselines. The increased brightness for all experimental stations at SSRL will greatly improve performance in a variety of applications and scientific studies.

▪ **Advanced Light Source Beamline**	**750**	**900**	**975**

This beamline is a major item of equipment with a total estimated cost of $6,000,000 that will provide capabilities for surface and interfacial science important to geosciences, environmental science, and aqueous corrosion science. It is being funded jointly by the Materials Sciences subprogram and the Chemical Sciences subprogram. **Performance will be measured** by maintaining cost and schedule within 10% of baselines.

Facilities Operations	**70,290**	**65,595**	**67,911**

The facilities included in Chemical Sciences are: National Synchrotron Light Source, Stanford Synchrotron Radiation Laboratory, High Flux Isotope Reactor, Radiochemical Engineering Development Center, and Combustion Research Facility. The facility operations budget request, which includes operating funds, capital equipment, general plant projects, and AIP funding under $5,000,000, is

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

described in a consolidated manner later in this budget. A summary table of the facilities included in this Chemical Sciences subprogram is provided below. Additional funds for facility operations for some of these facilities are included in the Materials Sciences subprogram of this budget. **Performance will be measured** by maintaining and operating these user facilities so that the unscheduled downtime, on average, is less than 10% of the total scheduled operating time, as reported to Headquarters by facilities at the end of each fiscal year.

AIP funding will support additions and modifications to accelerator and reactor facilities, which are supported in the Chemical Sciences subprogram. General Plant Project (GPP) funding is also required for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. The total estimated cost of each GPP project will not exceed $5,000,000. Capital equipment is needed for the facilities for items such as beam monitors, interlock systems, vacuum systems, beamline front-end components, monochromators, and power supplies.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Facilities			
National Synchrotron Light Source	7,781	7,813	7,813
Stanford Synchrotron Radiation Laboratory	18,749	16,838	17,838
High Flux Isotope Reactor	32,215	28,769	30,085
Radiochemical Engineering Development Center	6,809	6,712	6,712
Combustion Research Facility	4,736	5,463	5,463
Total, Facilities	70,290	65,595	67,911

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
SBIR/STTR Funding	**0**	**4,950**	**5,010**

In FY 2000, $4,435,000 and $266,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.

Total, Chemical Sciences	**197,940**	**216,526**	**218,714**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Chemical Sciences Research	
▪ Increase in funding for chemical physics reflects a transfer of activities previously funded in chemical energy and chemical engineering that focused on modeling of heat transfer in combustion systems. These efforts are maintained at the FY 2001 level.	+841
▪ Increase in research for separations and analysis to emphasize new opportunities in single-molecule detection for the study of molecule-molecule, molecule-membrane, and molecule-surface interactions.	+300
▪ Increase in research for heavy element chemistry to enable new opportunities in the emerging areas of actinide molecular speciation and reactivity and in advanced theoretical and computational methods for prediction of electronic and molecular structure of actinide complexes.	+275
▪ Decrease in funding for chemical energy and chemical engineering reflects the shift of combustion modeling efforts to the chemical physics activity.	-969
▪ Decrease in capital equipment funding for the SPEAR3 Upgrade MIE per approved funding profile	-1,000
▪ Increase in General Plant Projects	+290
▪ Increase in capital equipment funding for the ALS Beamline MIE per approved funding profile	+75
Total, Chemical Sciences Research	-188
Facilities Operations	
▪ Increase for the Stanford Synchrotron Radiation Laboratory for operations.	+1,000
▪ Increase for the High Flux Isotope Reactor (HFIR) for operations. This increase is offset by a decrease of $1,619,000 for HFIR operations under the Materials Sciences subprogram. Overall support for HFIR operations decreases by $303,000 due to decreased requirements associated with the tritium release	+1,316
Total, Chemical Sciences Facilities	+2,316
SBIR/STTR	
▪ Increase SBIR/STTR funding because of increase in operating expenses.	+60
Total Funding Change, Chemical Sciences	+2,188

Engineering and Geosciences

Mission Supporting Goals and Objectives

Engineering research supports basic research in nanotechnology and microsystems; multi-component fluid dynamics and heat transfer; and non-linear dynamic systems. New capabilities at the nano and micro scale will improve materials processing and quality, increase computing speed, improve sensing and control capabilities; together these lead to higher process efficiency and lower energy consumption. Improving the knowledge base on multi-components fluid dynamics and heat transfer will have a major impact on energy consumption, because these phenomena are an integral part of every industrial process. Advances in non-linear dynamics will lead to improved control and predictive capabilities of complex systems, thus resulting in higher efficiency and lower energy consumption. These activities are closely coordinated with work in the Materials Sciences subprogram, particularly with the Structure and Composition of Materials, Mechanical Behavior and Radiation Effects, Physical Behavior, and Synthesis and Processing activities.

Geosciences research supports basic research in geochemistry and geophysics emphasizing solid earth sciences. The geochemistry research focuses on advanced investigations of mineral-fluid interactions. Work includes studies on rates and mechanisms of reaction, coupled reactive fluid flow, and isotopic tracking of mineral-fluid interactions. The geophysics research focuses on developing an improved understanding of rock, fluid, and fracture physical properties. It includes studies on the surface determination of geologic structures and rock property distributions at depth; improved methods of collection, inversion, analysis of seismic and electromagnetic data; and identification of geophysical signatures of natural and man-made heterogeneities such as fractures, and fluid flow pathways. Also studied are the mechanical stability of geological reservoirs, multi phase flows within aquifers, geochemical reactivity and geophysical imaging; these areas provide fundamental scientific foundations to sequestration science associated with geological formations. The geosciences activity represents one third of the Nation's total federal support for investigator-driven basic research in solid earth sciences. It provides the majority of support in the federal government for basic research related to unique DOE missions, such as high-resolution shallow earth imaging and geochemical processes in the shallow subsurface. As such, it provides the scientific foundation for the multiple earth science-related mission activities in DOE applied programs.

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

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Engineering Research	14,024	17,383	16,577	-806	-4.6%
Geosciences Research	21,615	21,387	21,387	0	0%
SBIR/STTR	0	996	974	-22	-2.2%
Total, Engineering and Geosciences	35,639	39,766	38,938	-828	-2.1%

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Engineering Research	**14,024**	**17,383**	**16,577**

This activity focuses on nanotechnology and microsystems; multi-component fluid dynamics and heat transfer; and non-linear dynamic systems. Efforts will continue in select topics of nano-engineering; predictive non-destructive evaluation of structures coupled with micromechanics and nano/microtechnology; multi-phase flow and heat transfer; system sciences, control, and instrumentation; data and engineering analysis; and robotics and intelligent machines.

In the area of nanoscience, work focuses on nanomechanics and nano to micro assembly, networks of nano sensors, hybrid microdevices, energy transport and conversion, nanobioengineering, nucleation and nanoparticle engineering issues. Activities in the control and optimization of robotics and intelligent machines focuses on missions in dynamic, uncertain and extreme environments, sensor fusion and integration for distributive robot systems, collaborative research using remote and virtual systems, intelligent machine controls, and improved remote operation of SC strategic facilities to meet programmatic goals.

In FY 2002, there will be small decreases in research in the areas of fluid dynamics, control systems, sensors, and sensor integration.

	FY 2000	FY 2001	FY 2002
Geosciences Research	**21,615**	**21,387**	**21,387**

The Geosciences subprogram supports long term basic research in geochemistry and geophysics. Geochemical research focuses on fundamental understanding of and the ability to predict subsurface solution chemistry, mineral-fluid interactions, and isotopic distributions and migration in natural systems. The range of geochemical knowledge needed to impact energy and environmental technologies ranges from the molecular levels to the field scale.

Geophysical research focuses on new approaches to understand physical properties of fluids, rocks and minerals. It seeks fundamental understanding of the physics of wave propagation in complex media ranging from single crystals to the scale of the earth's crust. This research enables the advancement in remote imaging of subsurface properties. These studies provide the fundamental science base for new

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

capabilities to locate and monitor oil and gas reservoirs, contaminant migration and for characterizing disposal sites for energy related wastes. Improved understanding of earth processes is required to quantitatively predict the response of earth systems to natural and man-made perturbations. Research also seeks to understand the fundamental geological processes that impact concepts for sequestration of carbon dioxide in subsurface reservoirs.

SBIR/STTR Funding	**0**	**996**	**974**

In FY 2000, \$885,000 and \$53,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.

Total, Engineering and Geosciences	**35,639**	**39,766**	**38,938**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Engineering Research	
▪ Decrease in engineering research in areas of fluid dynamics, control systems, sensors, and sensor integration.	-806
SBIR/STTR	
▪ Decrease in SBIR/STTR funding because of decrease in operating expenses.	-22
Total Funding Change, Engineering and Geosciences	-828

Energy Biosciences

Mission Supporting Goals and Objectives

The Energy Biosciences subprogram supports fundamental research in the plant and microbial sciences to create the science base to develop future energy-related biotechnologies. The program supports research in a number of topic areas. These include fundamental molecular level understanding of solar energy capture by plants and microbes through photosynthesis; the genetic regulation of carbon fixation and carbon/energy storage; metabolic pathways for biological synthesis, degradation and molecular inter-conversions of energy-rich organic compounds and polymers; the regulation of plant growth and development. The subprogram also provides a fundamental biological research base to interface with traditional disciplines in the physical sciences. There are connections with research activities in each of the other BES subprograms, including, for example, materials sciences and engineering at the nanoscale; materials chemistry; photochemistry; biomaterials synthesis; and biogeochemistry.

Plant genome research will continue developing knowledge gained from sequencing efforts to characterize gene sets involved in specific metabolic and intermediary pathways and networks, providing a foundation for future control and manipulation of plant genetic resources. Research on the microbial cell will focus on understanding the complete physiological and biochemical roles of the genes required for growth and specific bioprocesses. This information will enable the control, modification, and use of microbes for both natural and industrial energy-related applications.

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

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Energy Biosciences	29,850	32,353	31,559	-794	-2.5%
SBIR/STTR	0	863	841	-22	-2.5%
Total, Energy Biosciences	29,850	33,216	32,400	-816	-2.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Energy Biosciences Research	**29,850**	**32,353**	**31,559**
▪ **Molecular Mechanisms of Energy Conversion**	**12.760**	**12,554**	**12,221**

This activity supports fundamental research to characterize the molecular mechanisms involved in the conversion of solar energy to biomass, biofuels, bioproducts, and other renewable energy resources. Research supported includes the characterization of the energy transfer processes occurring during photosynthesis, the kinetic and catalytic mechanisms of enzymes involved in the synthesis of methane, the biochemical mechanisms involved in the synthesis and degradation of lignocellulosics, and the mechanisms of plant oil production. The approaches used include biophysical, biochemical, and molecular genetic analyses. The goal is to enable the future biotechnological exploitation of these processes and, also, to provide insights and strategies into the design of non-biological processes. This activity also encourages fundamental research in the biological sciences that interfaces with other traditional disciplines in the physical sciences. In FY 2002, funding decreases reduce support for fundamental kinetic studies of enzyme catalyzed reactions.

▪ **Metabolic Regulation of Energy Production**	**17,090**	**17,391**	**16,930**

This activity supports fundamental research in regulation of metabolic pathways and the integration of multiple pathways that constitute cellular function in plants and microbes. Plants and microorganism have the capacity to synthesize an almost limitless variety of energy-rich organic compounds and polymers. Research supported includes the identification of genes and gene families in relation mechanisms of enzyme activity and the control of metabolic and signaling pathways of energy related pathways in plants. The goal is to understand entire gene expression profiles in response to developmental, environmental and metabolic requirements. Knowledge gained from plant and microbial gene sequencing, functional genomics and traditional molecular genetic, biochemical and biophysical studies will be integrated to address these goals. Plants and microbes are important commercial sources of materials such as cellulose (paper and wood), starch, sugars, oils, waxes, a variety of biopolymers, and many other biofuels and energy rich biomaterials. Thus, a basic understanding of plant and microbe cellular function has great ramifications for efficient energy utilization and renewal. In FY 2002, decreased funding will reduce support for studies on gene expression in response to environmental factors.

Major activities in FY 2002 will include functional genomic analysis of the *Arabidopsis* genome and continued use of *Arabidopsis* as a model system for the study of other plant systems with broader utility. Microbial research will include the molecular genetic, physiological, and biochemical characterization of the regulation and synthesis of components underlying energy relevant processes.

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		
▪ **Microbial Cell Research**	**0**	**2,408**	**2,408**

This activity supports fundamental research to understand reactions, pathways, and regulatory networks involved in bioprocesses relevant to the DOE mission, such as cellulose degradation; carbon sequestration; the production, conversion, or conservation of energy (e.g. fuels, chemicals, and chemical feedstocks); and the bioremediation of metals and radionuclides from contaminated sites. Research areas of particular interest include biochemical and physiological characterization of components involved in energy-related bioprocesses; intracellular localization of proteins and metabolites; microbial cell modeling; and functional analysis of the microbial proteome. Research will focus on such physiological processes as extracellular polymer degradation, photoautotrophy, cell movement, syntrophic or synergistic interactions with other bacterial, and responses to external physical stresses. Of particular scientific interest is understanding how individual genes (or gene families) and their encoded bioprocesses interact at the molecular level to permit control and stability in the entire microbial cell. This activity combines the strengths of the Energy Biosciences subprogram in biochemistry and physiology with the strengths of the Biological and Environmental Research program in genomics, structural biology and computational biology in a coordinated activity.

	FY 2000	FY 2001	FY 2002
SBIR/STTR Funding	**0**	**863**	**841**

Amounts shown are the estimated requirement for the continuation of the SBIR and STTR programs.

	FY 2000	FY 2001	FY 2002
Total, Energy Biosciences	**29,850**	**33,216**	**32,400**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Energy Biosciences Research	
▪ Decrease in molecular mechanisms reduces support for fundamental kinetic studies of enzyme catalyzed reactions.	-333
▪ Decrease in metabolic regulation reduces support for studies on gene expression in response to environmental factors.	-461
▪ Decrease in SBIR/STTR because of decrease in operating expenses.	-22
Total Funding Change, Energy Biosciences	-816

Construction

Mission Supporting Goals and Objectives

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

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Construction, SNS	100,000	258,929	276,300	+17,371	+6.7%
Project Engineering Design	0	0	4,000	+4,000	+100.0%
Total, Construction	100,000	258,929	280,300	+21,371	+8.3%

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Construction	**100,000**	**258,929**	**280,300**
Spallation Neutron Source	**100,000**	**258,929**	**276,300**

FY 2002 budget authority is requested to complete the ion source and continue component procurements for and fabrication of the linac structures and magnet systems, target assemblies, and the global controls. The assembly and testing of technical components will continue. Installation efforts will begin in the front end and the low energy sections of the linac. Title II design will continue for the target and experimental instruments. Work on conventional facilities will continue; some will reach completion and be turned over for equipment installation, such as the front end building, and portions of the klystron hall and linac tunnel. **Performance will be measured** by continued construction of the SNS, meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Once completed in mid-2006, the SNS will provide beams of neutrons used to probe and understand the physical, chemical, and biological properties of materials at an atomic level, leading to improvements in high technology industries.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Project Engineering Design...	**0**	**0**	**4,000**

FY 2002 budget authority is requested to provide Title I and Title II design-only funding for Nanoscale Science Research Centers (NSRCs) to assure project feasibility, define the scope, and provide estimates of construction costs and schedules. NSRCs will provide state-of-the-art facilities for materials nanofabrication and advanced tools for nanocharacterization to the scientific community.

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Construction	
▪ The increase in funding for the Spallation Neutron Source represents the scheduled ramp up of activities.	+17,371
▪ Increase in funding for Project Engineering Design related to design-only activities for Nanoscale Science Research Centers.	+4,000
Total Funding Change, Construction..	+21,371

Major User Facilities

Mission Supporting Goals and Objectives

The BES scientific user facilities provide experimental capabilities that are beyond the scope of those found in laboratories of individual investigators. Synchrotron radiation light sources, high-flux neutron sources, electron beam microcharacterization centers, and other specialized facilities enable scientists to carry out experiments that could not be done elsewhere. These facilities are part of the Department's system of scientific user facilities, the largest of its kind in the world. A description of each facility is provided in the "Site Descriptions" section. Any unusual or nonrecurring aspects of funding are described in the following section "Detailed Program Justification."

The facilities are planned in collaboration with the scientific community and are constructed and operated by BES for support of forefront research in areas important to BES activities and also in areas that extend beyond the scope of BES activities such as structural biology, medical imaging, and micro machining. These facilities are used by researchers in materials sciences, chemical sciences, earth and geosciences, environmental sciences, structural biology, superconductor technology, and medical research and technology development. The facilities are open to all qualified scientists from academia, industry, and the federal laboratory system whose intention is to publish in the open literature. The funding schedule includes only those facilities that have operating budgets for personnel, utilities, and maintenance.

Funding Schedule

Funding for the operation of these facilities is provided in the Materials Sciences and Chemical Sciences subprograms.

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Advanced Light Source	30,652	35,605	37,605	+2,000	+5.6%
Advanced Photon Source	84,783	90,314	90,314	0	0%
National Synchrotron Light Source	30,955	34,720	34,720	0	0%
Stanford Synchrotron Radiation Laboratory	22,741	20,696	21,696	+1,000	+4.8%
High Flux Beam Reactor	18,878	15,341	0	-15,341	-100.0%
High Flux Isotope Reactor	37,734	36,978	38,485	+1,507	+4.1%
Radiochemical Engineering Development Center	6,809	6,712	6,712	0	0%
Intense Pulsed Neutron Source	12,739	13,480	16,080	+2,600	+19.3%
Manuel Lujan, Jr. Neutron Scattering Center	6,968	9,190	9,190	0	0%
Spallation Neutron Source	17,900	19,059	15,100	-3,959	-20.8%
Combustion Research Facility	4,736	5,463	5,463	0	0%
Total, Major User Facilities	274,895	287,558	275,365	-12,193	-4.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Major User Facilities	**274,895**	**287,558**	**275,365**
▪ Advanced Light Source at Lawrence Berkeley National Laboratory.	**30,652**	**35,605**	**37,605**
▪ Advanced Photon Source at Argonne National Laboratory.	**84,783**	**90,314**	**90,314**
▪ National Synchrotron Light Source at Brookhaven National Laboratory.	**30,955**	**34,720**	**34,720**
▪ Stanford Synchrotron Radiation Laboratory at Stanford Linear Accelerator Center.	**22,741**	**20,696**	**21,696**
▪ High Flux Beam Reactor at Brookhaven National Laboratory. On November 16, 1999, Secretary Richardson announced the permanent closure of the reactor. Responsibility has been transferred from SC to the Office of Environmental Management for surveillance and decommissioning.	**18,878**	**15,341**	**0**
▪ High Flux Isotope Reactor at Oak Ridge National Laboratory.	**37,734**	**36,978**	**38,485**
▪ Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory.	**6,809**	**6,712**	**6,712**
▪ Intense Pulsed Neutron Source at Argonne National Laboratory.	**12,739**	**13,480**	**16,080**
▪ Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory.	**6,968**	**9,190**	**9,190**
▪ Spallation Neutron Source at Oak Ridge National Laboratory.	**17,900**	**19,059**	**15,100**
▪ Combustion Research Facility at Sandia National Laboratories/California.	**4,736**	**5,463**	**5,463**
Total, Major User Facilities	**274,895**	**287,558**	**275,365**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	10,622	12,300	12,190	-110	-0.9%
Accelerator Improvement Projects	11,816	9,435	11,645	+2,210	+23.4%
Capital Equipment	47,416	59,340	62,940	+3,600	+6.1%
Total, Capital Operating Expenses	69,854	81,075	86,775	+5,700	+7.0%

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Unapprop-riated Balances
99-E-334 Spallation Neutron Source, ORNL	1,192,700	101,400	100,000	258,929	276,300	456,071
02-SC-002 PED, Nanoscale Science Research Centers	14,000 [a]	0	0	0	4,000	10,000
Total, Construction		101,400	100,000	258,929	280,300	466,071

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 Request	Accept-ance Date
Short Pulse Spallation Upgrade at LANSCE – LANL	12,500	9,000	3,500	0	0	FY 2002
HB-2 Beam Tube Extension at HFIR - ORNL	5,550	2,800	1,600	1,150	0	FY 2001
SPEAR3 Upgrade	29,000 [b]	0	0	10,000	9,000	FY 2003
ALS Beamline	6,000	1,500	750	1,800	1,950	FY 2003
Total, Major Items of Equipment		13,300	5,850	12,950	10,950	

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[a] The full Total Estimated Cost (design and construction) ranges between $220,000,000 and $330,000,000. This estimate is based on conceptual data and should not be construed as a project baseline.

[b] DOE portion only; total estimated Federal cost, including NIH funding (beginning in FY 1999), is $58,000,000.

99-E-334 - Spallation Neutron Source, Oak Ridge National Laboratory, Oak Ridge, Tennessee

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

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1999 Budget Request (*Preliminary Estimate*)	1Q 1999	4Q 2003	3Q 2000	4Q 2005	1,138,800	1,332,800
FY 2000 Budget Request	1Q 1999	4Q 2003	3Q 2000	1Q 2006	1,159,500	1,360,000
FY 2001 Budget Request	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,220,000	1,440,000
FY 2001 Budget Request (*Amended*)	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2002 Budget Request (*Current Estimate*)	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
1999	101,400	101,400	37,140
2000	100,000	100,000	105,542
2001	258,929	258,929	228,506
2002	276,300	276,300	285,600
2003	210,571	210,571	231,600
2004	124,600	124,600	143,000
2005	79,800	79,800	94,800
2006	41,100	41,100	66,512

3. Project Description, Justification and Scope

The purpose of the Spallation Neutron Source (SNS) Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering and related research in broad areas of the physical, chemical, materials, biological, and medical sciences. The SNS will be a national facility with an open user policy attractive to scientists from universities, industries, and federal laboratories. It is anticipated that the facility, when in full operation, will be used by 1,000-2,000 scientists and engineers each year and that it will meet the national need for neutron science capabilities well into the 21st century. Neutrons enable scientists studying the physical, chemical, and biological properties of materials to determine how atoms and molecules are arranged and how they move. This is the microscopic basis for understanding and developing materials of technological significance to support information technology, transportation, pharmaceuticals, magnetic, and many other economically important areas.

The importance of neutron science for fundamental discoveries and technological development is universally acknowledged. The scientific justification and need for a new neutron source and instrumentation in the U.S. have been thoroughly established by numerous studies by the scientific community since the 1970s. These include the 1984 National Research Council study *Major Facilities for Materials Research and Related Disciplines* (the Seitz-Eastman Report), which recommended the immediate start of the design of both a steady-state source and an accelerator-based pulsed spallation source. More recently, the 1993 DOE Basic Energy Sciences Advisory Committee (BESAC) report *Neutron Sources for America's Future* (the Kohn Panel Report) again included construction of a new pulsed spallation source with SNS capabilities among its highest priorities. This conclusion was even more strongly reaffirmed by the 1996 BESAC Report (the Russell Panel Report), which recommended the construction of a 1 megawatt (MW) spallation source that could be upgraded to significantly higher powers in the future.

Neutrons are a unique and increasingly indispensable scientific tool. Over the past decade, they have made invaluable contributions to the understanding and development of many classes of new materials, from high temperature superconductors to fullerenes, a new form of carbon. In addition to creating the new scientific knowledge upon which unforeseen breakthroughs will be based, neutron science is at the core of many technologies that currently improve the health of our citizenry and the safety and effectiveness of our industrial materials.

The information that neutrons provide has wide impacts. For example, chemical companies use neutrons to make better fibers, plastics, and catalysts; drug companies use neutrons to design drugs with higher potency and fewer side effects; and automobile manufacturers use the penetrating power of neutrons to understand how to cast and forge gears and brake discs in order to make cars run better and more safely. Furthermore, research on magnetism using neutrons has led to higher strength magnets for more efficient electric generators and motors and to better magnetic materials for magnetic recording tapes and computer hard drives.

Based on the recommendations of the scientific community obtained via the Russell Panel Report, the SNS is required to operate at an average power on target of at least 1 megawatt (MW); although the designers had aimed for 2 MW, current projections fall between 1 to 2 MW. At this power level, the SNS will be the most powerful spallation source in the world-many times that of ISIS at the Rutherford Laboratory in the United Kingdom. Furthermore, the SNS is specifically designed to take advantage of improvements in technology, new technologies, and additional hardware to permit upgrades to substantially higher power as they become available. Thus, the SNS will be the nation's premiere neutron facility for many decades.

The importance of high power, and consequently high neutron flux (i.e., high neutron intensity), cannot be overstated. The properties of neutrons that make them an ideal probe of matter also require that they be generated with high flux. (Neutrons are particles with the mass of the proton, with a magnetic moment, and with no electrical charge.) Neutrons interact with nuclei and magnetic fields; both interactions are extremely weak, but they are known with great accuracy. Because they have spin, neutrons have a magnetic moment and can be used to study magnetic structure and magnetic properties of materials. Because they weakly interact with materials, neutrons are highly penetrating and can be used to study bulk phase samples, highly complex samples, and samples confined in thick-walled metal containers. Because their interactions are weak and known with great accuracy, neutron scattering is far more easily interpreted than either photon scattering or electron scattering. However, the relatively low flux of existing neutron sources and the small fraction of neutrons that get scattered by most materials means most measurements are limited by the source intensity.

The pursuit of high-flux neutron sources is more than just a desire to perform experiments faster, although that, of course, is an obvious benefit. High flux enables broad classes of experiments that cannot be done with low-flux sources. For example, high flux enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions. Put most simply, high flux enables studies of complex materials in real time and in all disciplines--physics, chemistry, materials science, geosciences, and biological and medical sciences.

The SNS will consist of a linac-ring accelerator system that delivers short (microsecond) pulses to a target/moderator system where neutrons are produced by a nuclear reaction process called spallation. The process of neutron production in the SNS consists of the following: negatively charged hydrogen ions are produced in an ion source and are accelerated to approximately 1 billion electron volts (GeV) energy in a linear accelerator (linac); the hydrogen ion beam is injected into an accumulator ring through a stripper foil, which strips the electrons off of the hydrogen ions to produce a proton beam; the proton beam is collected and bunched into short pulses in the accumulator ring; and, finally, the proton beam is injected into a heavy metal target at a frequency of up to 60 Hz. The intense proton bursts striking the target produce pulsed neutron beams by the spallation process. The high-energy neutrons so produced are moderated (i.e., slowed down) to reduce their energies, typically by using thermal or cold moderators. The moderated neutron beams are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations.

The primary objectives in the design of the site and buildings for the SNS are to provide optimal facilities for the DOE and the scientific community for neutron scattering well into the 21st Century and to address the mix of needs associated with the user community, the operations staff, security, and safety.

A research and development program is required to ensure technical feasibility and to determine physics design of accelerator and target systems that will meet performance requirements.

The objectives stated above will be met by the technical components described earlier (ion source; linac; accumulator ring; target station with moderators; beam transport systems; and initial experimental equipment necessary to place the SNS in operation) and attendant conventional facilities. In order to keep pace with the current state-of-the-art in scientific instruments, the average cost per instrument has roughly doubled in recent years. Although this translates into fewer than the ten instruments originally envisioned in the TEC, there will be no sacrifice in scientific capability. As with all scientific user facilities such as SNS, additional and even more capable instruments will be installed over the course of its operating lifetime.

The FY 2000 budget authority provided for completing most preliminary (Title I) design activities and starting detailed (Title II) design, construction site preparation, long-lead hardware procurement, and continued critical research and development work necessary to reduce technical and schedule risks.

FY 2001 budget authority is being used for conducting detailed design and starting fabrication of the ion source, low-energy beam transport, linac structures and magnet systems, target assemblies, experimental instruments and global control systems. Construction work will include site preparation, the beginning of several conventional facilities, and the completion of roads into the site.

FY 2002 budget authority is being requested to complete the ion source and continue component procurements for and fabrication of the linac structures and magnet systems, target assemblies, and the global controls. The assembly and testing of technical components will continue and installation efforts will begin in the front end, and the low energy sections of the linac. Title II design will continue for the target and experimental instruments. Several conventional facilities will be turned over for equipment installation: such as the front end building, portions of the klystron hall, and the linac tunnel.

The House Report (Report 106-253, pages 113-114) accompanying the FY 2000 Energy and Water Development Appropriations Act stipulated prerequisites to commitment of appropriated funds for the SNS project, and established a requirement for an annual status report for the project which is incorporated into this project data sheet. All conditions for commitment of funds were satisfied, and FY 2000 construction funds were released at the end of February 2000. The SNS Project has made significant progress. Site excavation began at Oak Ridge in April. At the end of FY 2000, the project was 14 percent complete (15 percent planned); had expended $225,000,000 ($221,000,000 planned); and was on schedule and budget for completion in June 2006 at a Total Project Cost of $1,411,700,000. Site preparation was well underway with 1.1 of 1.3 million cubic yards of earth moved, one access road complete and the second being prepared for paving. Title I design was nearly complete, and prototype equipment was being assembled for the ion source, linac, ring, target, and instruments. Preliminary safety documents for the facility had been prepared, and site construction was proceeding without a reportable injury. FY 2001 budget authority has been provided for 1) conducting detailed design; 2) beginning fabrication of the ion source, low-energy beam transport, linac structures and magnet systems, target assemblies, experimental instruments, and global control systems; and 3) beginning construction on several conventional facilities (buildings and accelerator tunnels). The project remains on-track for completion consistent with the baseline; Total Project Cost of $1,411,700,000 completion by June 2006, and with the capability of providing at least 1 MW of proton beam power on target.

4. Details of Cost Estimate.

(dollars in thousands)

	Current Estimate	Previous Estimate
Design and Management Costs		
Engineering, design and inspection at approximately 27% of construction costs	179,400	127,100
Construction management at approximately 3% of construction costs	20,400	15,400
Project management at approximately 18% of construction costs	121,800	135,000
Land and land rights	0	0
Construction Costs		
Improvements to land (grading, paving, landscaping, and sidewalks)	28,300	26,200
Buildings	173,600	144,800
Other structures	0	600
Utilities (electrical, water, steam, and sewer lines)	25,100	24,400
Technical Components	441,400	415,700
Standard Equipment	1,900	2,700
Major computer items	5,300	7,300
Removal cost less salvage	0	0
Design and project liaison, testing, checkout and acceptance	16,600	5,200
Subtotal	1,013,800	904,400
Contingencies at approximately 18 percent of above costs	178,900	288,300
Total Line Item Cost	1,192,700	1,192,700
Less: Non-Agency Contribution	0	0
Total, Line Item Costs (TEC)	1,192,700	1,192,700

5. Method of Performance

The SNS project is being carried out by a partnership of six DOE national laboratories, led by Oak Ridge National Laboratory, as the prime contractor to DOE. The other five laboratories are Argonne, Brookhaven, Lawrence Berkeley, Los Alamos National Laboratories and Thomas Jefferson National Accelerator Facility. Each laboratory is assigned responsibility for accomplishing a well defined portion of the project's scope that takes advantage of their technical strengths: Argonne - Instruments; Brookhaven - Accumulator Ring; Lawrence Berkeley - Front End; Los Alamos – Normal conducting Linac, RF Systems and overall linac physics design; TJNAF – Superconducting Linac; Oak Ridge - Target. Project execution is the responsibility of the SNS Project Executive Director with the support of a central SNS Project Office at ORNL, which provides overall project management, systems integration, ES&H, quality assurance, and commissioning support. The SNS Project Executive Director has authority for directing the efforts at all six partner laboratories and exercises financial control over all project activities. ORNL has subcontracted to an Industry Team which consists of an Architect-Engineer for the conventional facilities design and a Construction Manager for construction installation, equipment procurement, testing and commissioning support. Procurements by all six laboratories will be accomplished, to the extent feasible, by fixed price subcontracts awarded on the basis of competitive bidding.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2000	FY 2001	FY 2002	Outyears	Total
Project Cost (budget outlays)						
Facility Cost.[a]						
Line Item TEC	37,140	105,542	228,506	285,600	535,912	1,192,700
Plant Engineering & Design	0	0	0	0	0	0
Expense-funded equipment	0	0	0	0	0	0
Inventories	0	0	0	0	0	0
Total direct cost	37,140	105,542	228,506	285,600	535,912	1,192,700
Other project costs						
R&D necessary to complete project.[b]	42,378	17,978	12,199	5,673	7,524	85,752
Conceptual design cost.[c]	14,397	0	0	0	0	14,397
Decontamination & Decommissioning (D&D)	0	0	0	0	0	0
NEPA Documentation costs.[d]	1,916	32	0	0	0	1,948
Other project-related costs.[e]	1,150	2,674	6,880	9,580	95,516	115,800
Capital equipment not related construction.[f]	210	454	100	100	239	1,103
Total, Other project costs	60,051	21,138	19,179	15,353	103,279	219,000
Total project cost (TPC)	97,191	126,680	247,685	300,953	639,191	1,411,700

a Construction line item costs included in this budget request are for providing Title I and II design, inspection, procurement, and construction of the SNS facility for an estimated cost of $1,192,700,000.

b A research and development program at an estimated cost of $85,752,000 is needed to confirm several design bases related primarily to the accelerator systems, the target systems, safety analyses, cold moderator designs, and neutron guides, beam tubes, and instruments. Several of these development tasks require long time durations and the timely coupling of development results into the design is a major factor in detailed task planning.

c Costs of $14,397,000 are included for conceptual design and for preparation of the conceptual design documentation prior to the start of Title I design in FY 1999.

d Costs of $1,948,000 are included for completion of the Environmental Impact Statement.

e Estimated costs of $115,800,000 are included to cover pre-operations costs.

f Estimated costs of $1,103,000 to provide test facilities and other capital equipment to support the R&D program.

7. Related Annual Funding Requirements.

	(FY 2006 dollars in thousands)	
	Current Estimate	Previous Estimate
Facility operating costs	21,300	N/A
Facility maintenance and repair costs	25,300	N/A
Programmatic operating expenses directly related to the facility	22,500	N/A
Capital equipment not related to construction but related to the programmatic effort in the facility	2,100	N/A
GPP or other construction related to the programmatic effort in the facility	1,000	N/A
Utility costs	30,400	N/A
Accelerator Improvement Modifications (AIMs)	4,100	N/A
Total related annual funding (4Q FY 2006 will begin operations)	106,700	N/A

During FY 2001, more detailed planning for the SNS operating program will be conducted. Based on that planning, an updated estimate of the annual funding requirements will be submitted with the FY 2003 data sheet.

8. Design and Construction of Federal Facilities

All DOE facilities are designed and constructed in accordance with applicable Public Laws, Executive Orders, OMB Circulars, Federal Property Management Regulations, and DOE Orders. The total estimated cost of the project includes the cost of measures necessary to assure compliance with Executive Order 12088, "Federal Compliance with Pollution Control Standards"; section 19 of the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, and the related Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); and the Architectural Barriers Act, Public Law 90-480, and implementing instructions in 41 CFR 101-19.6. This project includes the construction of new buildings and/or building additions; therefore, a review of the GSA Inventory of Federal Scientific Laboratories is required. The project will be located in an area not subject to flooding determined in accordance with the Executive Order 11988.

02-SC-002 - Project Engineering Design (PED), Various Locations

1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost ($000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete	
FY 2002 Budget Request	2Q 2002	3Q 2004	N/A	N/A	14,000 [a]

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	4,000	4,000	4,000
2003	8,000	8,000	8,000
2004	2,000	2,000	2,000

3. Project Description, Justification and Scope

This PED request provides for Title I and Title II Architect-Engineering (A-E) services for Basic Energy Sciences (BES) projects related to the establishment of user centers for nanoscale science, engineering, and technology research. These funds allow designated projects to proceed from conceptual design into preliminary design (Title I) and definitive design (Title II). The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design and working drawings and specifications, and provide construction schedules including procurements. The design effort will ensure that construction can physically start or long-lead procurement items can be procured in the fiscal year in which Title III construction activities are funded.

FY 2002 PED design projects are described below. Some changes may occur due to continuing conceptual design studies or developments prior to enactment of an appropriation. These changes will be reflected in subsequent years. Construction funding will be separately requested after completion of preliminary (Title I) design work.

<u>Nanoscale Science Research Centers (NSRCs)</u>

To support research in nanoscale science, engineering, and technology, the U.S. has constructed outstanding

[a] The full Total Estimated Cost (design and construction) ranges between $220,000,000 - $330,000,000. This estimate is based on conceptual data and should not be construed as a project baseline.

facilities for *characterization and analysis* of materials at the nanoscale. Most of these world-class facilities are owned and operated by BES. They include, for example, the synchrotron radiation light source facilities, the neutron scattering facilities, and the electron beam microscope centers. However, world-class facilities that are widely available to the scientific research community for nanoscale *synthesis, processing, and fabrication* do not exist. NSRCs are intended to fill that need. NSRCs will serve the Nation's researchers and complement university and industrial capabilities in the tradition of the BES user facilities and collaborative research centers. Through the establishment of NSRCs affiliated with existing major user facilities, BES will provide state-of-the-art equipment for materials synthesis, processing, and fabrication at the nanoscale in the same location as facilities for characterization and analysis. NSRCs will build on the existing research and facility strengths of the host institutions in materials science and chemistry research and in x-ray and neutron scattering. This powerful combination of colocated fabrication and characterization tools will provide an invaluable resource for the Nation's researchers.

In summary, the purposes of NSRCs are to:

- provide state-of-the-art nanofabrication and characterization equipment to in-house and visiting researchers,
- advance the fundamental understanding and control of materials at the nanoscale,
- provide an environment to support research of a scope, complexity, and disciplinary breadth not possible under traditional individual investigator or small group efforts,
- provide a formal mechanism for both short- and long-term collaborations and partnerships among DOE laboratory, academic, and industrial researchers,
- provide training for graduate students and postdoctoral associates in interdisciplinary nanoscale science, engineering, and technology research,
- provide the foundation for the development of nanotechnologies important to the Department.

Centers have been proposed by: Argonne National Laboratory, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and a consortium of Los Alamos National Laboratory, Sandia National Laboratory and the University of New Mexico. PED funding will be provided to four of these centers in FY 2002. PED funding for the fifth center would begin in FY 2003. Construction funding, which will be contingent upon the results of the design studies and on scientific peer review of the proposal, would be staggered in the out years depending upon which centers actually receive final approval.

FY 2002 Proposed Design Projects

02-01: Center for Nanoscale Materials – Argonne National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002	2Q 2003	3Q 2003	N/A	2,000	45,000-65,000

Fiscal Year	Appropriations	Obligations	Costs
2002	1,000	1,000	1,000
2003	1,000	1,000	1,000

The Center for Nanoscale Materials (CNM) at ANL will consist of conventional facilities, fabrication facilities, characterization instruments, computational capabilities, and beamlines at the Advanced Photon Source (APS). The CNM will be attached to the APS at a location not occupied by one of the standard Laboratory-Office Modules that serve the majority of the APS sectors. Most specifications of the conventional facilities design for CNM will be intimately connected to the specifications of the technical systems. Towards this end, effort will be dedicated to optimizing both the conventional facilities and the technical facilities, looking for value engineering opportunities. The Center at Argonne will require approximately 10,000 square feet of class 1,000 clean room space for nanofabrication and characterization equipment. This facility will also require general purpose chemistry/biology laboratories (7,000 square feet) and electronic and physical measurement laboratories (3,000 square feet). To house the CNM staff, university collaborators (post docs, visiting students and faculty), and industry collaborators, approximately 16,000 square feet for offices and meeting rooms will be provided. The CNM is being coordinated with a State of Illinois effort.

02-02: The Molecular Foundry – Lawrence Berkeley National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002	3Q 2003	4Q 2003	N/A	3,000	55,000-75,000

Fiscal Year	Appropriations	Obligations	Costs
2002	1,000	1,000	1,000
2003	2,000	2,000	2,000

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[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

The Molecular Foundry will be a two to four story high structure adjacent to the Advanced Light Source, with a total gross area of approximately 90,000 square feet and net usable area of approximately 53,000 square feet. Space in the new facility will support studies in nanostructures by providing offices and laboratories for materials science, physics, chemistry, biology, molecular biology and engineering, as well as approximately 6,000 square feet of high bay area. The building will be a state-of-the art facility for the design, modeling, synthesis, processing, and fabrication of novel molecules and nanoscale materials and their characterization. State-of-the-art equipment will support this research; e.g.: cleanroom, class 10-100; controlled environment rooms; scanning tunneling microscopes; atomic force microscopes; transmission electron microscope; fluorescence microscopes; mass spectrometers; DNA synthesizer, sequencer; nuclear magnetic resonance spectrometer; ultrahigh vacuum scanning-probe microscopes; photo, uv, and e-beam lithography equipment; peptide synthesizer; advanced preparative and analytical chromatographic equipment; and cell culture facilities. New beamlines at the ALS, not part of this PED activity, will support efforts at the Molecular Foundry.

02-03: Center for Functional Nanomaterials – Brookhaven National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2002	3Q 2003	4Q 2003	N/A	3,000	45,000-65,000

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	1,000	1,000	1,000
2003	2,000	2,000	2,000

The Center for Functional Nanomaterials will include class 10 clean rooms, general laboratories, wet and dry laboratories for sample preparation, fabrication, and analysis. Included will be the equipment necessary to explore, manipulate, and fabricate nanoscale materials and structures. Also included are individual offices and landscape office areas, seminar area, transient user space for visiting collaborators with access to computer terminals, conference areas on both floors, and vending/lounge areas. In addition it will include circulation/ancillary space, including mechanical equipment area, toilet rooms, corridors, and other support spaces. Equipment procurement for the project will include equipment needed for laboratory and fabrication facilities for e-beam lithography, transmission electron microscopy, scanning probes and surface characterization, material synthesis and fabrication, and spectroscopy. The building will incorporate human factors into its design to encourage peer interactions and collaborative interchange by BNL staff and research teams from collaborating institutions. In addition to flexible office and laboratory space it will provide "interaction areas", a seminar room and a lunch room for informal discussions. This design approach is considered state-of-the-art in research facility design as it leverages opportunities for the free and open

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

exchange of ideas essential to creative research processes.

02-04: Center for Nanophase Materials Sciences – Oak Ridge National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q 2003	3Q 2004	4Q 2004	N/A	3,000	45,000-65,000

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	0	0	0
2003	1,000	1,000	1,000
2004	2,000	2,000	2,000

A major focus of the Center for Nanophase Materials Sciences (CNMS) will be the application of neutron scattering for characterization of nanophase materials. In this area, CNMS will be a world leader. With the construction of the new Spallation Neutron Source (SNS) and the upgraded High Flux Isotope Reactor (HFIR), it is essential that the U.S.-based neutron science R&D community grow to the levels found elsewhere in the world and assume a scientific leadership role. The CNMS will play a critical role in integrating the growing neutron scattering community with the emerging research in nanoscale science by encouraging the use of neutrons in this premier scientific area. Progress in nanoscale science and engineering requires determining the atomic-scale structure of nanomaterials, developing a detailed understanding of the synthesis and assembly processes of complex nanomaterials systems, and understanding collective (cooperative) phenomena that emerge on the nanoscale. Neutron scattering provides unique information about both atomic-scale structure and the dynamics of a wide variety of condensed matter systems including polymers, macromolecular systems, magnetic and superconducting materials, and chemically complex materials, particularly oxides and hydrogen-containing structures. Consequently, the intense neutron beams at HFIR and SNS will make, for the first time, broad classes of related nanoscale phenomena accessible to fundamental study.

The facility will consist of a multistory, mutipurpose building located east of the SNS complex. It will house the core support facilities, offices, and laboratories necessary to ensure the mission of the CNMS. The location and synergy off the functions for the facility will provide the required support and services for broad R&D collaborations in nanoscience among researchers from ORNL, other national laboratories, universities, and industries. The completed design will enable construction of a new two-story Laboratory/Office building of approximately 100,000 square feet. The facility will include two state-of-the-art clean rooms, (one class 100 and the other class 10), general laboratories, wet and dry laboratories for sample preparation, fabrication and analysis. Included will be equipment necessary to synthesize, manipulate, and characterize nanoscale materials and structures. Also included are individual offices, cubicles, visitor and viewing lobby, two conference rooms, a loading dock, and a common computer design and operations room.

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

02-05: Synthesis and Characterization Laboratory – Los Alamos National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2003	4Q 2003	N/A	1,500	15,000-30,000

Fiscal Year	Appropriations	Obligations	Costs
2002	500	500	500
2003	1,000	1,000	1,000

The Center for Integrated Nanotechnologies (CINT), a distributed Center operated by the Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL) and the University of New Mexico (UNM), has as its primary objective the development of the scientific principles that govern the performance and integration of nanoscale materials, thereby building the foundations for future nanotechnologies. The CINT brings together the strengths of the three institutions to generate the knowledge needed to integrate nanoscale electronic materials into micro and macro scale assemblies and devices needed for the DOE defense, energy, and environmental mission areas. The CINT will focus on nanophotonics, nanoelectronics, nanomechnics, and functional nanomaterials. The Center will make use of a wide range of specialized facilities at the three institutions, including the Los Alamos Neutron Science Center and the National High Magnetic Field Laboratory at LANL; the Miccroelectronics Development Laboratory and the Compound Semiconductor Research Laboratory at SNL; and the Center for High Technology Materials and the Center for Micro-Engineered Materials at University of New Mexico. Specialized nanoscale science laboratories are needed at Albuquerque and Los Alamos to take advantage of these existing facilities at each site. In Los Alamos, the Synthesis and Characterization Laboratory will focus on theory, synthesis, and characterization of nanoscale materials. In Albuquerque, the Nanofabrication and Integration Laboratory will focus on fabrication and integration of nanoscale materials.

The LANL role in CINT requires the construction in Los Alamos of an approximately 40,000 gross sq ft Synthesis and Characterization Laboratory with an integrated theory, modeling, and simulation module. The laboratory will house state-of-the-art equipment, CINT research, collaborators from Sandia and UNM, visiting research collaborators, students and postdocs, appropriate additional complementary funded research, and central high-speed communications between the Sandia and UNM sites. It will be located to meet the CINT's mission of ease of access and collaboration as well as access to complementary Los Alamos research capabilities. In addition, the existing Los Alamos Electron Microscopy Laboratory and Ion Beam Materials Laboratory will be part of the CINT program and will be upgraded to further nanoscale research. Los Alamos will seek a DOE waiver for open and unrestricted access, similar to that for several existing buildings, to support this mission.

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

02-06: Nanofabrication and Integration Laboratory – Sandia National Laboratory

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2003	4Q 2003	N/A	1,500	15,000-30,000

Fiscal Year	Appropriations	Obligations	Costs
2002	500	500	500
2003	1,000	1,000	1,000

The Center for Integrated Nanotechnologies (CINT), a distributed Center operated by the Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL) and the University of New Mexico (UNM), has as its primary objective the development of the scientific principles that govern the performance and integration of nanoscale materials, thereby building the foundations for future nanotechnologies. The CINT brings together the strengths of the three institutions to generate the knowledge needed to integrate nanoscale electronic materials into micro and macro scale assemblies and devices needed for the DOE defense, energy, and environmental mission areas. The CINT will focus on nanophotonics, nanoelectronics, nanomechnics, and functional nanomaterials. The Center will make use of a wide range of specialized facilities at the three institutions, including the Los Alamos Neutron Science Center and the National High Magnetic Field Laboratory at LANL; the Miccroelectronics Development Laboratory and the Compound Semiconductor Research Laboratory at SNL; and the Center for High Technology Materials and the Center for Micro-Engineered Materials at University of New Mexico. Specialized nanoscale science laboratories are needed at Albuquerque and Los Alamos to take advantage of these existing facilities at each site. In Los Alamos, the Synthesis and Characterization Laboratory will focus on theory, synthesis, and characterization of nanoscale materials. In Albuquerque, the Nanofabrication and Integration Laboratory will focus on fabrication and integration of nanoscale materials.

The SNL role in CINT requires the construction in Albuquerque of the Nanofabrication and Integration Laboratory in an open environment readily accessible by students and visitors, including foreign nationals. This structure will house state-of-the-art clean rooms and equipment for nanolithography, atomic layer deposition, and materials characterization along with general purpose chemistry and electronics labs and offices for Center staff and collaborators. The complex will require 5,500 sq ft of class 1,000 clean room space for nanofabrication and characterization equipment and an additional 500 sq ft of class 100 clean room space for lithography activities. This facility will also require general purpose chemistry/biology laboratories and electronic and physical measurement laboratories. To house the Center staff, collaborators, Center-sponsored post docs,

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

visiting students and faculty, and industry collaborators, offices and meeting rooms will be provided.

4. Details of Cost Estimate [a]

(dollars in thousands)

	Current Estimate	Previous Estimate
Design Phase		
Preliminary and Final Design costs (Design Drawings and Specifications)	10,500	N/A
Design Management costs (15% of TEC)	2,100	N/A
Project Management costs (10% of TEC)	1,400	N/A
Total Design Costs (100% of TEC)	14,000	N/A
Total, Line Item Costs (TEC)	14,000	N/A

5. Method of Performance

Design services will be obtained through competitive and/or negotiated contracts. M&O contractor staff may be utilized in areas involving security, production, proliferation, etc. concerns.

6. Schedule of Project Funding

(dollars in thousands)

	Prior Year Costs	FY 2000	FY 2001	FY 2002	Outyears	Total
Facility Cost						
PED	0	0	0	4,000	10,000	14,000
Other project costs						
Conceptual design cost	0	0	1,155	0	0	1,155
NEPA documentation costs	0	0	0	0	0	0
Other project related costs	0	0	0	0	0	0
Total, Other Project Costs	0	0	1,155	0	0	1,155
	0	0	1,155	4,000	10,000	15,155

[a] This cost estimate is based on direct field inspection and historical cost estimate data, coupled with parametric cost data and completed conceptual studies and designs when available. The cost estimate includes design phase activities only. Construction activities will be requested as individual line items on completion of Title I design. The annual escalation rates assumed in the FY 2002 estimate for FY 2002 and FY 2003 are 3.3 and 3.4 percent respectively.

Advanced Scientific Computing Research

Program Mission

The primary mission of the Advanced Scientific Computing Research (ASCR) program, which is carried out by the Mathematical, Information, and Computational Sciences (MICS) subprogram, is to discover, develop, and deploy the computational and networking tools that enable researchers in the scientific disciplines to analyze, model, simulate, and predict complex physical, chemical, and biological phenomena important to the Department of Energy (DOE). These tools are crucial if DOE researchers in the scientific disciplines are to maintain their world leadership. To accomplish this mission, the program fosters and supports fundamental research in advanced scientific computing – applied mathematics, computer science, and networking – and operates supercomputers, a high performance network, and related facilities. The applied mathematics research efforts provide the fundamental mathematical methods and algorithms needed to model complex physical, chemical, and biological systems. The computer science research efforts enable scientists to efficiently implement these models on the highest performance computers available and to store, manage, analyze, and visualize the massive amounts of data that result. Networking research provides the techniques to link the data producers, e.g., supercomputers and large experimental facilities, with the data consumers, i.e., scientists who need the data.

In fulfilling this primary mission, the ASCR program supports the Office of Science Strategic Plan's goal of providing extraordinary tools for extraordinary science as well as building the foundation for research in support of the other goals of the strategic plan. In the course of accomplishing this mission, the research programs of ASCR have played a critical role in the evolution of high performance computing and networks. The accomplishments of researchers funded by ASCR, which are listed later in this budget, amply demonstrate the world leadership of this program.

In addition to this primary mission, the ASCR program is also responsible for the Laboratory Technology Research subprogram in the Office of Science. The mission of this subprogram is to foster and support high-risk research in the natural sciences and engineering in partnership with the private sector leading to innovative applications relevant to the Nation's energy sector.

The high quality of the research in the entire ASCR program, supporting both of its missions, is continuously evaluated through the use of merit-based peer review and scientific advisory committees.

The research and facilities supported by ASCR are critical to the success of all the missions of the Office of Science (SC) because computational modeling and simulation have become an important contributor to progress in all SC scientific research programs. Modeling and simulation is particularly important for the solution of research problems that are insoluble by traditional theoretical and experimental approaches, hazardous to study in the laboratory, or time-consuming or expensive to solve by traditional means. All of the research programs in the U.S. Department of Energy's Office of Science—in Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, and High Energy and Nuclear Physics—have identified major scientific challenges that can best be addressed through advances in scientific computing.

Advances in computing technologies during the past decade have set the stage for a major step forward in modeling and simulation. By 2005, computers 1,000 times faster than those generally available to the scientific community in 2000, *i.e., terascale* computers (computers that can perform trillions of operations per second, or over one teraflop), will be at hand. However, to deliver on this promise, these increases in "peak" computing power, *i.e.*, the maximum theoretical speed that a computer can attain, must be translated into corresponding increases in the modeling and simulation capabilities of scientific codes. This is a daunting problem that will only be solved by increased investments in *computer software*—the scientific codes for simulating physical phenomena, the mathematical algorithms that underlie these codes, and the computing systems software that enables the use of high-end computer systems. These investments in software research must be made by DOE and other government agencies whose missions depend on high-end computing because technology trends and business forces in the U.S. computer industry have resulted in radically reduced development and production of high-end systems necessary for meeting the most demanding requirements of scientific research. The U.S. computer industry has become focused on the computer hardware and software needs of business applications, which dominate the market, and cannot justify sufficient investments in software research, focused on the computational needs of the scientific community.

An example that shows the dramatic difference between the requirements of scientific computing and business computing is the calculation that won the 1998 Gordon Bell Prize awarded by the Supercomputing 1998 Conference sponsored by the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronic Engineers (IEEE). This calculation resulted from a research project supported by the Mathematical, Information, and Computational Sciences (MICS) subprogram. This calculation, the first to achieve a teraflop on a real scientific application, was undertaken to better understand and predict the magnetic behavior of atoms in a magnetic material. Such calculations are important for understanding the properties of magnetic storage devices, such as computer hard drives, and permanent magnets. The actual calculation that was performed involved a cube of iron approximately two millionths of a centimeter in each dimension containing 1,458 atoms. In order to predict the magnetic behavior of this cube of iron, using the most efficient mathematical tools available today, approximately 30 trillion operations, i.e. additions, subtractions, multiplications and divisions **per atom**, were required. In addition, each atom required 48 megabytes of memory to store critical data. Therefore, the entire calculation required approximately 70 gigabytes of memory and 45 quadrillion (45×10^{15}) operations to complete.

To put this in context, if you could buy a 500Mhz PC with 70 gigabytes of memory (approximately 1000 times the memory on a typical PC), this problem would take approximately 3 years to solve. In addition, while this calculation represents a major scientific advance, to really understand the behavior of materials in real systems, scientists estimate that they need to solve problems with at least 27,000 atoms, almost twenty (20) times larger than this calculation.

In addition to the development of software to address scientific challenges on high performance computers, the Office of Science faces significant challenges in enabling its research community to have effective access to the computational and experimental data resources at its facilities and in enabling geographically-distributed research teams to work effectively together. Many of the DOE facilities produce thousands to millions of gigabytes of data per year that must be managed and analyzed by scientists at universities, government laboratories, and industrial laboratories across the nation, and in some cases across the world. In addition, remote users increasingly need to be able to control experiments from their home institutions. This enables university professors to integrate their research activities at DOE's facilities into their home research and educational activities. In addition, it decreases both the time and cost of performing the research at remote facilities. These geographically-distributed teams of scientists and engineers along with the supporting experimental and computational facilities, tied together with high performance networks are called National Collaboratories. The current technologies that underlie National Collaboratories, many of which were developed by ASCR, only provide support for basic services and must be significantly enhanced to enable collaborative technologies to achieve their full potential as tools for scientists.

In National Collaboratories it is again the scale of the scientific problems that drives SC's need for advances in information technology. For example, the current state of the art in simulations of the earth's climate uses a grid that measures 0.5 degrees of latitude by 0.5 degrees of longitude. A single snapshot of the data from these simulations may contain 300 megabytes of data (over 3,000 times larger than the Netscape home page), and the output of a full simulation may total 75,000 gigabytes (or 75 terabytes). Sharing this data with a distributed scientific team represents a major technical challenge. It should also be noted that there is considerable interest in using grids much finer than 0.5 degrees which corresponds to distances of approximately 50km on a side, (e.g., Washington DC, Baltimore MD, and Frederick MD could be in the same grid element). Again, because of the scale of DOE's requirements, DOE must support significant network and collaboratory research to satisfy its missions. This research complements commercial research investments.

Program Goals

- Maintain world leadership in areas of advanced scientific computing research relevant to the missions of the Department of Energy.
- Integrate the results of advanced scientific computing research into the natural sciences and engineering.
- Provide world-class supercomputer and networking facilities for scientists working on problems that are important to the missions of the Department.
- Integrate and disseminate the results of high-risk research in natural sciences and engineering to the private sector through the Laboratory Technology Research subprogram.

Program Objectives

- *Advance the frontiers of knowledge in advanced scientific computing research.* — Foster research to create new fundamental knowledge in areas of advanced computing research important to the Department, e.g., high performance computing, high speed networks, and software to enable scientists to make effective use of the highest performance computers available and to support National Collaboratories.
- *Apply advanced computing knowledge to complex problems of importance to DOE.* — Promote the transfer of results of advanced scientific computing research to DOE missions in areas such as the improved use of fossil fuels, including understanding the combustion process; the atmospheric and environmental impacts of energy production and use, including global climate modeling and subsurface transport; and future energy sources, including fusion energy, as well as the fundamental understanding of matter and energy.
- *Plan, construct, and operate premier supercomputer and networking facilities.* — Serve researchers at national laboratories, universities, and industry, thus enabling new understanding through analysis, modeling, and simulation of complex natural and engineered systems and effective integration of geographically distributed teams through national collaboratories.
- *Transfer results of fundamental research to the private sector.* — Provide tangible results of research and development activities through cost-shared partnerships with industry.

Evaluation of Objectives

The Advanced Scientific Computing Research (ASCR) program evaluates the progress being made toward 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. Facilities, including the National Energy Research Scientific Computing Center (NERSC) and ESnet, will be operated within budget and successfully meet user needs and satisfy overall SC program requirements. All new projects are selected by peer review and merit evaluation for their scientific excellence. Beginning in FY 2001, the Advanced Scientific Computing Advisory Committee (ASCAC) will provide advice on subprogram portfolios. As part of these evaluations, the international leadership of ASCR's advanced scientific computing research programs will be assessed. Specific performance measures are included within the detailed program justification narratives as appropriate.

The overall quality of the research in the ASCR program will be judged excellent and relevant by external review by peers, and through various forms of external recognition.

Leadership in key ASCR 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 ASCR will be peer reviewed and competitively selected, and will undergo regular peer review merit evaluation.

ASCR will keep within 10%, on average, of cost and schedule milestones for upgrades and construction of the scientific user facilities it manages.

The ASCR scientific user facilities will be operated and maintained so that unscheduled operational downtime will be less than 10%, on average, of scheduled operating time. This includes the National Energy Research Scientific Computing Center and ESnet.

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

The ASCR program builds on decades of leadership in high performance computing and has many pioneering accomplishments. Building on this long history, principal investigators of the ASCR program have received recognition through numerous prizes awards and honors. A sample of pioneering results, recent accomplishments and current awards is given below.

SCIENCE ACCOMPLISHMENTS

Mathematical, Information and Computational Sciences

- *A Fundamental Problem of Quantum Physics Solved*. For over half a century, theorists tried and failed to provide a complete solution to scattering in a quantum system of three charged particles, one of the most fundamental phenomena in atomic physics. Such interactions are everywhere;

ionization by electron impact, for example, is responsible for the glow of fluorescent lights and for the ion beams that engrave silicon chips. Collaborators at Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL), and the University of California at Davis used NERSC's Cray T3E supercomputer to obtain a complete solution of the ionization of a hydrogen atom by collision with an electron, the simplest nontrivial example of the problem's last unsolved component. Their breakthrough employs a mathematical transformation of the Schroedinger wave equation that makes it possible to treat the outgoing particles as if their wave functions simply vanish at large distances from the nucleus instead of extending to infinity if treated conventionally.

- *Biggest Dataset Ever from Cosmic Microwave Background*. Since ancient times, the geometry of the universe has been a topic of speculation and inquiry. An international team of scientists reported in Nature that the universe is, as Euclid thought, flat. They obtained their results by combining cosmic microwave radiation data collected during an Antarctic balloon flight and extensive analysis, amounting to 50,000 hours of computer time, using NERSC's Cray T3E supercomputer and software written at NERSC. Called BOOMERANG for "Balloon Observations Of Millimetric Extragalactic Radiation And Geophysics," the collaboration includes over two dozen researchers from seven countries. Supercomputers at NERSC, along with software developed there, were crucial to extracting fundamental cosmological parameters from the data, the largest and most precise set of cosmic microwave background (CMB) data yet collected. From the dataset, the BOOMERANG team was able to make the most detailed map of the CMB's temperature fluctuations ever seen. From a CMB map, cosmologists derive a "power spectrum," a curve that registers the strength of these fluctuations on different angular scales, and which contains information on such characteristics of the universe as its geometry and how much matter and energy it contains. The power spectrum derived from the BOOMERANG Antarctic flight data is detailed enough to allow the determination of fundamental cosmic parameters to within a few percent, indicating that the geometry of the universe is flat and that the universe will expand forever. The calculation required would have taken almost six years to complete if run on a desktop personal computer. On the NERSC Cray T3E, processing time over the life of the project totaled less than 3 weeks.

- *Access Grid: A New Collaborative Environment*. Argonne computer scientists have developed a new collaborative environment, the Access Grid, that can be used not just for science and engineering applications but for lectures, seminars, tutorials, and training. An Access Grid comprises a large-format multimedia display system about 18 feet by 6 feet; several video streams (for example, a wide audience shot, a close-up shot of the presenter, a wide area shot of the display screen, and a roving camera) projected onto the display; numerous microphones and speakers; and several computers for audio capture, video capture, control, and display. Each Access Grid "node," or site, involves 3-20 people, providing a compelling new environment far beyond desktop-to-desktop collaborative systems.

- *Parallel Computational Oil Reservoir Simulator*. To meet the Nation's energy needs, the United States oil and gas industry must continue to advance the technology used to extract oil and gas from both new and old fields. Until recently, most drilling and recovery activities were based on past practices that often lacked a sound scientific basis. Computer scientists at Argonne National Laboratory, in collaboration with petroleum engineers at the University of Texas at Austin, have recently developed a software package capable of simulating the flow of oil and gas in reservoirs. These codes, which are based on software tools designed at Argonne, are able to run on a variety of computer platforms, including massively parallel systems with hundreds and even thousands of processors. The software codes will enable the oil and gas industry to lower exploration and drilling costs and enhance the yield of oil from new and old fields alike.

- *Cracking the Chemistry of Nuclear Waste Characterization and Processing*. Many DOE research areas require accurate and efficient calculations of molecular electronic structure (e.g., catalysis, combustion, and chemistry in the environment or atmosphere). However, the single most challenging environmental issue confronting the DOE is the safe and cost-effective management of highly radioactive mixed wastes generated by four decades of nuclear weapons production. Modeling the chemistry of these heavy elements (e.g., the actinides which include uranium and plutonium) present an enormous challenge, since relativistic effects must be included, and these greatly increase the cost and complexity of the calculations. The MICS project, Computational Chemistry for Nuclear Waste Characterization and Processing: Relativistic Quantum Chemistry of Actinides, has developed major new capabilities for understanding actinide processes. The seven institution team created new chemistry codes for massively parallel computers (Pacific Northwest, Argonne, and Lawrence Berkeley National Laboratories; Stevens Institute; Eloret; Ohio State University; and Syracuse University) and formed liaisons with experimental research at four DOE labs (Pacific Northwest, Argonne, Lawrence Berkeley, and Los Alamos). This project broke new ground in a number of areas, implementing several models that include relativistic effects. In addition, new models were developed, that provide a very significant improvement in accuracy over previous approaches. This is the first time that any of these methods are available on massively parallel computers.

- *High Performance Algorithms for Scientific Simulation*. Many problems in science and engineering involve the complex interplay of forces and effects on different time and length scales. Two significant examples of such nonlinear multi-time, multi-scale phenomena are the interaction of the atmosphere and the oceans in the creation of the global climate and the burning of fossil fuels in engines and other devices. The size and complexity of such problems require the development of fast and efficient algorithms and software that can take advantage of the resolution power of today's massively parallel computing platforms. Applied mathematicians at the Lawrence Berkeley National Laboratory, working in collaboration with applied mathematicians at the Lawrence Livermore National Laboratory and New York University, have developed adaptive mesh refinement algorithms capable of automatically redistributing grid points in computational regions where significant physics is occurring over small time scales. At finer and finer length scales the continuous flow solver is replaced by a particle method such as Monte Carlo, thus allowing the researchers to accurately resolve phenomena over a broad range of length and time scales. Applications of this work to the Accelerated Strategic Computing Initiative (ASCI) and Office of Science problems are many, although the primary focus of the research is the accurate simulation of diesel combustion in realistic, three-dimensional geometries. Laboratory and academic researchers are working on this project closely with engineers from Caterpillar and Cummins.

- *Solving Optimization Problems Easily and Inexpensively*. Optimization applications range from designing circuits, to estimating the value at risk of financial institutions, to determining routing patterns on the Internet, to finding energy functions for molecular structures. Argonne researchers (together with Northwestern University) completed a project to attack such problems successfully. The project involves development of a novel environment, called the Network-Enabled Optimization System (NEOS). NEOS allows users to solve optimization problems over the Internet with state-of-the-art software without downloading and linking code. Given the definition of a nonlinear optimization problem, NEOS determines an appropriate solver, uses tools to compute derivatives and sparsity patterns, compiles all subroutines, links with the appropriate libraries, and executes the solver. The user is given a solution in a matter of hours instead of days or weeks. The NEOS project has recently gained considerable visibility with the release of a new portable version that can be run on various computers, Web servers, and email servers. Over the past year, the number of users has risen to an average of 2,600 problem submissions per month. Moreover, NEOS is now being used as an educational tool at universities worldwide. Students and professors alike find it easy to use and have rated it as one of the more efficient ways to access state-of-the-art optimization software.

- *Bringing Powerful Scientific Visualizations to the Desktop*. As part of their work in DOE's Combustion Corridor research project, visualization researchers at Lawrence Berkeley National Laboratory created a new application that will enable distributed scientific visualization of large data volumes on remote workstations. Such visualizations typically represent complex, three-dimensional scientific problems varying over time, such as how two gases mix in a turbulent environment. To visualize these models, researchers previously required access to very powerful computers — moving such large files onto local workstations is either impossible or impractical. The fundamental idea behind Image-Based-Rendering-Assisted Volume Rendering (IBRAVR) is that large data are partially pre-rendered on a large "computational engine" close to the data, with the final image rendering performed on a workstation. The benefits and advantages of the IBRAVR technique include using a new type of visualization and rendering technology which "decomposes" nicely for parallel processing and sharing the workload between a remote multiprocessor machine and a local workstation.
- *Parallel Multigrid Methods*. LLNL researchers, in close collaboration with university colleagues, developed parallel multigrid methods for the solution of large, sparse systems of linear equations. The solution of these large systems (having upwards of one billion unknowns) is often the key computational bottleneck in scientific and engineering application codes. Multigrid is a so-called scalable algorithm, and LLNL's work in this area is already reducing overall simulation times of important LLNL application codes by up to ten-fold (linear solve time is up to 100 times faster than previous solution methods). The largest problem solved by LLNL researchers was a one billion unknown anisotropic diffusion problem, which took just 54 seconds on 3150 processors of the Advanced Strategic Computing Initiative (ASCI) Red platform. These methods are being developed for a variety of different applications, including inertial confinement fusion, structural dynamics, and flow in porous media. The problems of interest are defined on a variety of grids, including structured grids, block-structured grids, adaptive mesh refinement composite grids, overset grids, and unstructured grids. Both geometric and algebraic multigrid techniques are being investigated.
- *Adaptive Laser-Plasma Simulation*. LLNL computational scientists have developed new numerical algorithms and software to enable the use of parallel adaptive mesh refinement in the simulation of laser plasma interaction. The ability to predict and control the interaction of intense laser light with plasmas is critical in the design of laser-driven fusion energy experiments such as those to be conducted at the National Ignition Facility currently under construction at LLNL. These new algorithms solve a system of plasma fluid equations coupled with a laser light propagation model, incorporating parallel adaptive mesh refinement to use fine meshes only where they are needed. This approach has been shown to reduce overall computational requirements ten-fold on certain problems. These novel algorithms have been implemented in a research code called ALPS (Adaptive Laser Plasma Simulator). ALPS solves problems in two or three spatial dimensions and runs on a variety of high performance computing platforms, including massively parallel computers. Substantial speedups relative to conventional uniform grid algorithms has been achieved on problems involving single mode beams and beams smoothed with random phase plates.

FACILITY ACCOMPLISHMENTS

Mathematical, Information and Computational Sciences

- *NERSC Accepts New IBM Supercomputer*. DOE's National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory accepted the first phase of its new IBM RS/6000 SP system. As part of the acceptance testing, a group of computational scientists at national laboratories and universities were given early access to the machine to thoroughly test the entire system. Those researchers noted the high performance and ability to scale problems on the IBM SP, which is providing useful scientific results in such areas as climate modeling, materials science, and physics research. The first phase of NERSC's IBM system consists of an RS/6000 SP with 304 POWER3 SMP nodes, each with two processors per node. In all, Phase I has 512 processors for computing, 256 gigabytes of memory and 10 terabytes of disk storage for scientific computing. The system has a peak performance of 410 gigaflops, or 410 billion calculations per second. Phase II, delivered in December 2000, will have 2,048 processors dedicated to large-scale scientific computing and another 384 processors devoted to system tasks. The system will have a peak performance capability of more than 3 teraflops, or 3 trillion calculations per second.
- *ESnet Capability Expanded*. DOE's Energy Sciences Network, known as ESnet, selected Qwest Communications to provide advanced data communications services for the scientific research network. The awarded contract is up to seven years in length, including option years, and is valued at approximately $50,000,000. Under the contract, Qwest will provide a terabit (one million megabits/second) network by the year 2005, offering 500 times the highest speed available on the highest speed networks today. This network will also offer a staggering amount of capacity — more than that of all today's carriers combined.
- *Scientists Install New Testbed for Open Source Software*. A 512-CPU Linux cluster was installed at Argonne's Mathematics and Computer Science Division. The cluster provides a flexible development environment for scalable open source software in four key categories: cluster management, high-performance systems software (file systems, schedulers and libraries), scientific visualization, and distributed computing. Its modular design makes it easily reconfigurable for systems management experiments, and its availability for testing open-source code and algorithms ensures broad use by researchers both within the Laboratory and externally.

AWARDS

Mathematical, Information and Computational Sciences

- *Supercomputing (SC'99) Awards*. Special awards were given to scientists from Argonne National Laboratory and the University of Chicago for their achievements in simulating incompressible flows and another special award was given to a team of scientists from NASA and DOE laboratories for their achievements in fluid dynamics simulations.
- *The Maxwell Prize*. A new international prize in applied mathematics, the Maxwell Prize, has been awarded for MICS supported research at the Applied Mathematics Research program at Lawrence Berkeley National Laboratory. The research involved analysis of problems dominated by complexity, such as turbulence, failure and cracks in solids, flow in porous and inhomogeneous media, and combustion. The work on crack formation provided some of the basic tools used today in failure analysis, especially failure due to fatigue. The prize was awarded by the Committee for International Conferences on Industrial and Applied Mathematics (CICIAM) that is made up of the major applied mathematics organizations in 14 countries.

- *Herbrand 2000 Award*. A senior scientist at Argonne National Laboratory was named recipient of the Herbrand Award for the year 2000. The award is given by the Conference on Automated Deduction Inc. to honor exceptional contributions to the field of automated reasoning. Automated reasoning involves the use of powerful computers to solve the logical (as distinct from the numerical) aspects of problems. Applications range from the design and validation of electronic circuits to assisting in research in mathematics and logic. Only six Herbrand awards have been given in the past decade.
- *An Algorithm for the Ages*. Among the top 10 "Algorithms of the Century" announced by Computing in Science and Engineering magazine is the integer-relation algorithm dubbed PSLQ. PSLQ was discovered by a mathematician at the University of Maryland and implemented in practical computer software by a LBNL researcher. PSLQ has unearthed many surprising relations in mathematics and physics, although its most startling result may well be a simple formula for calculating any binary digit of pi without calculating the digits preceding it. Before PSLQ, mathematicians had not thought that such a digit-extraction algorithm for pi was possible. Using the remarkably simple formula, even a personal computer can calculate pi's millionth binary digit in about 60 seconds. As a tool of experimental mathematics, PSLQ's purpose is to discover new mathematical relations among numbers — for example, constants that occur in various groups of mathematical formulas. Very high precision arithmetic is needed by PSLQ, or else nonsense results are obtained.
- *Global Arrays Power Award Winning Applications*. Supported by the DOE Advanced Computational Testing and Simulation program, Pacific Northwest National Laboratory's Global Array (GA) toolkit provides a unique and portable "shared memory" interface that enables codes to efficiently access massive data structures distributed across thousands of processors. GA also provides easy-to-use interfaces to key numerical libraries, and interoperability with message passing standards like MPI, forming a powerful and complete environment for parallel software development. GA is a critical component of a series of award-winning applications, including Molecular Science Software Suite (MS^3), which was awarded both an R&D-100 award in 1999 and a Federal Laboratory Consortium Technology Transfer award in 2000; and COLUMBUS, featured in the SC'98 Conference Best Overall Paper.
- *Supercomputing (SC 2000) Awards*. Scientists at LBNL won the "Fastest and Fattest" category in the High-Bandwidth Applications Competition for achieving a peak performance of over 1.48 gigabits/second in a prototype application for the visualization of terascale datasets. A team that included members from ANL, LLNL and LBNL won the "Hottest Infrastructure" category for demonstrating secure, high-performance data transfer and replication for large-scale climate modeling data sets. These awards recognize DOE's unique requirements for network services that far exceed usual commercial offerings and DOE's success in solving the significant research problems in networking and applications design to satisfy critical mission requirements.
- *1999 R&D 100 Awards*. Awards were made: to PNNL for the Molecular Science Software Suite (MS3) as the first package to offer advanced computational chemistry components optimized for high-performance massively parallel computers; to ORNL, the University of California at San Diego and the University of Tennessee for Netsolve 1.2, which unifies disparate high-performance computers and software libraries and delivers them as a powerful, easy to use computational service; and to the University of Tennessee and ORNL for ATLAS which automatically generates optimized basic linear algebra subprograms resulting in significant improvements in performance and portability.

The Laboratory Technology Research (LTR) subprogram received one R&D-100 Awards in 2000 for the following research:

- *Carbon Monoxide Monitoring Device.* Lawrence Berkeley National Laboratory (LBNL), in collaboration with Quantum Group, has developed an inexpensive, passive carbon monoxide (CO) occupational dosimeter, which has achieved control of sensor reversibility, humidity dependence, and sensor variability. CO is one of the most deadly environmental pollutants encountered in indoor and outdoor occupational settings. An inexpensive but sensitive and accurate CO monitoring device should help to identify and mitigate high CO environments.

The LTR subprogram received five Federal Laboratory Consortium (FLC) Awards for Excellence in Technology Transfer in 2000 for the following research:

- *Quick, Cost-effective Filler for Potholes.* Argonne National Laboratory, in collaboration with Rostoker, Inc., has developed a versatile, unique, room-temperature technology that uses a nontoxic, nonflammable binder to form products that are impermeable to groundwater and have twice the strength of cement. The technology is filling an important need in the road repair industry as a quick, cost-effective filler for potholes. It also benefits the environment by reducing landfill requirements by encapsulating waste more efficiently than traditional methods.

- *Innovative Purification Method.* LBNL, in collaboration with WaterHealth International, has developed a device that uses readily available, energy-efficient, low-maintenance technologies and materials to disinfect water. For less than 2 cents per metric ton of water, the ultraviolet light from a single 40-watt compact UV bulb disrupts the DNA of contaminating bacteria and viruses within 12 seconds. As of late 1999, about 100,000 people used daily drinking water disinfected by the LBNL device in several developing countries. The children in these countries will now have better survival rates, and more of them will grow up without being stunted from repeated diarrheal episodes.

- *Proton Therapy Used to Treat Cancer.* LBNL, in collaboration with General Atomics, has developed an accelerator-based proton therapy center at Massachusetts General Hospital in Boston to safely destroy cancerous tumors. The recent addition of proton therapy to the arsenal of cancer treatments promises new hope in the battle against the disease. In the U.S. each year, about 375,000 cancer patients use conventional radiation therapy for curative treatments. Of these, about 130,000 patients will benefit if treated with 3D conformal therapy, which is best delivered using proton beams.

- *Superplastic Forming Process for Automotive Components.* Pacific Northwest National Laboratory (PNNL), in collaboration with General Motors and MARC Analysis Research, has significantly reduced the technical and economic impediments to using superplastic forming processes for automotive and other manufacturing. This technology is a metal-forming process that can reduce the weight and cost of manufactured devices such as automotive structural components. Cars with lightweight automotive components that are strong enough to meet design requirements will be safer, more fuel efficient, and have lower emissions.

- *Software to Solve Complex Environmental Problems.* PNNL, in collaboration with DuPont and Amoco, has developed the first general-purpose software that provides chemists with access to high-performance, massively-parallel computers for a wide range of applications. The software is now used by more than 37 universities and supercomputer centers, 14 national laboratories or Federal agencies, and 15 industries. The software will enable the scientific community to quickly and cost-effectively solve complex environmental problems in the atmosphere, aquatic systems, and the subterranean environment.

In addition to the R&D-100 and FLC awards, two scientists supported by the LTR subprogram were recipients of the following distinguished awards in 2000:

- The 1999 Tennessee Industrial Scientist of the Year Award to a group leader in the Metals and Ceramics Division of Oak Ridge National Laboratory.

- The 1999 Battelle Inventor of the Year Award to an analytical biochemist at PNNL.

In FY 2000, the Laboratory Technology Research subprogram initiated a portfolio of Rapid Access Projects that addresses research problems of small businesses by utilizing the unique facilities of the Office of Science laboratories. These projects were selected on the basis of scientific/technical merit and commercial potential, using competitive external peer review.

PROGRAM SHIFTS

The FY 2002 ASCR budget continues the research portfolio enhancements, initiated in FY 2001, to create the next generation of high performance computing and communications tools to support the missions of the Office of Science and the Department of Energy in the next century.

A Federally-chartered advisory committee was established for the Advanced Scientific Computing Research program in FY 2000 and 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 for research and facilities.

Taking the Next Steps in Scientific Computing, Networking, and Collaboration: Scientific Discovery through Advanced Computing.

In FY 2002, the MICS subprogram of ASCR will continue its components of the collaborative program across the Office of Science to produce the scientific computing, networking and collaboration tools that DOE researchers will require to address the scientific challenges of the next decade. This program was described in the report to Congress entitled, "Scientific Discovery through Advanced Computing," (SciDAC). These enhancements build on the historic strength of the Department of Energy's Office of Science in computational science, computer science, applied mathematics, and high-performance computing and in the design, development, and management of large scientific and engineering projects and scientific user facilities. They also take full advantage of the dramatic increases in computing capabilities being fostered by the *Accelerated Strategic Computing Initiative* (*ASCI*) in the National Nuclear Security Agency (NNSA).

The ASCR contributions to this effort, which are described in detail in the MICS subprogram description, are briefly described below:

1. Continue the competitively selected partnerships focused on discovering, developing, and deploying to scientists key enabling technologies that were initiated in FY 2001. These partnerships, which are

called Integrated Software Infrastructure Centers, play a critical role in providing the software infrastructure that will be used by the SciDAC applications research teams.

2. Continue the integrated program of fundamental research in networking and collaboratory tools, partnerships with key scientific disciplines, and advanced network testbeds to provide the electronic collaboration tools that SciDAC teams, and DOE's next generation of experimental facilities, need to accomplish their goals. These projects were competitively selected in FY 2001.

Interagency Environment

The research and development activities supported by the MICS subprogram are coordinated with other Federal efforts through the Interagency Principals Group, chaired by the President's Science Advisor, and the Information Technology Working Group (ITWG). The ITWG represents the evolution of an interagency coordination process that began under the 1991 High Performance Computing Act as the High Performance Computing, Communications, and Information Technology (HPCCIT) Committee. DOE has been a key participant in these coordination bodies from the outset and will continue to coordinate its R&D efforts closely through this process.

In FY 1999, the President's Information Technology Advisory Committee (PITAC) recommended significant increases in support of basic research in: Software; Scalable Information Infrastructure; High End Computing; Socio-Economic and Workforce Impacts; support of research projects of broader scope; and visionary "Expeditions to the 21st Century" to explore new ways that computing could benefit our world.

Although the focus of the enhanced DOE program is on solving mission critical problems in scientific computing, this program will make significant contributions to the Nation's Information Technology Basic Research effort just as previous DOE mission-related research efforts have led to DOE's leadership in this field. In particular, the enhanced MICS subprogram will place emphasis on software research to improve the performance of high-end computing as well as research on the human-computer interface and on information management and analysis techniques needed to enable scientists to manage, analyze and visualize data from their simulations, and develop effective collaboratories. DOE's program, that focuses on the information technology research needed to enable scientists to solve problems in their disciplines, differs from the National Science Foundation's portfolio, that covers all of information technology. In addition, DOE's focus on large teams with responsibility for delivering software that other researchers can rely on differs from NSF's single investigator focus.

Scientific Facilities Utilization

The ASCR program request includes $28,244,000 in FY 2002 to support the National Energy Research Scientific Computing (NERSC) Center, which is ASCR's component of the SC-wide Scientific Facilities Initiative that started in FY 1996. This investment will provide computer resources for about 2,000 scientists in universities, federal agencies, and U.S. companies. 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 enable NERSC to maintain its role as one of the Nation's largest, premier unclassified computing centers, which is a critical element in the success of many SC research programs. Research communities that benefit from NERSC include structural biology; superconductor technology; medical research and technology development; materials, chemical, and plasma sciences; high energy and nuclear physics; and environmental and atmospheric research.

Workforce Development

The R&D Workforce Development mission is to ensure the supply of computational and computer science and Ph.D. level scientists for the Department and the Nation through graduate student and post doctoral research support. In FY 2002, this program will support approximately 800 graduate students and post doctoral investigators, of which 500 will be supported at Office of Science user facilities.

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

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Advanced Scientific Computing Research					
Mathematical, Information, and Computational Sciences	113,914	160,000	-3,830	156,170	156,170
Laboratory Technology Research	8,424	10,000	-420	9,580	6,880
Subtotal, Advanced Scientific Computing Research	122,338	170,000	-4,250	165,750	163,050
General Reduction	0	-1,732	1,732	0	0
General Reduction for Safeguards and Security	0	-2,153	2,153	0	0
Omnibus Rescission	0	-365	365	0	0
Subtotal, Advanced Scientific Computing Research	122,338 [a] [b]	165,750	0	165,750	163,050
Pending Budget Amendment	0	0	0	0	2,700 [c]
Total, Advanced Scientific Computing Research	122,338	165,750	0	165,750	165,750

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 $3,041,000 which has been transferred to the SBIR program and $182,000 which has been transferred to the STTR program.

[b] Excludes $2,322,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[c] A Budget Amendment transferring $2,700,000 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	11,637	5,020	5,020	0	--
Sandia National Laboratories	4,961	3,889	3,889	0	--
Total, Albuquerque Operations Office	16,598	8,909	8,909	0	--
Chicago Operations Office					
Ames Laboratory	1,957	1,668	1,668	0	--
Argonne National Laboratory	12,861	10,447	10,047	-400	-3.8%
Brookhaven National Laboratory	1,847	1,566	1,266	-300	-19.2%
Fermi National Accelerator Laboratory	59	60	60	0	--
Princeton Plasma Physics Laboratory	38	0	0	0	--
Chicago Operations Office	8,760	7,240	7,240	0	--
Total, Chicago Operations Office	25,522	20,981	20,281	-700	-3.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	57,069	54,501	54,151	-350	-0.6%
Lawrence Livermore National Laboratory	2,884	3,068	3,068	0	--
Stanford Linear Accelerator Center	590	234	234	0	--
Oakland Operations Office	3,160	960	960	0	--
Total, Oakland Operations Office	63,703	58,763	58,413	-350	-0.6%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science and Education	147	99	99	0	--
Oak Ridge National Laboratory	12,016	10,563	10,223	-340	-3.2%
Thomas Jefferson National Accelerator Facility	49	0	0	0	--
Total, Oak Ridge Operations Office	12,212	10,662	10,322	-340	-3.2%
Richland Operations Office					
Pacific Northwest National Laboratory	2,844	2,038	1,738	-300	-14.7%
Washington Headquarters	1,459	64,397	63,387	-1,010	-1.6%
Subtotal, Advanced Scientific Computing Research	122,338 [a] [b]	165,750	163,050	-2,700	-1.6%
Pending Budget Amendment	0	0	2,700 [c]	+2,700	--
Total, Advanced Scientific Computing Research	122,338	165,750	165,750	0	--

[a] Excludes $3,041,000 which has been transferred to the SBIR program and $182,000 which has been transferred to the STTR program.

[b] Excludes $2,322,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[c] A Budget Amendment transferring $2,700,000 from this program will be submitted shortly. The narrative description for this program has already been adjusted to reflect the revised levels.

Site Description

Ames Laboratory

Ames Laboratory is a Multiprogram Laboratory located on 10 acres in Ames, Iowa. The MICS subprogram at Ames Laboratory conducts research in the materials scientific application pilot project, which focuses on applying advanced computing to problems in microstructural defects, alloys, and magnetic materials, and in computer science. The LTR subprogram at Ames conducts research in the physical, chemical, materials, mathematical, engineering, and environmental sciences through cost-shared collaborations with industry.

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 MICS subprogram at ANL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. ANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research facility. The testbed at ANL focuses on a large cluster of Intel-based compute nodes with an open source operating system based on LINUX, this cluster has been given the name of "Chiba City." The LTR subprogram at ANL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are chemistry of ceramic membranes, separations technology, near-frictionless carbon coatings, and advanced methods for magnesium production.

Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The LTR subprogram at BNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are materials for rechargeable lithium batteries, sensors for portable data collection, catalytic production of organic chemicals, and DNA damage responses in human cells.

Fermi National Accelerator Laboratory (Fermilab)

Fermilab is located on a 6,800-acre site about 35 miles west of Chicago, Illinois. The LTR subprogram at Fermilab conducts research in areas such as superconducting magnet research, design and development, detector development and high-performance computing through cost-shared collaborations with industry.

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. The MICS subprogram at LBNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. LBNL participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research testbed. The testbed at LBNL currently focuses on very large scale computing on hardware in the T3E architecture from SGI-Cray including issues of distributing jobs over all the processors efficiently and the associated system management issues. LBNL manages the Energy

Sciences Network (ESnet). ESnet is one of the world's most effective and progressive science-related computer networks that provides worldwide access and communications to Office of Science (SC) facilities. In 1996, the National Energy Research Scientific Computing Center (NERSC) was moved from the Lawrence Livermore National Laboratory to LBNL. NERSC provides a range of high-performance, state-of-the-art computing resources that are a critical element in the success of many SC research programs. The LTR subprogram at LBNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are molecular lubricants for computers, advanced material deposition systems, screening novel anti-cancer compounds, and innovative membranes for oxygen separation.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. The MICS subprogram at LLNL involves significant participation in the advanced computing software tools program as well as basic research in applied mathematics.

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. The Mathematical Information and Computational Sciences (MICS) subprogram at LANL conducts basic research in the mathematics and computer science and in advanced computing software tools. LANL also participates in several scientific application and collaboratory pilot projects as well as supporting an advanced computing research testbed. The testbed at LANL focuses on a progression of technologies from SGI – Cray involving Origin 2000 Symmetric Multiprocessor Computers linked with HiPPI crossbar switches. This series of research computers has been given the name "Nirvana Blue."

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on 150 acres in Oak Ridge, Tennessee. ORISE provides support for education activities funded within the ASCR program.

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 MICS subprogram at ORNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools.

ORNL also participates in several scientific application and collaboratory pilot projects. The LTR subprogram at ORNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are high temperature superconducting wires, microfabricated instrumentation for chemical sensing, and radioactive stents to prevent reformation of arterial blockage.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The MICS subprogram at PNNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. PNNL also participates in several scientific application pilot projects. The LTR subprogram at PNNL conducts research motivated by practical energy payoffs through cost-shared collaborations with industry. The areas emphasized in the research portfolio are mathematical simulations of glass production, interactions of biological polymers with model surfaces, and characterization of microorganisms in environmental samples.

Princeton Plasma Physics Laboratory

The Princeton Plasma Physics Laboratory (PPPL), a laboratory located in Plainsboro, New Jersey, is dedicated to the development of magnetic fusion energy. The LTR subprogram at PPPL conducts research in areas that include the plasma processing of semiconductor devices and the study of beam-surface interactions through cost-shared collaborations with industry.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with sites in Livermore, California, and Tonopah, Nevada. The MICS subprogram at SNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. SNL also participates in several scientific application and collaboratory pilot projects.

Stanford Linear Accelerator Center

The Stanford Linear Accelerator Center (SLAC) is located at the edge of Silicon Valley in California about halfway between San Francisco and San Jose on 426 acres of Stanford University land. The LTR subprogram at SLAC conducts research in areas such as advanced electronics, large-scale ultra-high vacuum systems, radiation physics and monitoring, polarized and high-brightness electron sources, magnet design and measurement, and controls systems through cost-shared collaborations with industry.

Thomas Jefferson National Accelerator Facility

The Thomas Jefferson National Accelerator Facility (TJNAF) is a basic research laboratory located on a 200 acre site in Newport News, Virginia. The LTR subprogram at the TJNAF conducts research in such areas as accelerator and detector engineering, superconducting radiofrequency technology, speed data acquisition, and liquid helium cryogenics through cost-shared collaborations with industry.

All Other Sites

The ASCR program funds research at 71 colleges/universities located in 24 states supporting approximately 117 principal investigators. Also included are funds for research awaiting distribution pending completion of peer review results.

A number of Integrated Software Infrastructure Centers will be established at laboratories and/or universities. Specific site locations will be determined as a result of competitive selection. These centers will focus on specific software challenges confronting users of terascale computers.

Mathematical, Information, and Computational Sciences

Mission Supporting Goals and Objectives

The Mathematical, Information, and Computational Sciences (MICS) subprogram is responsible for carrying out the primary mission of the ASCR program: discovering, developing, and deploying advanced scientific computing and communications tools and operating the high performance computing and network facilities that researchers need to analyze, model, simulate, and — most importantly — predict the behavior of complex natural and engineered systems of importance to the Office of Science and to the Department of Energy. The MICS subprogram supports fundamental research and research facilities in all of the areas in which MICS supports research:

- *Applied Mathematics*. This includes research on the underlying mathematical understanding as well as the numerical algorithms to enable effective description and prediction of physical systems such as fluids, magnetized plasmas, or protein molecules. This includes, for example, methods for solving large systems of partial differential equations on parallel computers, techniques for choosing optimal values for parameters in large systems with hundreds to hundreds of thousands of parameters, improving our understanding of fluid turbulence, and developing techniques for reliably estimating the errors in simulations of complex physical phenomena.
- *Computer Science*. This includes research in computer science to enable large scientific applications through advances in massively parallel computing, such as very lightweight operating systems for parallel computers, distributed computing such as development of the Parallel Virtual Machine (PVM) software package that has become an industry standard, and large scale data management and visualization. The development of new computer and computational science techniques will allow scientists to use the most advanced computers without being overwhelmed by the complexity of rewriting their codes every 18 months.
- *Networking*. This includes research in high performance networks and information surety required to support high performance applications – protocols for high performance networks, methods for measuring the performance of high performance networks, and software to enable high speed connections between high performance computers and networks, and scalable methods for providing scientific users of networks the security services they need. The information security and assurance research supported by MICS is focused on the requirements of scientists engaged in unclassified research for applications such as remote control of experimental devices and research collaborations. The development of high-speed communications and collaboration technologies will allow scientists to view, compare, and integrate data from multiple sources remotely.

MICS also operates supercomputer and network facilities that are available to researchers 24 hours a day, 365 days a year. The computing and networking requirements of the Office of Science far exceed the current state-of-the-art; furthermore, the requirements far exceed the tools that the commercial marketplace will deliver. For this reason, the MICS subprogram must not only support basic research in the areas listed above, but also the development of the results from this basic research into software usable by scientists in other disciplines and partnerships with users to test the usefulness of the research. These partnerships with the scientific disciplines are critical because they provide rigorous tests of the usefulness of current advanced computing research, enable MICS to transfer the results of this research to scientists in the disciplines, and help define promising areas for future research. This integrated approach is critical for MICS to succeed in providing the extraordinary computational and communications tools that DOE's civilian programs need to carry out their missions. It is important to note that these tools have applications beyond the Office of Science in the NNSA and in the private sector after they have been initially discovered and developed by MICS.

As noted earlier, in FY 2002, the MICS subprogram will continue its components of the collaborative SciDAC program across the Office of Science to produce the scientific computing, networking and collaboration tools that DOE researchers will require to address the scientific challenges of the next decade. The MICS components include investments in scientific computing research and networking and collaboration research that are complemented by investments in computing and networking facilities.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health. In addition, **performance will be measured by** serving researchers at national laboratories, universities, and industry, thus, enabling new understanding through analysis, modeling and simulation of complex natural and engineered systems and effective integration of geographically distributed teams through national collaboratories.

Scientific Computing Research Investments

As noted earlier, advances in computing technologies during the past decade have set the stage for a major step forward in modeling and simulation. The key measure of success in translating peak computing power into science is the percent of peak performance that is delivered to an application over the *entire* calculation. In the early to mid-1990's on computers such as the Cray Research C-90, many scientific codes realized 40% to 50% of the peak performance of the supercomputer. In contrast, on today's parallel supercomputers, scientific computing codes often realize only 5% to 10% of "peak" performance, and this fraction could decrease as the number of processors in the computers grows.

This challenge is a direct result of the fact that the speed of memory systems and the speed of interconnects between processors is increasing much more slowly than processor speed. For many scientific applications these factors dominate the performance of the application. Two types of solutions are available to the computer hardware designer in addressing the mismatch of speed between the components: (1) clever hierarchical arrangements of memory with varying speeds and software to find data before it is needed and move it into faster memory, closer to the processor that will need it; and (2) techniques to increase parallelism, for example, by using threads in the processor workloads or by combining parallel data streams from memory or disks. Current technology forecasts indicate a doubling or quadrupling in the numbers of layers in the memory hierarchy, and a 100- to 1000-fold increase in the amount of parallelism in disk and tape systems to accommodate the relative increase in the mismatch between processor speed and memory, disk and tape speeds in the next five years.

One result of this increasing complexity of high-performance computer systems is the importance of the underlying systems software. Operating systems, compilers, runtime environments, mathematical libraries, and end-user applications must all work together efficiently to extract the desired high performance from these systems.

In addition to the challenges inherent to managing the required level of parallelism, technology trends and business forces in the U.S. computer system industry have resulted in radically reduced development and production of high-end systems necessary for meeting the most demanding requirements of scientific research. In essence, the U.S. computer industry has become focused on the computer hardware and software needs of business applications, and little attention is paid to the special computational needs of the scientific community. Therefore, to achieve the performance levels required for agency missions and world leadership in computational science, large numbers of smaller commercial systems must be combined and integrated to produce terascale computers. Unfortunately, the operating systems software and tools required for effective use of these large systems are significantly different from the technology offered for the individual smaller components. Therefore, new enabling software must be developed if scientists are to take advantage of these new computers in the next five years.

The following are specific examples of *computer science* research challenges:

- Efficient, high-performance operating systems, compilers, and communications libraries for high-end computers.
- Software to enable scientists to store, manage, analyze, visualize, and extract scientific understanding from the enormous (terabyte to petabyte) data archives that these computers will generate.
- Software frameworks that enable scientists to reuse most of their intellectual investment when moving from one computer to another and make use of lower-level components, such as runtime services and mathematical libraries, that have been optimized for the particular architecture.
- Scalable resource management and scheduling software for computers with thousands of processors.
- Performance monitoring tools to enable scientists to understand how to achieve high performance with their codes.

In addition to these computer science challenges, significant enhancements to the MICS applied mathematical research activity are required for the Department to satisfy its mission requirements for computational science. Over the history of computing, improvements in algorithms have yielded at least as much increase in performance as has hardware speedup. Large proportions of these advances are the products of the MICS applied mathematics research activity. In addition to improving the speed of the calculations, many of these advances have dramatically increased the amount of scientific understanding produced by each computer operation. For example, a class of mathematical algorithms called "fast multipole algorithms," were discovered for a number of important mathematical operations required to process 1,000 datapoints by a factor of 1,000; 10,000 datapoints by a factor of 10,000; and so on. Another example of how powerful these methods can be is that they enable a scientist to process 10,000 datapoints in the time that it would have taken to process 100 using earlier techniques, or 1,000,000 datapoints in the time older techniques would have needed to process 1,000. The requirements of scientific domains for new algorithms that can scale to work effectively across thousands of processors and produce the most science in the fewest number of computer operations drives the need for improved mathematical algorithms and the supporting software libraries that must be made available for ready use by domain scientists. In this area of research the MICS applied mathematics activity is the core of the nationwide effort.

The MICS subprogram will address these challenges by continuing the competitively selected partnerships (based on a solicitation notice to labs and universities) focused on discovering, developing, and deploying to scientists key enabling technologies that were initiated in FY 2001. These partnerships, which are called Integrated Software Infrastructure Centers, must support the full range of activities from basic research through deployment and training because the commercial market for software to support terascale scientific computers is too small to be interesting to commercial software providers. These centers play a critical role in providing the software infrastructure that will be used by the SciDAC applications research teams. The management of these centers will build on the successful experience of the MICS subprogram in managing the DOE2000 initiative, as well as on the lessons learned in important programs supported by DARPA such as Project Athena at MIT, the Berkeley Unix Project, and the initial development of the Internet software and the Internet Activities Board (IAB). These Integrated Software Infrastructure Centers will have close ties to key scientific applications projects to ensure their success.

The efforts initiated in FY 2001 address the important issues of understanding and developing the tools that applications developers need to make effective use of machines that will be available in the next several years.

The MICS activities that respond to these challenges are described later in the Detailed Program Justification section of the MICS subprogram budget under the headings:

Applied Mathematics,

Computer Science, and

Advanced Computing Software Tools.

Networking and Collaboration Research Investments

Advances in network capabilities and network-based technologies now make it possible for large geographically distributed teams to effectively collaborate on the solution of complex problems. This is especially important for the teams using the major experimental facilities, computational resources, and data resources supported by DOE.

- Significant research is needed to enable today's Internet to be effectively used for scientific data retrieval and analysis and collaboratories. The requirements this places on the network are very different than the requirements of the commercial sector where millions of users are moving to small web pages. The MICS subprogram includes research on advanced protocols, special operating system services to support very high-speed transfers, and advanced network control.
- Research is also needed to understand how to integrate the large number of network devices, network-attached devices, and services that collaboratories require. Examples of the components and services that need to be integrated include network resources, data archives on tape, high

performance disk caches, visualization and data analysis servers, authentication and security services, and the computer on a scientist's desk. Common software framework building blocks or "middleware" to enable the collaboratories of the future to succeed must tie all of these physical and software services together.

The MICS subprogram will address these challenges through an integrated program of fundamental research in networking and collaboratory tools, partnerships with key scientific disciplines, and advanced network testbeds.

The MICS activities that respond to these challenges are described in the Detailed Program Justification section of the MICS subprogram budget under the headings:

Networking,

Collaboratory Tools, and

National Collaboratory Pilot Projects.

Enhancements to Computing and Networking Facilities

To realize the scientific opportunities offered by advanced computing, enhancements to the Office of Science's computing and networking facilities are also required. The MICS subprogram supports a suite of high-end computing resources and networking resources for the Office of Science:

- **Production High Performance Computing Facilities.** The National Energy Research Scientific Computing Center (NERSC) provides high performance computing for investigators supported by the Office of Science. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support.
- **Energy Sciences Network (ESnet).** ESnet provides worldwide access to Office of Science facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, high-end computing facilities and other leading-edge instruments and facilities.
- **Advanced Computing Research Testbeds.** These testbeds provide advanced computational hardware for testing and evaluating new computing hardware and software. In addition, these testbeds will provide specialized computational resources to support SciDAC applications teams in FY 2002.

Current production resources provide less than half of the computer resources that were requested last year. The pressure on production facilities will only increase in future years as more applications become ready to move from testing the software to using the software to generate new science. In addition, as the speed of computers increases, the amount of data they produce also increases. Therefore, focused enhancements to the Office of Science's network infrastructure are required to enable scientists to access and understand the data generated by their software. These network enhancements are also required to allow researchers to have effective remote access to the experimental facilities that the Office of Science provides for the Nation.

The MICS activities that respond to these challenges are described later in the Detailed Program Justification section of the MICS subprogram budget under the headings:

National Energy Research Scientific Computing Center (NERSC),
Advanced Computing Research Testbeds, and
Energy Sciences Network (ESnet).

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Mathematical, Computational, and Computer Sciences Research	42,713	70,654	70,681	+27	--
Advanced Computation, Communications Research and Associated Activities	71,201	81,543	81,543	0	--
SBIR/STTR	0	3,973	3,946	-27	-0.7%
Total, Mathematical, Information, and Computational Sciences	113,914	156,170	156,170	0	--

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Mathematical, Computational, and Computer Sciences Research	**42,713**	**70,654**	**70,681**
Applied Mathematics	**20,391**	**32,339**	**32,366**

Research is conducted on the underlying mathematical understanding and numerical algorithms to enable effective description and prediction of physical systems. Research in applied mathematics is critical to the DOE because of the potential of improved mathematical techniques to enable large computational simulations. As discussed earlier in the ASCR overview, improvements in mathematical algorithms are responsible for greater improvement in scientific computing capabilities than the increases in hardware performance. This activity supports research at DOE laboratories, universities, and private companies at a level similar to previous years. Many of the projects supported by this activity are partnerships between researchers at universities and DOE laboratories. To accomplish its goals, the program supports research in a number of areas including: ordinary and partial differential equations, including numerical linear algebra, iterative methods, sparse solvers, and dense solvers; fluid dynamics, including compressible, incompressible and reacting flows, turbulence modeling, and multiphase flows; optimization, including linear and nonlinear programming, interior-point methods, and discrete and integer programming; mathematical physics, including string theory, superstring theory, geometry of space-time, and quantum effects; control theory, including differential-algebraic systems, order

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

reduction, queuing theory; shock wave theory systems, multipole expansions, mixed elliptic-hyperbolic problems, including hyperbolic and wavelet transforms; dynamical systems, including chaos-theory and control, and bifurcation theory; programming; and geometric and symbolic computing, including minimal surfaces and automated theorem proving.

The FY 2002 budget continues the FY 2001 increased level of funding for the Computational Sciences Graduate Fellowship program and the competitively selected Integrated Software Infrastructure Centers (ISICs) partnerships focused on algorithms and mathematical libraries for critical DOE applications on terascale computers that are a significant component of the SciDAC program.

Performance will be measured in a number of ways. Efforts in applied mathematics will be continuously evaluated for their leadership and significant contributions to the worldwide applied mathematics effort using a number of measures including awards, significant advances, and invited participation and membership on organizing and program committees of major national and international conferences. Progress reviews of the Integrated Software Infrastructure Centers (ISICs) will be conducted to ensure that these partnerships are moving forward to accomplish their missions. The Computational Science Graduate Fellowship Program will appoint 20 new students to develop the next generation of leaders in computational science for DOE and the Nation.

	FY 2000	FY 2001	FY 2002
Computer Science	**13,747**	**21,051**	**21,051**

Research in computer science to enable large scientific applications is critical to DOE because its unique requirements for high performance computing significantly exceed the capabilities of computer vendors' standard products. Therefore, much of the computer science to support this scale of computation must be developed by DOE. This activity supports research in two general areas: the underlying software to enable applications to make effective use of computers with hundreds or thousands of processors as well as computers that are located at different sites; and large scale data management and visualization under circumstances where the underlying resources and users are geographically distributed. The first area includes research in protocols and tools for interprocessor communication and parallel input/output (I/O) as well as tools to monitor the performance of scientific applications and advanced techniques for visualizing very large-scale scientific data. Researchers at DOE laboratories and universities, often working together in partnerships, carry out this research. In FY 2002, support for the competitively selected Integrated Software Infrastructure Centers to address critical computer science and systems software issues for terascale computers will be continued. The teams in these Centers focus on critical issues including: tools for analyzing and debugging scientific simulation software that uses thousands of processors; and the development of data management and visualization software capable of handling terabyte scale data sets extracted from petabyte scale data archives. These Integrated Software Infrastructure Centers are a critical component in DOE's strategy for SciDAC.

	FY 2000	FY 2001	FY 2002

(dollars in thousands)

Performance in computer science will be measured through peer review, periodic external expert review of ongoing projects, production of significant research results, and adoption of these technologies by other researchers supported by the Office of Science. In addition, the ISICs initiated in FY 2001 will undergo a progress review to ensure effective coupling both between the ISICs, and between the ISICs and application teams in the MICS Scientific Applications Pilot Projects efforts and with the SciDAC teams funded by the other Programs in the Office of Science.

Advanced Computing Software Tools	**4,910**	**8,473**	**8,473**

This research uses the results of fundamental research in applied mathematics and computer science to develop an integrated set of software tools that scientists in various disciplines can use to develop high performance applications (such as simulating the behavior of materials). These tools, that provide improved performance on high-end systems, are critical to the ability of scientists to attack the complex scientific and engineering problems that can only be solved with high-end computing systems. The initial goal of this program element was to develop foundational tools (math libraries, runtime systems, etc.) that will have a useful life spanning many generations of computer hardware. From the experience gained with end user application scientists applying these tools, it has become clear that to promote wide usage across the scientific community, the tools must also be reliable, documented, and easy to use. In addition, users of the tools need the tools to be maintained so that the tools continue to be available, have bugs fixed, etc. Since many of the tools needed in the high performance arena have no commercial market, the Integrated Software Infrastructure Centers initiated in FY 2001 will provide a means for focused investment to deploy these tools to the scientific community. These competitively selected centers focus research in several areas that include software frameworks, problem-solving environments, distributed computing and collaboration technologies, as well as visualization and data management.

Performance will be measured through peer review, periodic external expert review of ongoing projects, production of significant research results, and adoption of these technologies by other researchers in the Office of Science. In addition, the ISICs initiated in FY 2001 will undergo a progress review to ensure effective coupling between the ISICs and between the ISICs and application teams in the MICS Scientific Applications Pilot Projects efforts and in the SciDAC teams funded by the other Programs in the Office of Science.

Scientific Applications Pilot Projects	**3,665**	**8,791**	**8,791**

This research is a collaborative effort with disciplinary computational scientists to apply the computational techniques and tools developed by MICS supported research to basic research problems relevant to the mission of SC. This effort tests the usefulness of current advanced computing research, transfers the results of this research to the scientific disciplines, and helps define promising areas for future research. The FY 2002 funding for this activity will allow the continuation of the pilot projects that were competitively selected in FY 2001. These pilot projects are tightly coupled to the Integrated Software Infrastructure Centers (described above in applied

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

mathematics, computer science and advanced computing software tools) to ensure that these activities are an integrated approach to the challenges of terascale simulation and modeling that DOE faces to accomplish its missions.

Advanced Computation, Communications Research, and Associated Activities	**71,201**	**81,543**	**81,543**
Networking	**5,892**	**7,066**	**7,066**

Research is needed to develop high-performance networks that are capable of supporting distributed high-end computing and secure large-scale scientific collaboration. High performance networks enable scientists to collaborate effectively and to have efficient access to distributed computing resources such as tera-scale computers, and experimental scientific instruments, and large scientific data archives. This research is carried out at national laboratories and universities. It focuses in areas such as high-performance transport protocols for high-speed networks; scalable techniques for measuring, analyzing, and controlling traffic in high performance networks; network security research to support large-scale scientific collaboration; advanced network components to enable high-speed connections between terascale computers, large scientific data archives, and high-speed networks; and research on high-performance "middleware." Middleware is a collection of network-aware software components that scientific applications need in order to couple efficiently to advanced network services and make effective use of experimental devices, data archives, and terascale computers at different locations. In all of these cases, the network and middleware requirements of DOE significantly exceed those of the commercial market.

Collaboratory Tools	**2,946**	**5,527**	**5,527**

This research uses the results of fundamental research in computer science and networking to develop an integrated set of software tools to support scientific collaborations. This includes enabling scientists to remotely access and control facilities and share data in real time, and to effectively share data with colleagues throughout the life of a project. These tools provide a new way of organizing and performing scientific work that offers the potential for increased productivity and efficiency. These tools will also enable broader access to important DOE facilities and data resources by scientists and educators across the country. This research includes, for example, developing and demonstrating an open, scalable approach to application-level security in widely distributed, open network environments that can be used by all the collaboratory tools as well as by the advanced computing software tools whenever access control and authentication are issues. Having demonstrated feasibility of the security architecture on a small scale, an additional investment is needed to support the integration of collaboratory tools with advanced networking services in a research setting. In this way, security features can be integrated into more end user applications or collaboratory tools, and demonstrated on a large user base. An example of research in collaboratory tools is the development of a modular electronic notebook that extends the capabilities of its paper counterpart by allowing scientists located across the country to share a common record of ideas, data and events of their joint experiments and research programs. These are designed to be valid as a long term, legally defensible record of research,

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

invention, and records management. Tools are being developed for managing distributed collaborations where videoconferencing, whiteboards, and other shared applications are important. Software to enable geographically distributed teams to collaboratively control visualization of data is also being investigated.

	FY 2000	FY 2001	FY 2002
National Collaboratory Pilot Projects	**4,910**	**10,857**	**10,857**

This program is intended to test, validate, and apply collaboratory tools in real-world situations in partnership with other DOE programs. The competitively selected partnerships involve national laboratories, universities, and U.S. industry. It is important to continue to demonstrate and test the benefits of collaboratory tools technology in order to promote its widespread use and enable more effective access to the wide range of resources within the Department, from light sources to terascale computers to petabyte data storage systems. The partnerships that were initiated in FY 2001 focus on developing user environments where collaboration is ubiquitous and distributed computing is seamless and transparent for DOE mission applications such as High Energy and Nuclear Physics data as well as remote analysis and visualization of experimental and simulation results. This level of funding will permit the continuation of the efforts funded in FY 2001.

	FY 2000	FY 2001	FY 2002
National Energy Research Scientific Computing Center (NERSC)	**26,252**	**28,244**	**28,244**

NERSC, located at LBNL, provides high performance computing for investigators supported by the Office of Science. The Center serves 2,000 users working on about 700 projects; 35 percent of users are university based, 60 percent are in National Laboratories, and 5 percent are in industry. NERSC provides a spectrum of supercomputers offering a range of high performance computing resources and associated software support. The two major computational resources at NERSC are a 512 processor Cray T3E computer and a large IBM SP computer whose initial installation was completed in early FY 2000 in a fully competitive procurement process. The FY 2002 funding will support the operation of the IBM-SP computer at about 3.5 teraflops "peak" performance. These computational resources will be integrated by a common high performance file storage system that facilitates interdisciplinary collaborations. Related requirements for capital equipment, such as high-speed disk storage systems, archival data storage systems, and high performance visualization hardware, and general plant projects (GPP) funding are also supported. The MIE for the distributed visualization server was completed in FY 2001. FY 2002 capital equipment requirements continue at the same level as in FY 2001; however, no individual anticipated capital purchase exceeds the MIE threshold.

Performance will be measured in a number of ways. The operating time lost due to unscheduled NERSC downtime, which will be less than 10 percent of the total scheduled possible operating time. In addition, user surveys will continue to show a high degree of satisfaction with the services at NERSC and annual reports will continue to demonstrate production of world-class science from the facility. In FY 2000, the measured operating time lost to unscheduled downtime on systems at NERSC ranged from .08% to .52% of total scheduled possible operating time. NERSC will be operated within budget while meeting user needs and satisfying overall SC program requirements.

Advanced Computing Research Testbeds	**15,739**	**13,061**	**13,061**

This activity supports the advanced computational hardware testbeds that play a critical role in testing and evaluating new computing hardware and software, especially with regard to their applicabilities to scientific problems. Current testbeds are located at Argonne National Laboratory (IBM/ Intel Cluster); and ORNL (Compaq-Alpha technology). These testbeds represent the evolution of Advanced Computing Research Facilities that supported the computational requirements of the scientific application partnerships that were completed in FY 2000. Support for the Nirvana Blue Computer Testbed at LANL was phased out in FY 2001. This activity also supports the distributed high performance storage system (HPSS) testbed collaboration between ORNL and LBNL. Because many of the issues to be investigated only appear in the computer systems at significantly larger scale than the computer manufacturers' commercial design point, these testbeds must procure the largest scale systems that can be afforded and develop software to manage and make them useful. In addition, the ACRTs, taken together, must have a full range of computer architectures to enable comparison and reduce overall program risk. These all involve significant research efforts, often in partnership with the vendors to resolve issues including operating system stability and performance, system manageability and scheduling, fault tolerance and recovery, and details of the interprocessor communications network. Therefore, these systems are managed as research programs and not as information technology investments. In addition, these testbeds will provide specialized computational resources to support SciDAC applications teams in FY 2002.

Performance will be measured by the importance of the research that results from these testbeds as viewed by publications in the scientific literature, the ASCR Advisory Committee and external reviews and the demand for access to these facilities by the nationwide computer and computational science communities.

Energy Sciences Network (ESnet).......................................	**15,462**	**16,788**	**16,788**

ESnet provides worldwide access to the Office of Science facilities, including: advanced light sources; neutron sources; particle accelerators; fusion reactors; spectrometers; supercomputers; Advanced Computing Research Testbeds (ACRTs); and other leading-edge science instruments and facilities. ESnet provides the communications fabric that links worldwide DOE researchers to one another and forms the basis for fundamental research in networking, enabling R&D in collaboratory tools, and applications testbeds such as the national collaboratory pilot projects. To provide these facilities, DOE employs ESnet management at LBNL, who contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM) and Wave Division Multiplexing (WDM). LBNL ESnet management provides system integration to provide a uniform interface to these services for DOE laboratories. In

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

addition, LBNL ESnet management is responsible for the interfaces between the network fabric it provides and the worldwide Internet including the University Corporation for Advanced Internet Development (UCAID) Abilene network that provides high performance connections to many research universities. One reason that ESnet, in the words of the 1998 external review committee, is able to provide the capabilities and services to its users “at significantly lower budgets than other agencies” is its management structure with strong user and site coordination committees. This management structure is built on DOE’s experience in operating large user facilities. The funding in FY 2002 will continue support for an advanced network testbed established in FY 2001 to enable research in collaboratory tools and pilots. Related capital equipment needs are also supported such as high-speed network routers, ATM switches, and network management and testing equipment.

Performance will be measured in a number of ways. The operating time lost due to unscheduled ESnet downtime will be less than 10 percent of the total scheduled possible operating time. In addition, the ESnet program will be reviewed by an external committee during FY 2001 to ensure its effectiveness in meeting its goals. In FY 2000, the measured operating time lost to unscheduled downtime on ESnet was 4 percent of total scheduled possible operating time. ESnet will operate within budget while meeting user needs and satisfying overall SC program requirements. Network enhancements improve researchers access to high performance computing and software support, and enhance scientific opportunities by enabling scientists to access and understand greater amounts of scientific data.

	FY 2000	FY 2001	FY 2002
SBIR/STTR	**0**	**3,973**	**3,946**

In FY 2000, $2,821,000 and $169,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.

	FY 2000	FY 2001	FY 2002
Total, Mathematical, Information, and Computational Sciences	**113,914**	**156,170**	**156,170**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Mathematical, Computational, and Computer Sciences Research	
Provides a slight increase for the competitively selected Integrated Software Infrastructure Centers (ISICs) partnerships focused on algorithms and mathematical libraries for critical DOE applications on terascale computers that are a significant component of the SciDAC program.	+27
SBIR/STTR	
Decrease in SBIR/STTR due to decrease in operating expenses.	-27
Total Funding Change, Mathematical, Information, and Computational Sciences	0

Laboratory Technology Research

Mission Supporting Goals and Objectives

The mission of the Laboratory Technology Research (LTR) subprogram is to support high risk research that advances science and technology to enable applications that could significantly impact the Nation's energy economy. LTR fosters the production of research results motivated by a practical energy payoff through cost-shared collaborations between the Office of Science (SC) laboratories and industry.

An important component of the Department's strategic goals is to ensure that the United States maintains its leadership in science and technology. LTR is the lead program in the Office of Science for leveraging science and technology to advance understanding and to promote our country's economic competitiveness through cost-shared partnerships with the private sector.

The National Laboratories under the stewardship of the Office of Science conduct research in a variety of scientific and technical fields and operates unique scientific facilities. Viewed as a system, these ten laboratories — Ames Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, and Thomas Jefferson National Accelerator Facility — offer a comprehensive resource for research collaborations. The major component of the LTR research portfolio consists of investments at these laboratories to conduct research that benefits all major stakeholders — the DOE, the industrial collaborators, and the Nation. These investments are further leveraged by the participation of an industry partner, using Cooperative Research and Development Agreements (CRADAs). Another LTR subprogram component provides funding to the Office of Science national laboratories to facilitate rapid access to the research capabilities at the SC laboratories through agile partnership mechanisms including personnel exchanges and technical consultations with small business. The LTR subprogram currently emphasizes three critical areas of DOE mission-related research: advanced materials processing and utilization, nanotechnology, intelligent processes and controls, and energy-related applications of biotechnology.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Laboratory Technology Research..........	8,424	9,326	6,698	-2,628	-28.2%
SBIR/STTR	0	254	182	-72	-28.3%
Total, Laboratory Technology Research..	8,424	9,580	6,880	-2,700	-28.2%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Laboratory Technology Research	**8,424**	**9,326**	**6,698**

This activity supports research to advance the fundamental science at the Office of Science (SC) laboratories toward innovative energy applications. Through CRADAs, the SC laboratories enter into cost-shared research partnerships with industry, typically for a period of three years, to explore energy applications of research advances in areas of mission relevance to both parties. The research portfolio consists of 45 projects and emphasizes the following topics: advanced materials processing and utilization, nanotechnology, intelligent processes and controls, and energy-related applications of biotechnology. Efforts underway include the exploration of: (1) a new mask-less photoelectrochemical method for depositing conductive metal patterns with nanometer-scale precision for use in fabricating miniaturized and rugged electrical interconnects and biomolecular electronic devices on any surface or in solution; (2) an innovative injector design for a compact, low-cost, high brightness electron gun to be used in linear colliders, short wavelength Free Electron Lasers, and as a test bed for advanced accelerator concepts; and (3) a new design for a compact scintillation camera for medical imaging for use in the detection of thyroid disease and for pre-surgical imaging of breast cancer and nodal metastases. A small but important component of this activity provides industry, particularly small businesses, with rapid access to the unique research capabilities and resources at the SC laboratories. These research efforts are usually supported for a few months to quantify the energy benefit of a specific problem posed by industry. Recent projects supported the development of: (1) Metal Plasma Immersion Ion Implantation and Deposition to produce various layers of reduced size in copper metallization for the next generation of integrated circuits; (2) the optimization of the composition and mechanical properties of new steels for elevated temperature applications used in the power generation, chemical, and petrochemical industries; and (3) infrared thermography and computer modeling of electrical surge arresters which should lead to increased reliability of electrical energy transmission and reduced inconvenience and expense of power outages for end users. The FY 2002 budget will allow the LTR subprogram to continue technology research partnership projects in emerging areas of interest to DOE; however, the number of research projects supported by CRADAs will be reduced by approximately 30 percent from FY 2001. The Rapid Access portion of the LTR subprogram will be preserved.

Performance in this activity will be measured through merit-based peer and on-site reviews.

SBIR/STTR	**0**	**254**	**182**

In FY 2000, $220,000 and $13,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.

Total, Laboratory Technology Research................................	**8,424**	**9,580**	**6,880**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Laboratory Technology Research	
Decrease the number of supported collaborative research projects by approximately 30 percent.	-2,628
SBIR/STTR	
SBIR/STTR decreases due to decrease in operating expenses.	-72
Total Funding Change, Laboratory Technology Research	-2,700

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects.......................	0	0	1,000	+1,000	+100.0%
Capital Equipment (total)...................	3,797	6,250	6,250	0	0.0%
Total, Capital Operating Expenses	3,797	6,250	7,250	+1,000	+16.0%

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
Archival Systems Upgrade – LBNL.........	2,000	0	2,000	0	0	FY 2002
Distributed Visualization Server – LBNL ..	2,500	0	0	2,500	0	FY 2001
Total, Major Items of Equipment............		0	2,000	2,500	0	

Multiprogram Energy Laboratories - Facilities Support

Program Mission

The mission of the Multiprogram Energy Laboratories - Facilities Support (MEL-FS) program is to support the infrastructure of the five Office of Science (SC) multiprogram national laboratories to enable them to conduct today's high technology scientific research. The notable success of the SC multiprogram laboratories in delivering insights and innovations rests on their distinctive technical and scientific expertise and unique capabilities, including the major user facilities. Continued success depends critically on the ability to maintain both the facilities and the expertise, which requires the existence of an adequate, ES&H compliant and cost effective general purpose infrastructure.

The program funds line item construction funding (i.e., projects with a total estimated cost of $5,000,000 or above) for general purpose facilities at Argonne National Laboratory - East (ANL-E), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest National Laboratory (PNNL). These laboratories are government-owned, contractor-operated (GOCO) and 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. Total operating funding for these laboratories is over $3 billion a year.

The program provides Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation. Local communities around ANL-E, BNL, and ORNL qualify for PILT.

The program also supports costs incurred for centralized Oak Ridge Operations Office (ORO) infrastructure requirements and general operating costs essential to maintaining a viable, functioning operations office. Activities include roads and grounds maintenance, infrastructure maintenance, physical security, emergency management, support of the Oak Ridge Financial Service Center and other technical needs related to landlord responsibilities of the ORO.

Program Goals

- To ensure that the general purpose infrastructure at the multiprogram laboratories meets the Department's research needs in a safe, environmentally sound, and cost-effective manner primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose infrastructure.
- To provide landlord support for the centralized Oak Ridge Operations Office and the Oak Ridge Reservation activities.

Program Objectives

- To correct Environment, Safety and Health (ES&H) inadequacies.
- To reduce risk of operational interruptions due to failed support systems.
- To provide cost effective operations and reduce maintenance costs.
- To provide quality space for multiprogram research and support activities.
- To preserve the government investment in the physical plant of the multiprogram laboratories.
- To promote performance-based infrastructure management.
- To support local communities via Payments in Lieu of Taxes (PILT).
- To provide landlord support for the Oak Ridge Reservation and for the Oak Ridge Operations Office.

Significant Accomplishments and Program Shifts

- Progress in Line Item Projects – Two projects were completed in FY 2000: the Building Electrical Services Upgrade – Phase I at ANL-E and the Electrical Services Rehabilitation – Phase IV at LBNL. Three projects are scheduled for completion in FY 2001: the Central Supply Facility at ANL-E; the Electrical Systems Modifications – Phase I at BNL; and the Electrical Systems Upgrade - Phase III at ANL-E. Two projects are scheduled for completion in FY 2002: Building 77 - Rehabilitation of Building Structure and Systems at LBNL and the Sanitary Systems Modifications – Phase III at BNL.
- The scope of the Building 77-Rehabilitation of Building Structure and Systems project at LBNL was reduced to eliminate the mechanical, electrical and architectural work from the project. This leaves only the structural work which will arrest the differential settling and reinforce the lateral force resisting system of the building. This reduction was necessitated by the original bids for construction being significantly higher than expected due to a tight labor market, work difficulty and location, and operational commitments in the facility that limited the work site availability. This rescoping of the project has added seven months to the project schedule.
- The direct funding for the American Museum for Science and Energy under the Oak Ridge Landlord subprogram ended in FY 2000. Museum operation was transferred to the Oak Ridge National Laboratory where alternative funding mechanisms are being developed, including support by private or industrial partners, and, possibly, an admission fee for adults.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Multiprogram Energy Laboratories-Facilities Support					
Multiprogram Energy Laboratories-Facilities Support	21,255	23,219	-404	22,815	22,816
Oak Ridge Landlord	8,302	10,711	-3,352	7,359	7,359
Total, Multiprogram Energy Laboratories-Facilities Support	29,557[a]	33,930	-3,756	30,174	30,175
General Reduction	0	-315	315	0	0
General Reduction for Safeguards and Security	0	-3,373	3,373	0	0
Omnibus Rescission	0	-68	68	0	0
Total, Multiprogram Energy Laboratories – Facilities Support	29,557 [a]	30,174	0	30,174	30,175

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 $3,498,000 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
Chicago Operations Office					
Argonne National Laboratory	4,980	6,611	2,833	-3,778	-57.1%
Brookhaven National Laboratory	6,881	6,444	6,063	-381	-5.9%
Chicago Operations Office	1,890	1,020	1,020	0	0.0%
Total, Chicago Operations Office	13,751	14,075	9,916	-4,159	-29.5%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	6,133	2,113	4,400	+2,287	+108.2%
Oak Ridge Operations Office					
Oak Ridge National Laboratory	1,101	6,627	7,620	+993	+15.0%
Oak Ridge Operations Office	8,302	7,359	7,359	0	0.0%
Total, Oak Ridge Operations Office	9,403	13,986	14,979	+993	+7.1%
Richland Operations Office					
Pacific Northwest National Laboratory	0	0	880	+880	+100.0%
Washington Headquarters	270	0	0	0	--
Total, Multiprogram Energy Laboratories - Facilities Support	29,557 [a]	30,174	30,715	+1	--

[a] Excludes $3,498,000 in FY 2000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Site Description

Argonne National Laboratory - East

Argonne National Laboratory - East (ANL-E) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. The laboratory consists of 122 facilities, 4.6 million gross square feet of space, with the average age of the facilities being 31 years. Approximately 44 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes funding the following projects:

- MEL-001-09 Fire Safety Improvements - Phase IV (TEC $8,381,000) This project will bring 30 major facilities into compliance with the Life Safety Code and the National Fire Alarm Code.

- MEL-001-17 Mechanical and Control Systems Upgrade – Phase I (TEC $9,000,000) This proposed new start for FY 2002 will upgrade or replace 30-40 year old, deteriorated mechanical system components in various facilities. These will include HVAC, drainage, steam supply, and condensate return systems. This project will optimize capacity, enhance system reliability and performance, improve safety, and reduce maintenance costs. These systems are no longer adequate, reliable, or efficient, and do not meet current ES&H standards (e.g., failure of a laboratory exhaust system could lead to release of radioactive material).

The program also provides funding through the Chicago Operations Office for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Brookhaven National Laboratory

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The laboratory consists of 349 facilities, 4.1 million gross square feet of space, with the average age of the facilities being 39 years. Approximately 35 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes funding the following projects:

- MEL-001-13 Groundwater and Surface Water Protection Upgrades (TEC $6,050,000) This on-going project will address a backlog of ground and surface water protection projects which are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; and replacement of radioactive waste tanks with secondarily contained tanks.

- MEL-001-16 Electrical Systems Modifications, II (TEC $6,770,000) This ongoing project is the second phase of the modernization and refurbishment of the laboratory's deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 2.4 kV switchgear to increase system reliability and safety; reconditioning of 50 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of 10 13.8 kV air breakers with new vacuum technology.

The program also provides funding through the Chicago Operations Office for Payments in Lieu of Taxes (PILT) as authorized by the Atomic Energy Act of 1954, as amended. These discretionary payments are made to state or local governments where the Department or its predecessor agencies have acquired property previously subject to state or local taxation.

Lawrence Berkeley National Laboratory

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 branch of the University of California. The laboratory consists of 118 facilities, 1.6 million gross square feet of space, with the average age of the facilities being 34 years. Approximately 15 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes funding the following project:

- MEL-001-12 Site-wide Water Distribution System Upgrade (TEC $8,300,000) This ongoing project rehabilitates the Lab's High Pressure Water (HPW) System to include: replacement of all 1.4 km of cast iron pipe with ductile iron pipe; installing cathodic protection; replacing and adding pressure reducing stations to prevent excessive system pressure at lower lab elevations; adding an emergency fire water tank to serve the East Canyon; and providing the two current emergency fire water tanks with new liners and seismic upgrades.

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 laboratory consists of 466 facilities, 3.4 million gross square feet of space, with the average age of the facilities being 37 years. Approximately 20 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program is currently funding or proposes to fund the following projects:

- MEL-001-14 Fire Protection System Upgrade (TEC $5,920,000) This ongoing project replaces deteriorated, obsolete systems with more reliable fire alarm and suppression capabilities; replaces the single 16-inch water main in the east central section of ORNL with a looped system; and extends coverage of automatic alarm and sprinkler systems to areas not previously served. Upgrading the fire alarm receiving equipment at the site fire department headquarters ensures its reliability, modernizes its technology, and meets the demands of an expanded fire alarm system network.

- MEL-001-15 Laboratory Facilities HVAC Upgrade (TEC $7,100,000) This ongoing project provides improvements to aging HVAC systems (average age 38 years) located in the 13 buildings which comprise ORNL's central research complex and make additions and improvements to the chilled water distribution system. This includes: redesign of the cooling water distribution system to reduce the number of pumps required and installing more efficient pumps, thereby reducing operations and maintenance costs; installation of an 800 ft., 8-inch-diameter pipe, chill water cross-tie to Buildings 4501/4505 from the underground tie-line between Buildings 4500N/4509 to address low capacity problems in 4501/4505; installation of a 500 ft. 4-inch-diameter pipe to feed new chilled water coils in the east wing of Building 3500; upgrade of the existing 50 year-old air handler with new dampers, filters, steam coils, and controls; and replacement of constant volume, obsolete air handlers in various buildings with variable air volume (VAV) improvements to more efficiently control temperature.

- MEL-001-25 Research Support Center (TEC $16,100,000) This proposed new start for FY 2002 will construct a 50,000 sq. ft. facility to house the core support service facilities and serve as the cornerstone and focal point of the East Research Campus envisioned in the ORNL Facility Revitalization Project. This building will include an auditorium and conference center, cafeteria, visitor reception and control area, and support offices for approximately 50 occupants. It will facilitate consolidation of functions which are presently scattered throughout the Laboratory complex in facilities that are old (30-50 years), undersized, poorly located, or scheduled for surplus. The facility will serve as a modern center for meeting, collaborating, and exchanging scientific ideas for ORNL staff and the nearly 30,000 visitors, guests, and collaborators that use ORNL facilities each year. The new cafeteria will replace the existing cafeteria, which was constructed in 1953. The existing cafeteria is poorly located to serve the current staff and is adjacent to the original production area of the lab now undergoing decontamination. The estimated simple payback is seven years.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on a 960 acre site on the south end of the Hanford Reservation near Richland, Washington. The laboratory consists of 40 facilities, 0.9 million gross square feet of space, with the average age of the facilities being 29 years. Approximately 36 percent of the space is considered adequate, while the remainder needs rehabilitation or replacement/demolition. The MEL-FS program proposes funding the following project:

- MEL-001-18 Laboratory Systems Upgrades (TEC $9,000,000) This proposed new start for FY 2002 will upgrade or replace 20-50 year old mechanical system components in eight high occupancy facilities at PNNL. This project will upgrade these obsolete systems with more efficient, better performing systems to enhance the quality of science while reducing maintenance and energy costs. This upgrade will include: replacement of HVAC supply and exhaust fans; replacement, rehabilitation or modification of numerous chemical exhaust fume hoods; installation of computerized, remote, digital controls on various systems to improve operations; and replacement of an emergency power generator.

Chicago Operations Office

The Chicago Operations Office processes the Payments in Lieu of Taxes made to the local taxing authorities at Brookhaven National Laboratory and Argonne National Laboratory-East.

Oak Ridge Operations Office

The Oak Ridge Landlord program provides for centralized Oak Ridge Operations Office (ORO) infrastructure requirements and general operating costs for activities on the Oak Ridge Reservation outside plant fences and activities to maintain a viable operations office, including maintenance of roads and grounds and other infrastructure, operation of the Emergency Management Program Office, Payments In Lieu of Taxes, and support for the Oak Ridge Financial Service Center as well as other technical needs related to landlord activities.

Multiprogram Energy Laboratories - Facilities Support

Mission Supporting Goals and Objectives

This subprogram supports the program's goal to ensure that support facilities at the five Office of Science (SC) multiprogram national laboratories can meet the Department's research needs primarily by refurbishing or replacing deteriorated, outmoded, unsafe, and inefficient general purpose infrastructure. General purpose facilities are general use, service and support facilities such as administrative space, cafeterias, general office/laboratory space, utility systems, sanitary sewers, roads, etc.

The subprogram strives to improve the condition of laboratory buildings (i.e., increasing the percentage of buildings rated adequate). **Performance will be measured** by the increase in the percentage of facilities rated adequate over time. The percentage of space rated adequate increased from 26% in FY 1998 to 30% in FY 2000.

Capital investment requirements are identified in laboratory Strategic Facilities Plans that address infrastructure needs through the year 2011 to adequately support expected programmatic activities. These plans (currently under SC review) assume the full modernization/revitalization of the general purpose infrastructure of the multiprogram labs will be completed over this period. The projected investments total is ~$1,000,000,000. Of this amount, 85% is to rehabilitate or replace buildings; 9% is for utility projects; and 6% for ES&H and other projects.

The large backlog of building related projects reflects the fact that the condition of only 50% of the laboratory space is considered fully adequate, while the remaining 50% needs rehabilitation or replacement/demolition. Often, even adequate space is not functional for modern research purposes (e.g., a well maintained 1940 vintage wooden barracks is not particularly useful when modern lab/office space is needed). The large percentage of inadequate space is due to:

- the age of the facilities (over 69% of the buildings are 30 years old or older and, 43% are 40 years old or older)
- changing research needs that require different kinds of space (e.g., more office space and light laboratory space than hot cells)
- obsolescence of existing systems and components
- changing technology (e.g., digital controls)
- changing environmental, safety and health regulations, and
- inadequate capital investment in the past

The backlog of utilities and ES&H projects is much lower ($150,000,000 or 15% of the total backlog) due to investments by the MEL-FS program over the last 20 years. Utilities and ES&H projects consistently scored highest and limited funding did not allow many building needs to be addressed.

In any given budget year, all candidate projects for funding are first ranked using the Life Cycle Asset Management (LCAM) Cost-Risk-Impact Matrix that takes into account risk, impacts, and mission need. The projects that have ES&H as the principal driver are further prioritized using the Risk Prioritization Model from the DOE ES&H and Infrastructure Management Plan process. Based on these rankings, the subprogram funds the highest priority projects that reduce risk, ensure continuity of operations, avoid or reduce costs, and increase productivity. **Performance will be measured by** the percentage of projects that rank among the highest priority projects and have a Capital Asset Management Process (CAMP) ranking score of greater than 50. All FY 2000-FY 2002 funded projects were evaluated by an integrated infrastructure management team as the highest priority projects and each has a CAMP score greater than 60.

The subprogram ensures that the funded projects are managed effectively and completed within the established cost, scope and schedule baselines. **Performance will be measured by** the number of projects completed within the approved baselines for cost (at or below the appropriated TEC), scope (within 10%), and schedule (within six months). Both projects scheduled for completion in FY 2000 were completed within the approved baselines for cost, scope, and schedule.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Purpose Facilities	14,495	8,816	5,380	-3,436	-39.0%
Environment, Safety and Health	4,600	12,979	16,416	+3,437	+26.5%
Infrastructure Support	2,160	1,020	1,020	0	--
Total, Multiprogram Energy Laboratories - Facilities Support	21,255	22,815	22,816	+1	--

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
General Purpose Facilities	**14,495**	**8,816**	**5,380**

Provides funding to support the initiation of two new subprojects in FY 2002 as well as the continuation of one FY 2001 subproject under the Multiprogram Energy Laboratories Infrastructure Project (MEL-001). The FY 2002 funding is for design activities for the following projects: Laboratory Systems Upgrade at PNNL ($880,000); and Research Support Center at ORNL ($1,500,000). The FY 2001 subproject is the Laboratory Facilities HVAC Upgrade at ORNL ($3,000,000).

	FY 2000	FY 2001	FY 2002
Environment, Safety and Health	**4,600**	**12,979**	**16,416**

Provides funding to support the initiation of one new ES&H subproject in FY 2002, as well as the continuation of four FY 2001 subprojects under the Multiprogram Energy Laboratories Infrastructure

	FY 2000	FY 2001	FY 2002

(dollars in thousands)

Project (MEL-001). The FY 2002 funding for the new start is for design activities for the Mechanical and Control Systems Upgrade – Phase I at ANL-E ($803,000). The FY 2001 subprojects are: Groundwater and Surface Water Protection Upgrades at BNL ($2,763,000); Fire Protection System Upgrade at ORNL ($ 3,120,000); Site-wide Water Distribution System Upgrade at LBNL ($4,400,000); and Electrical Systems Modifications - Phase II at BNL ($3,300,000). The request also supports the completion of Fire Safety Improvements - Phase IV at ANL-E ($2,030,000).

	FY 2000	FY 2001	FY 2002
Infrastructure Support	**2,160**	**1,020**	**1,020**
■ **Payment in Lieu of Taxes (PILT)**	2,160	1,020	1,020

Continue meeting Payments in Lieu of Taxes (PILT) assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory-East. **Performance will be measured** by the Department funding the PILT payments at the levels negotiated with the local governments. The PILT payments equaled the negotiated levels in FY 2000.

	FY 2000	FY 2001	FY 2002
Total, Multiprogram Energy Laboratories – Facilities Support	**21,255**	**22,815**	**22,816**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Multiprogram Energy Laboratories – Facilities Support	
■ Continue at FY 2001 level.	+1
Total Funding Change, Multiprogram Energy Laboratories - Facilities Support	+1

Oak Ridge Landlord

Mission Supporting Goals and Objectives

This subprogram supports landlord responsibilities for the centralized Oak Ridge Operations Office (ORO) including infrastructure of the Oak Ridge Reservation (the 24,000 acres of the Reservation outside of the Y-12 plant, ORNL, and the East Tennessee Technology Park), and DOE facilities in the town of Oak Ridge. This includes roads and grounds and other infrastructure maintenance, ES&H support and improvements, support for the emergency management operations, support of the Oak Ridge Financial Service Center, PILT for Oak Ridge communities, and other technical needs related to landlord requirements. These activities maintain continuity of operations at the Oak Ridge Reservation and the ORO and minimize interruptions due to infrastructure or emergency management and other systems failures. **Performance will be measured** by the number of significant ORO interruptions which can be directly attributed to infrastructure failures. In FY 2000 there were no significant interruptions due to infrastructure failures.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Oak Ridge Landlord	8,302	7,359	7,359	0	--

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
■ **Roads, Grounds and Other Infrastructure and ES&H Support and Improvements**	2,180	2,200	2,200
■ **Emergency Management Program Office**	1,223	664	664

Provides for the operation of the Oak Ridge Emergency Operations Center and the Communications and Operations Center.

	FY 2000	FY 2001	FY 2002
■ **Payments in Lieu of Taxes (PILT)**	1,916	1,900	1,900

Payments in Lieu of Taxes (PILT) to the City of Oak Ridge, and Anderson and Roane Counties.

	FY 2000	FY 2001	FY 2002
■ **American Museum of Science and Energy**	400	0	0

FY 2000 is the last year direct support for the museum is provided. Museum operation was transferred to ORNL where alternative funding mechanisms are being developed, including support by private or industrial partners, and, possibly, an admission fee for adults.

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
■ **Oak Ridge Financial Service Center**..................................	1,635	1,700	1,700

Provides computer and systems support to the Center which serves other DOE field offices as well as Oak Ridge.

	FY 2000	FY 2001	FY 2002
■ **Technical Support**..	948	895	895

Includes recurring activities such as computer and systems support for Directives and Training activities and one-time activities such as the identification, packaging, and shipment of documents relating to Human Radiation Experimentation to the National Archives for permanent storage, and support for legacy legal cases.

	FY 2000	FY 2001	FY 2002
Total, Oak Ridge Landlord..	**8,302**	**7,359**	**7,359**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Oak Ridge Landlord	
■ No changes from FY 2001 to FY 2002.	

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	0	200	0	-200	-100.0%
Capital Equipment	100	315	315	0	--
Total, Capital Operating Expenses	100	515	315	-200	-38.8%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 2000	FY 2001	FY 2002	Unapprop. Balance
Project – 02-SC-001 Multiprogram Energy Laboratories Infrastructure Project FY 2002 PED Datasheet	N/A	N/A	0	0	3,183	0
Project - MEL-001 Multiprogram Energy Laboratories Infrastructure Project FY 2002 Construction Datasheet	N/A	N/A	18,351	21,795	18,613	13,029
Total, MELFS Construction	N/A	N/A	19,095 [a]	21,795	21,796	13,029

[a] Total MELFS construction, including projects fiscally completed prior to FY 2001. Includes $744 to complete funding for project 94-E-363, Roofing Improvements (ORNL).

MEL-001 - Multiprogram Energy Laboratories, Infrastructure Project, Various Locations

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

Significant Changes

The scope on the Building 77-Rehabilitation of Building Structure and Systems project was reduced to eliminate the mechanical, electrical and architectural work from the project. This leaves only the structural work which will arrest the differential settling and reinforce the lateral force resisting system of the building. This reduction was necessitated by the original bids for construction being significantly higher than expected due to a tight labor market, work difficulty and location, and operational commitments in the facility that limited the work site availability. The rescoping of the project has added seven months to the project schedule.

1. Construction Schedule History

Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		

N/A -- See subproject details

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Construction			
Prior Years	10,383	10,383	3,916
FY 2000	18,351	18,351	17,789
FY 2001	21,795	21,795	22,303
FY 2002	18,613	18,613	17,631
FY 2003	13,029	13,029	19,477
FY 2004	0	0	1,055

3. Project Description, Justification and Scope

This project funds two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Projects to correct ES&H deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades and electrical system replacements.

General Purpose Facility Projects:

a. Subproject 04 - Electrical Systems Modifications, Phase I (BNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
5,730	849	3,881	1,000	0	0	2Q 2000 - 4Q 2001

This project is the first phase of a planned modernization and refurbishment of the Laboratory's electrical infrastructure. The project provides for the replacement of 30 to 50 year old deteriorating underground electrical cables, the addition of underground ductbanks to replace damaged portions and support new cabling, the installation of a new 13.8 kV - 2.4 kV step-down transformer substation to address capacity and operational problems, and the retrofitting/reconditioning of switchgear power circuit breakers.

b. Subproject 05 - Bldg. 77 - Rehabilitation of Building Structure and Systems (LBNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
8,000	754	6,133	1,113	0	0	3Q 2000 - 2Q 2002

This project will rehabilitate Building 77's structural system to restore lateral force resistance and arrest differential foundation settlement. These upgrades will restore this 33 year-old, 68,000 sq.ft. building to acceptable seismic performance and prevent loss at this facility due to structure failures.

c. Subproject 06 - Central Supply Facility (ANL-E)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates

5,900	1,860	3,380	660	0	0	3Q 2000 - 4Q 2001

This project includes a 22,000 sq.ft. addition to the Transportation and Grounds Facility (Bldg. 46) along with remodeling of 3,500 sq.ft. of space in the existing Transportation and Grounds Facility. The project will result in economies and efficiencies by providing a highly efficient and cost-effective consolidated facility to meet the missions of the Materials Group and the Property Group of ANL-East and will eliminate the need for 89,630 square feet of substandard (50 year-old) space in six buildings which will be demolished (Bldgs. 4, 5, 6, 26, 27, and 28). The Materials Group receives, sorts, stores, retrieves, and distributes the majority of all materials and supplies for the Laboratory. The Property Group tags, controls, stores, and distributes excess property and precious metals for the Laboratory. This facility will contain truck docks; receiving and distribution areas; inventory control; general material storage; support and office areas; property storage; and exterior hazardous storage. This project will also eliminate 7,000 linear feet of steam supply and return lines.

d. Subproject 08 - Electrical Systems Upgrade (ORNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
5,900	0	357	5,543	0	0	3Q 2001 - 2Q 2003

This project will replace electrical distribution feeders and upgrade transformers and switchgear feeding research facilities and primary utility support facilities throughout the Oak Ridge National Laboratory (ORNL) complex. It will also provide advanced protective relaying and metering capabilities at major substations. The project is part of a phased infrastructure upgrade to restore the electrical distribution systems serving the ORNL. The purpose of the upgrade is to maintain a reliable source of electrical power appropriate for servicing scientific research facilities. Without the proposed upgrade, the potential for electrical faults and outages will increase as the distribution system ages, with attendant increased risk of equipment damage and the potential inability to meet laboratory programmatic goals due to downtime of critical facilities. These facilities include the central research facilities, supercomputing facility, Robotics and Process Systems facility, the central chilled water plant, and the steam plant. Also, maintenance costs involved in continued operation of the existing deteriorated system will increase as the system ages.

e. Subproject 15 – Laboratory Facilities HVAC Upgrade (ORNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
7,100	0	0	500	3,000	3,600	3Q 2002 – 2Q 2004

This project will provide improvements to aging HVAC systems (average age 38 years) located in the thirteen (13) buildings which comprise Oak Ridge National Laboratory's (ORNL's) central research complex and additions and improvements to the chiller water distribution system. This includes:

redesign of the cooling water distribution system to reduce the number of pumps required and installing more efficient pumps, thereby reducing operations and maintenance costs; installation of an 800 ft., 8-inch-diameter pipe, chill water cross-tie to Bldgs. 4501/4505 from the underground tie-line between Bldgs. 4500N/4509 to address low capacity problems in 4501/4505; installation of a 500 ft. 4-inch-diameter pipe to feed new chilled water coils in the east wing of Bldg. 3500; upgrade of the existing 50 year-old air handler with new dampers, filters, steam coils, and controls; and replacement of constant volume, obsolete air handlers in various buildings with variable air volume (VAV) improvements to more efficiently control temperature.

ES&H Projects:

a. Subproject 03 - Electrical Systems Upgrade - Phase III, (ANL-E)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
7,620	6,420	1,200	0	0	0	2Q 1999 - 1Q 2001

The project provides for the upgrade of the main electrical substation at Facility 543 and Facility 549A.

The work consists of the following items: install a new 138 kV overhead steel pole transmission line and upgrade the existing transmission line, relocate an existing transformer, upgrade existing transformers, replace existing 13.2 kV outdoor switchgear, and replace existing oil circuit breaker.

The intended project will accomplish several objectives related to system reliability, personnel safety, environmental hazards, risk reduction and system expansion.

b. Subproject 07 - Sanitary System Modifications - Phase III, (BNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
6,500	500	3,000	3,000	0	0	1Q 2000 - 2Q 2002

The BNL Sanitary System consists of over 20 miles of collection piping that collects sanitary waste from nearly all the BNL facilities. The collection piping transports the waste via gravity piping and lift stations to a sewage treatment plant (STP). This project is the third phase of the upgrade of the Laboratory sanitary waste system. In the first two phases, major operations of the STP were upgraded and approximately 14,000 feet of trunk sewer lines were replaced, repaired, or lined. Phase III will continue this upgrade and will replace or rehabilitate approximately 9,900 feet of existing deteriorated (8 to 20 inch) sewer piping, connect five facilities to the sanitary system by installing 7,500 feet of new sewer pipe, and two new lift stations. This will eliminate non-compliant leaching fields and cess pools, reduce non-contact cooling water flow into the sewage system by 72 million gallons per year by: diverting flow to the storm system; converting water heat exchangers to air cooled condensers; and replacing water cooled equipment in 15 buildings. The STP anaerobic sludge digester will be replaced with an aerobic sludge digester to eliminate high maintenance activity and improve performance.

c. Subproject 09 - Fire Safety Improvements, Phase IV, (ANL-E)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
8,381	0	400	5,951	2,030	0	3Q 2001 - 2Q 2003

This project will complete the effort of correcting known deficiencies with respect to fire detection and alarm systems; life safety and OSHA related sprinkler systems; and critical means of egress in twenty-eight (28) buildings at the Argonne National Laboratory-East (ANL-E) site. Correction of these deficiencies is required to comply with DOE Order 420.1, OSHA 1910,164, and OSHA Subpart C. These deficiencies, if uncorrected, could result in unmitigated risks of injury to personnel and/or damage to DOE property in case of fire.

d. Subproject 12 - Site-wide Water Distribution System Upgrade, (LBNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
8,300	0	0	1,000	4,400	2,900	2Q 2002 – 1Q 2004

This project will rehabilitate the Laboratory's High Pressure Water (HPW) System that supplies over 100 facilities at LBNL. The HPW System provides domestic water, fire water, treated water, cooling tower water and low conductivity water. It consists of 9.6 km of pipe (1.4 km of cast iron pipe, 6.3 km of ductile iron pipe, and 1.9 km of cement lined coated steel pipe), associated valves, pumps, fittings etc. and two 200,000 gallon emergency fire water tanks. This project will: replace all cast iron pipe, which is in imminent danger of failing, with ductile iron pipe; electrically isolate pipe and provide cathodic protection; replace leaking valves and add pressure reducing stations to prevent excessive system pressure at lower lab elevations; add an emergency fire water tank to serve the East Canyon; and provide the two current emergency fire water tanks with new liners and seismic upgrades.

e. Subproject 13 - Groundwater and Surface Water Protection Upgrades, (BNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
6,050	0	0	1,889	2,763	1,398	2Q 2002 - 1Q 2004

This project will implement a backlog of ground and surface water protection projects that are commitments to regulators. These include: proper closure of inactive supply and injection wells; runoff control for the surplus material storage yard; containment and runoff control for the radioactive material storage yard; replacement of 12 hydraulic elevator cylinders; removal of 22 underground fuel oil tanks; and other Suffolk County DHS Article 12 upgrades.

f. Subproject 14 - Fire Protection System Upgrade, (ORNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
5,920	0	0	584	3,120	2,216	3Q 2002 - 4Q 2004

This project will upgrade the 36 year-old fire protection system with improved, more reliable fire alarm and suppression capabilities by: replacing deteriorated, obsolete systems; replacing the single 16-inch water main in the east central section of ORNL with a looped system (7,000 lf of 16 inch pipe); and by extending coverage of automatic alarm systems and sprinkler systems to areas not previously served. New fire alarm equipment will provide emergency responders with greatly improved annunciation of the causes and locations of alarms and will provide code compliant occupant notification evacuation alarms for enhanced life safety. It will also include timesaving, automatic diagnostic capabilities that will reduce maintenance costs. The new occupant notification systems will comply with the Americans with Disabilities Act. The fire alarm receiving equipment at the site fire department headquarters will be upgraded to ensure its reliability, modernize its technology, and meet the demands of an expanded fire alarm system network.

g. Subproject 16 – Electrical Systems Modifications II, (BNL)

TEC	Prev.	FY 2000	FY 2001	FY 2002	Outyear	Construction Start/ Completion Dates
6,770	0	0	555	3,300	2,915	2Q 2002 – 1Q 2004

This project is the second phase of the modernization and refurbishment of the Laboratory's deteriorating 50 year-old electrical infrastructure. The project includes: installation of two new 13.8 kV feeders to provide alternate sources to existing, aged feeders; installation of additional underground ductbanks to support a new 13.8 kV feeder; replacement of 2.4 kV switchgear to increase system reliability/safety; reconditioning of 50 480-volt circuit breakers including replacing obsolete trip units with modern, solid-state trip devices; and the retrofit of 10 13.8 kV air breakers with new vacuum technology.

4. Details of Cost Estimate

N/A

5. Method of Performance

To the extent feasible, construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids.

6. Schedule of Project Funding

N/A

7. Related Annual Funding Requirements

N/A

8. Design and Construction of Federal Facilities

All DOE facilities are designed and constructed in accordance with applicable Public Laws, Executive Orders, OMB Circulars, Federal Property Management Regulations, and DOE Orders. The total estimated cost of the project includes the cost of measures necessary to assure compliance with Executive Order 12088, “Federal Compliance with Pollution Control Standards;” section 19 of the Occupational Safety and Health Act of 1970, the provisions of Executive Order 12196, and the related Safety and Health provisions for Federal Employees (CFR Title 29, Chapter XVII, Part 1960); and the Architectural Barriers Act, Public Law 90-480, and implementing instructions in 41 CFR 101-19.6. The project will be located in an area not subject to flooding determined in accordance with Executive Order 11988. DOE has reviewed the GSA inventory of Federal Scientific laboratories and found insufficient space available, as reported by the GSA inventory.

02-SC-001 - Multiprogram Energy Laboratories, Project Engineering Design (PED), Various Locations

1. Construction Schedule History

Fiscal Quarter				Total Estimated Cost ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete	

N/A – See Subproject details

2. Financial Schedule

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
2002	3,183	3,183	2,385
2003	0	0	798

3. Project Description, Justification and Scope

This project funds PED for two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Projects to correct Environment, Safety and Health (ES&H) deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades and electrical system replacements.

This PED data sheet requests design funding for three FY 2002 new starts. The following three new projects that will be started in FY 2002 are: Mechanical and Control Systems Upgrade – Phase I at Argonne National Laboratory – East; Laboratory Systems Upgrades at Pacific Northwest National Laboratory; and Research Support Center at Oak Ridge National Laboratory.

FY 2002 Proposed Design Projects

General Purpose Facility Projects:

02 -01: MEL-001-018 – Laboratory Systems Upgrades (PNNL)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2002	2Q 2003	N/A	880	9,000

Fiscal Year	Appropriations	Obligations	Costs
2002	880	880	660
2003	0	0	220

This design project will provide design to upgrade or replace 20-50 year old mechanical system components in eight high occupancy facilities at PNNL. This project will upgrade these obsolete systems with more efficient, better performing systems to enhance the quality of science while reducing maintenance and energy costs. This upgrade will include: replacement of HVAC supply and exhaust fans; replacement, rehabilitation or modification of numerous chemical exhaust fume hoods; installation of computerized, remote, digital controls on various systems to improve operations; and replacement of an emergency power generator.

02 -03: MEL-001-025 – Research Support Center (ORNL)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2002	2Q 2004	N/A	1,500	16,100

Fiscal Year	Appropriations	Obligations	Costs
2002	1,500	1,500	1,125
2003	0	0	375

This design project will construct a 50,000 sq. ft. facility to house the core support service facilities and serve as the cornerstone and focal point of the East Research Campus envisioned in the ORNL Facility Revitalization Project. This building will include an auditorium and conference center, cafeteria, visitor reception and control area, and support offices for approximately 50 occupants. It will facilitate consolidation of functions which are presently scattered throughout the Laboratory complex in facilities that

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

are old (30-50 years), undersized, poorly located, or scheduled for surplus. The facility will serve as a modern center for meeting, collaborating, and exchanging scientific ideas for ORNL staff and the nearly 30,000 visitors, guests, and collaborators that use ORNL facilities each year. The new cafeteria will replace the existing cafeteria which was constructed in 1953. The existing cafeteria is poorly located to serve the current staff and is adjacent to the original production area of the lab now undergoing decontamination. The estimated simple payback is seven years.

ES&H Projects:

02-08: MEL-001-017 – Mechanical and Control Systems Upgrade – Phase I (ANL-E)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection [a] ($000)
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q 2002	3Q 2002	2Q 2003	NA	803	9,000

Fiscal Year	Appropriations	Obligations	Costs
2002	803	803	600
2003	0	0	203

This design project will provide design to upgrade and replace 30-40 year old mechanical system components in various facilities. It will optimize capacity, enhance system reliability and performance, improve safety, and reduce maintenance and repair costs of primary building mechanical equipment and control systems. The mechanical systems designated for replacement are no longer adequate, reliable, or efficient, and do not meet current ES&H standards (i.e. failure of laboratory exhaust systems could lead to the release of radioactive material). Specifically, this project will: upgrade HVAC systems in Bldgs. 221 and 362, including heating and cooling coils, fans, filter systems, ductwork, controls, and variable frequency drive fans; upgrade lab exhaust systems in Bldgs. 202 and 306, including new fans, ductwork, and controls; upgrade corroded drainage systems in Bldgs. 200, 205 and 350; and upgrade steam and condensate return systems in 12 facilities in the 360 area. This will include high and low pressure steam supply piping and associated pressure reducing stations, valves, and accessories; and replacing condensate pumping systems including piping, valves and system controls.

4. Details of Cost Estimate

N/A

5. Method of Performance

[a] The full TEC Projection (design and construction) is a preliminary estimate based on conceptual data and should not be construed as a project baseline.

Design services will be obtained through competitive and/or negotiated contracts. M&O contractor staff may be utilized in areas involving security, production, proliferation, etc. concerns.

6. Schedule of Project Funding

N/A

Fusion Energy Sciences

Program Mission

By providing support for the Fusion Energy Sciences (FES) program, DOE serves a unique role as the only source of funding for fusion science and high temperature plasma physics in the United States, and as a major source of funds for general plasma science research. The mission of the FES program, a multi-purpose, scientific research effort, is

> *"to advance plasma science, fusion science, and fusion technology--the knowledge base needed for an economically and environmentally attractive fusion energy source."*

The Policy Goals associated with this mission are:

- Advance plasma science and technology in pursuit of national science and technology goals.
- Develop fusion science, technology, and plasma confinement innovations as the central theme of the domestic program.
- Pursue fusion energy science and technology as a partner in the international effort.

This mission statement and its associated Policy Goals have been developed with extensive stakeholder input, and they have been endorsed by the Fusion Energy Sciences Advisory Committee (FESAC) and the Secretary of Energy Advisory Board (SEAB).

Plasma science is the study of the ionized matter that makes up 99 percent of the observable universe. Plasmas can be seen in many different venues, ranging from neon lights to stars. Plasma science includes not only plasma physics but also other physical phenomena in ionized matter, such as atomic, molecular, radiation-transport, and excitation and ionization processes. These phenomena can play significant roles in plasmas and in the interaction of plasmas with particles that result from the fusion process, electro-magnetic waves used to heat the plasma, and the material walls surrounding the plasma. Plasma science and technology contributes not only to fusion research, but also to national security and many other fields of science and technology such as astrophysics and industrial processing.

Fusion science deals primarily with describing the fundamental processes taking place in plasmas where the temperature and density approach those needed to allow the nuclei of two light elements, like hydrogen, to join together, or fuse. When these nuclei fuse, a large amount of energy is released. While fusion science shares many issues with plasma science, research is organized around the two leading methods of confining the fusion plasma—magnetic, wherein strong magnetic fields constrain the charged plasma particles, and inertial, wherein laser or particle beams compress the plasma for short pulses. For magnetic fusion, the scientific issues include:

1. the transport of plasma heat from the core outwards to the plasma edge and to the material walls as a result of electromagnetic turbulence in the plasma (chaos, turbulence, and transport),
2. the stability of the magnetic configuration and its variation in time as the plasma pressure, density, turbulence level, and population of high energy fusion products changes (stability, reconnection, and dynamo),
3. the role of the colder plasma at the plasma edge and its interaction with both material walls and the hot plasma core (sheaths and boundary layers), and

4. the interaction of electrons and ions in the plasma with high-power electromagnetic waves injected into the plasma for plasma heating, current drive and control (wave-particle interaction).

For inertial fusion, the scientific issues include:

1. high energy density physics, such as laser-plasma and beam-plasma interactions, and
2. the behavior of non-neutral plasmas (such as beams of electrons or ions).

Progress in all of these issues is likely to be required for ultimate success in achieving a practical fusion energy source.

Enabling research and development activities, such as support for enhancing the operational capabilities of experimental facilities, and materials science research are closely associated with fusion science.

Fusion energy science and technology refers to the science of a self-heated, or burning plasma, and the specific set of activities that need to be explored to make fusion a practical energy source in the long term. The program is pursuing these specific activities at a low level of funding; any major effort in this area will only be undertaken in collaboration with international partners.

Both the President's Committee of Advisors on Science and Technology and SEAB have recognized the potential of fusion and have recommended that fusion be a key component of the nation's long-term energy strategy. The National Research Council (NRC) has endorsed the dual nature of the FES program as a science program and as a long-term energy program. NRC has stated that fusion research has made remarkable strides over the years, and the quality of the science produced by the DOE funded fusion program is easily on a par with other leading areas of contemporary physical science. In recent years, as the program has focused on the key science issues described above, we have made dramatic progress in understanding the extraordinarily complex medium called plasma. For the first time, we are able to predict detailed behavior and control some of the micro-turbulence that has limited our ability to confine hot plasma in magnetic fields.

Program Goals

During 1998-1999, FESAC conducted a major review of the fusion program that culminated in the report "Priorities and Balance within the Fusion Energy Sciences Program," dated September 1999. A hallmark of this report is its attempt to deal even handedly with magnetic fusion science and inertial fusion science. In December 2000, FESAC reaffirmed that the priorities, balance, and strategic vision laid out in its 1999 report remain valid. Based on that report, the programmatic goals for the Magnetic Fusion Energy (MFE) and the Inertial Fusion Energy (IFE) parts of the program are given below. Consistent with the recommendations of the NRC report, these goals reflect both the science and energy aspects of the FES program.

<u>MFE Program Goals</u>

- Advance the fundamental understanding of plasma, the fourth state of matter, and enhance predictive capabilities, through the comparison of well-diagnosed experiments, theory and simulation.
- Resolve outstanding scientific issues by investigating a broad range of innovative plasma confinement configurations.
- Advance understanding and innovation in high-performance plasmas, and participate in a burning plasma experiment.

- Develop the technologies needed to advance fusion science; pursue innovative technologies and materials to improve the long-range vision for fusion energy.

IFE Program Goals

- Advance the fundamental understanding and predictability of high energy density plasmas for IFE, leveraging from the Inertial Confinement Fusion (ICF) target physics work sponsored by the National Nuclear Security Agency (NNSA).
- Develop the science and technology of attractive repetition-rated IFE power systems.

Each set of goals is derived from different program imperatives that have evolved over time.

For MFE and IFE, the imperatives included the continued development of fundamental scientific understanding and innovative technologies through the advancement of innovative concepts.

For MFE, in addition, the international fusion effort, including construction decisions for major next-step experiments, defines a broad context and a possible time frame for the MFE program.

For IFE, the program is paced by the need to obtain critical high energy density physics information from NNSA-funded programs, including the National Ignition Facility and other facilities. Another imperative is the eventual initiation of an Integrated Research Experiment that would integrate IFE elements, including a driver and target chamber. These two imperatives provide a possible time frame for the IFE program.

Program Objectives

Management Objectives

- Deliver excellent research in plasma science, fusion science and fusion technology, cognizant of DOE mission needs as well as the needs of the broad national science agenda.
- Provide national and international leadership in select areas of plasma science, fusion science, and fusion technology.
- Be the steward for plasma science, fusion science, and fusion technology at the DOE laboratory complex and research facilities, and for the scientific and technical workforce, providing the infrastructure to meet elements of the Nation's science agenda now and in the future. Ensure that the fusion research program is effectively integrated to produce results that advance the program's mission while working to build effective, mutually beneficial connections with other fields of science.
- Manage the fusion program's human resources and the operations of the national fusion science user facilities to the highest standards for efficiency, productivity, and safety. Use peer reviews and merit evaluations to plan, select, implement, and review fusion energy sciences programs.
- Enhance the effectiveness of available U.S. funding through mutually beneficial collaborative activities with fusion programs abroad.
- Coordinate with the NNSA's Office of Defense Programs on IFE.
- Continue to educate and train young scientists who will contribute broadly to the Nation's progress in many fields of science and technology.

Evaluation of Objectives

In October 2000, the NRC Fusion Assessment Committee released a draft of its final report "An Assessment of the Department of Energy's Office of Fusion Energy Sciences Program." The NRC concluded that the U.S. FES program "… has made remarkable strides over the years … Significant progress has been made in understanding and controlling instabilities and turbulence in plasma fusion experiments, facilitating improved plasma confinement. … Many of the major experimental and theoretical tools that have been developed are now converging to produce a qualitative change in the approach to scientific discovery in the program." The Committee concluded "… the quality of science funded by the United States fusion research program …is easily on a par with other leading areas of contemporary physical science." It recommended:

- making the scientific understanding of fusion plasmas a major program goal.
- initiating a systematic effort to reduce the isolation of the fusion research community from the rest of the scientific community.
- broadening the program's institutional base into the wider scientific community.
- establishing a new frontier plasma science center, even in a level budget scenario.
- developing solid support within the broad scientific community for U.S. investment in a burning plasma experiment.
- involving the NSF in extending the reach of fusion science and sponsoring general plasma research.

FES evaluates the progress being made toward achieving its scientific and management objectives in a variety of ways. Regular peer review and merit evaluation is conducted on all funded activities based on the procedures contained in 10 CFR 605 for the extramural grant program and under a similar but modified process for the laboratory programs and scientific user facilities. At least 80% of all new research projects supported by FES will be selected using a competitive peer review process.

The overall quality of the research in the FES program will be judged excellent and relevant by peers, and through various forms of external recognition.

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

Upgrades, construction and decommissioning of FES scientific user facilities will keep within 10 percent, on average, of cost and schedule milestones.

Operational downtime of FES operated facilities will be less than 10 percent of total operating time; this includes the three major fusion experimental facilities, DIII-D, Alcator C-Mod, and NSTX.

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

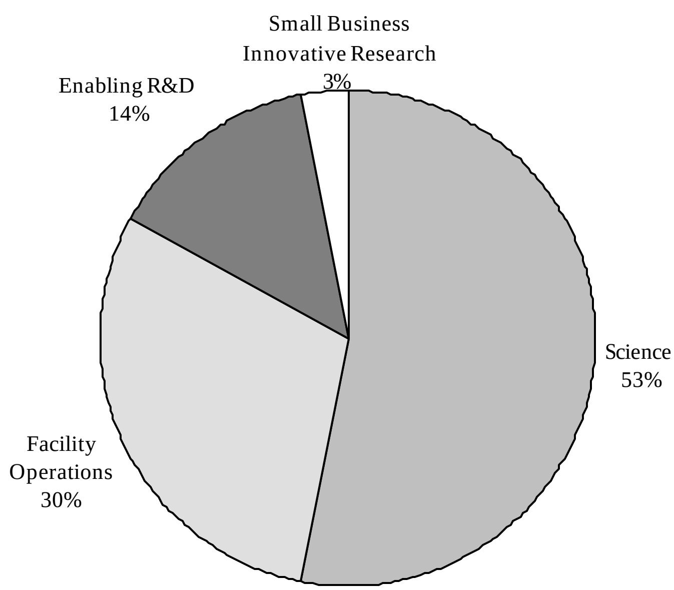
<u>Program Organization</u>

To meet the program objectives, the FES program is organized into three subprograms:

- The Science subprogram includes funds for general plasma science; for experiments on the physics of high temperature plasmas in various magnetic field configurations; for the physics of inertial fusion energy drivers; and for theory and modeling of fusion plasmas.

- The Facility Operations subprogram includes funds for building, operating, upgrading and decommissioning major facilities, and for infrastructure and waste management at the Princeton Plasma Physics Laboratory (PPPL).
- The Enabling R&D subprogram includes funds for the development of innovative technologies and materials research. The technologies support the enhancement of the operational capabilities of experimental facilities as well as the exploration of innovative advances for possible future facilities. The materials science activities are aimed at understanding the fundamental behavior of materials in the harsh fusion environment where they are bombarded by high-energy neutrons, and subjected to radiation, high heat fluxes, high magnetic fields and high temperatures.

In addition, the program includes funding for the Small Business Innovation Research program (SBIR) and the Small Business Technology Transfer program (STTR).



The FES FY 2002 Budget Request is $238.5 million

During the next four years, we expect:

significant progress in understanding the science of high temperature plasmas in magnetic fields,

decisions by the European Union, Japan, and Russia on the construction of major next-step fusion facilities of significant scientific importance, and

clarification of the availability of NNSA-funded facilities such as the National Ignition Facility.

The FES program will use these inputs to make assessments of possible U.S. participation in any international fusion collaborations, while aiming toward making more fundamental decisions at the end of that 4-year period about the future evolution of the U.S. domestic fusion program.

In FY 2002 the FES program will:

- address the recommendations of the NRC review to the extent possible.
- maintain the balance among science and technology elements as recommended by SEAB, NRC, and FESAC.
- provide for use of the U.S. program's unique experimental facilities to add to our understanding of the key physics issues governing toroidal fusion concepts. The three major facilities have complementary size, shape, and operating parameter regimes. All three programs are investigating stability, transport, and boundary layer plasma physics in the regimes accessible to each device. Key physics questions such as anomalous electron transport, stabilization of slow-growing instabilities (important to achieving steady state operation), and investigation of off-axis radio-frequency or microwave current drive as a means of plasma confinement and stability control will be the focus of experiments. There is increased effort in coupling together diagnostics, experiments and theory/modeling in order to better understand the results and compare them in different parameter regimes. These experiments are expected to contribute significantly to an assessment of the U.S. fusion program in the next four years, as recommended by FESAC.
- continue to participate in mutually beneficial international collaborative activities to advance understanding through pooling of scarce intellectual, experimental, and financial resources.
- continue to be ready to capitalize on advances in the worldwide fusion effort and the NNSA-funded inertial fusion target physics program.
- continue the Scientific Discovery through the Advanced Scientific Computing initiative to develop integrated models of both magnetic and inertial fusion systems.
- continue work on innovative confinement concept experiments (mostly at universities) that have resulted from competitive solicitations.
- continue fabrication of new, high current modules that will be used to upgrade and replace existing heavy ion accelerator physics facilities, allowing unique new studies of beam dynamics and instabilities. The results will be of interest to the beam and accelerator physics communities at large.
- continue innovative technology research efforts that will enable the achievement of major scientific goals on experimental fusion facilities in areas such as tritium science, the physics of high-power microwave heating, and very high heat flux interactions with solid and liquid surfaces. The innovations to be pursued will be determined using a competitive peer review process.
- meet our programmatic responsibilities by proceeding in a safe manner to complete the decontamination and decommissioning of the Tokamak Fusion Test Reactor (TFTR) and removing most or all of the recoverable tritium stored at the Tritium Systems Test Assembly (TSTA) facility at Los Alamos National Laboratory (LANL).

Scientific Facilities Utilization

The Fusion Energy Sciences request includes $91,717,000 to operate and make use of major fusion scientific user facilities. The Department's three major fusion energy physics facilities are: the DIII-D tokamak at General Atomics in San Diego, California; the Alcator C-Mod tokamak at the Massachusetts Institute of Technology; and the National Spherical Torus Experiment at the Princeton Plasma Physics Laboratory. These three facilities are each unique in the world's fusion program and offer opportunities to address specific fusion science issues that will contribute to the expanding knowledge base of fusion. Taken together, these facilities represent more than an $850,000,000 capital investment by the U.S. Government, in current year dollars.

The funding requested will provide research time for about 500 scientists in universities, federally sponsored laboratories, and industry, and will leverage both federally and internationally sponsored research, consistent with a strategy for enhancing the U.S. National science investment.

Significant Accomplishments and Program Shifts

Science

SCIENCE ACCOMPLISHMENTS

Research funded by the Fusion Energy Sciences program in FY 2000 produced major scientific results over a wide range of activities. Examples of these results include:

- Researchers have discovered a powerful tool for creating and manipulating desired “internal transport barriers” which prevent unwanted heat leakage from magnetically confined fusion plasmas. At the Alcator C-Mod, researchers are developing a technique known as “off-axis ion cyclotron radio frequency” (ICRF) heating. Normally, hot ions in plasmas circle around the magnetic field at different rates; the ions’ resulting “cyclotron frequencies” vary according to their positions in the tokamak. For reasons not completely understood, the overall plasma rotates around the tokamak. In traditional techniques for heating the plasma with radio waves, researchers send in waves with a frequency that matches the cyclotron frequency of ions at the center of the plasma. However, when this frequency matching location was moved off the center of the plasma, the rotation profile of the plasma was significantly changed. Simultaneously with this change, a clear internal transport barrier can develop, resulting in an extraordinary peaking of the plasma density, one that can be at least two times greater than without off-axis heating.
- Recent experiments in Germany and the United States have shown that fusion energy content and other properties in magnetically confined plasmas can be significantly improved by a relatively small amount of microwave power applied at precisely the right location in the plasma. Tokamak plasmas and, indeed, most magnetically trapped plasmas are subject to the growth of “magnetic islands.” These islands break up the smooth magnetic field surfaces that confine the plasma, leading to more rapid loss of heat from the plasma and making it more difficult to reach the high temperatures and pressures needed for nuclear fusion. Experiments first carried out in Germany and, more recently, in the DIII-D tokamak have confirmed theoretical predictions that islands due to high plasma pressure can be eliminated by adding a small amount of electrical current at the island location. A narrow beam of microwaves can drive the desired current in the plasma, with surgical precision, by interacting with electrons at the appropriate location. In recent experiments, a magnetic island degraded the plasma pressure by about 20%. Adding one megawatt of microwave power, about one-tenth of the total power needed to heat the plasma, drove enough current to suppress the island. This allowed the plasma pressure to recover, resulting in an increase in the energy content in the DIII-D plasma. These pioneering experiments show the feasibility of improving the temperature and density of fusion plasmas by small, precisely controlled modifications of their internal structure.
- Scientists have made use of magnetic reconnection, which underlies events in the sun’s corona, to help drive current in the National Spherical Torus Experiment, a new magnetic fusion device at the Princeton Plasma Physics Laboratory. It is called a “spherical torus” (ST) because the surface of the

plasma in it is shaped like a sphere with a narrow hole through the center. To maintain plasma confinement in an ST and to help heat the plasma, a strong electric current, encircling the central hole, must be driven in the plasma. In December 1999, NSTX reached a primary design goal by operating with one million amperes of current induced in the plasma by a solenoid (a spool-shaped coil) passing through the central hole. In addition to this traditional way of driving the plasma current, the researchers are developing a new method for producing this current. Known as coaxial helicity injection (CHI), this technique involves injecting an electric current directly from coaxial circular electrodes inside the plasma chamber, in the presence of an applied magnetic field.

- The current loops formed during CHI have similarities to the coronal loops seen on the sun's outer surface during solar flares. Just as in the solar corona, these loops can become unstable and relax to a lower energy state through a process known as magnetic reconnection. In the case of the ST, this lower energy state is one in which some of the current flows on field lines that close on themselves inside the vessel to form a confined plasma core. Whereas the traditional technique of inducing the current with a solenoid can only produce brief bursts of plasma current in an ST, the CHI technique holds promise for helping them to operate continuously.
- A modular energy transport computer code that can be accessed from the Internet was developed based on modern computing techniques. Theory based transport models, deduced from numerical studies of transport driven by strong turbulence are included in the code. The code is a first step to allow experimentalists to use such a code to explain the development of energy transport barriers associated with the stabilization of turbulent fluctuations.
- Scientists have applied a new theoretical model to explain the onset of plasma rotation observed in Alcator C-Mod prior to the transition to an improved confinement regime. The theory is that edge oscillations in the plasma propagate toward the center, carrying angular momentum. This causes the plasma to spin up and make a transition to a more energetic plasma. This is analogous to proposed explanations for the creation of rotating accretion disks observed around black holes in space.

FACILITY ACCOMPLISHMENTS

- Three new, innovative concept exploration experiments—the Translation, Confinement, and Sustainment (TCS) field reversed configuration experiment, and the flow-through Z-Pinch (ZaP) experiment, both at the University of Washington, and the Pegasus quasi-spherical torus experiment at the University of Wisconsin—became fully operational and have begun providing basic scientific understanding of plasma science phenomena. These include the creation of equilibrium plasma states, stabilization of kink instabilities by sheared flow, resolution of internal magnetic field configurations, and stability limits as a function of relevant plasma parameters.
- The Department jointly funded with NSF the operation of a new large-scale plasma science user facility at UCLA. The facility will be funded through an NSF cooperative agreement and jointly managed by NSF and DOE. The Large Plasma Device at UCLA is a flexible and low maintenance device for studying a variety of waves and nonlinear effects in fully magnetized plasmas.

Facility Operations

FACILITY ACCOMPLISHMENTS

In FY 2000, funding was provided to operate facilities in support of fusion research experiments and to upgrade facilities to enable further research in fusion and plasma science. Examples of accomplishments in this area include:

- The National Spherical Torus Experiment (NSTX) was operated with plasma currents of 500,000 amperes for periods of one-half second, and with plasma currents of 1 million amperes for shorter times. The program goal is to operate at 1 million amperes for one second. Installation of a neutral beam plasma heating system has been completed, providing a significant enhancement in physics research capability. The neutral beam provides both needed heating to the core of the plasma and an important enhancement to the range of plasma diagnostic systems that depend upon the perturbing aspects of the neutral beam and/or its byproducts.
- The cost of the TFTR D&D activities at PPPL was reduced by about $4,000,000 to $43,300,000 by removing the tritium from the tritium systems and components and then storing the equipment at the laboratory instead of shipping the equipment off site for disposal. Technical reviews confirmed that this equipment will retain much of its value for possible future use within the fusion program.
- After many years of successful and productive tritium handling technology research at TSTA, research operations have been completed. A new tritium laboratory, selected by competitive peer review, is being sited at an existing INEEL facility. Compared to TSTA, the INEEL laboratory will operate with much lower cost and tritium inventories, focusing on basic scientific issues of tritium use and behavior for a wide spectrum of Fusion Energy Sciences program elements.

Enabling R&D

SCIENCE ACCOMPLISHMENTS

- While the U.S. fusion program severed all ties with the ongoing ITER project in FY 1999, it continued to collaborate with Japan under the US-Japan Bilateral Agreement to test the ITER Central Solenoid Model Coil. The United States designed and fabricated the inner module of the coil before it was shipped to Japan for testing. The Model Coil is the largest pulsed superconducting magnet ever built. Test results have demonstrated that the coil meets or exceeds all of its performance objectives. This accomplishment is an important landmark for the scientific understanding of superconducting magnet behavior for fusion, and for potential applications of this technology in other fields.
- Scientists at PPPL conducted initial experiments in a toroidal plasma to investigate phenomena of plasma contact with liquid surfaces and guide development of models for plasma-liquid interactions critical to research on innovative concepts for plasma particle removal and surface heat flux removal. Such capabilities could be readily used for scientific studies in plasma experiments to control key parameters of the plasma edge, such as plasma particle density and temperature, and to carry away intense surface heat locally deposited by the plasma at its edge. For the longer-term, liquid surface technology can provide for much longer lifetimes and higher performance plasma-facing components than is possible with conventional solid surface approaches.
- Researchers at ORNL developed models for molecular dynamics, and dislocation dynamics for an atomistic description of microstructural evolution in ferritic steels under simulated conditions associated with fusion. These models unify and integrate the theories on mechanisms that control damage production from energetic neutron bombardment. Also, the models enable nanosystem methods for designing ferritic steel alloys with significantly improved performance and lifetimes, and with elemental tailoring that minimizes radioactivity generation by neutron-induced transmutation. The ability to produce superior metal alloys for fusion applications is critical to the viability of using fusion energy for practical applications with benign environmental impacts.
- Relative to non-metallic materials for fusion, such as ceramic composites based on silicon carbide, research in tailored nanoscale microstructures are producing remarkable advances in achieving high

ductility and radiation damage resistance. Crack reflecting interfaces deposited in ceramic composites are providing greatly improved toughness and micromechanical models are providing tools for predicting and controlling the growth of cracks that could lead to structural failures.

Awards

- Twelve fusion researchers were elected Fellows of the American Physical Society in 2000.
- A PPPL scientist received the Presidential Early Career Award and the DOE Office of Science Early Career Award
- A leading fusion scientist received the American Physical Society's 2000 Nicholson Award for Humanitarian Service.
- The head of the Engineering Department at PPPL received the 2000 Outstanding Achievement Award from the American Nuclear Society's Fusion Energy Division
- An INEEL scientist received the Woman's Achievement Award from the American Nuclear Society
- An INEEL scientist received the Outstanding Technical Accomplishment Award from the Fusion Energy Division of the American Nuclear Society
- A former Bell Laboratories scientist received the American Physical Society's James Clerk Maxwell Prize for Plasma Physics for important contributions to theoretical plasma physics
- A New York University professor was awarded an honorary doctorate by the order of the French Education Minister. The honorary degree makes the award winner an adjunct professor at the University of Provence
- A PPPL scientist was elected President of IEEE-USA
- An MIT professor received the Robert L. Woods Award from the Advisory Group on Electronics of the Department of Defense
- A LLNL scientist was elected Fellow of the American Association for the Advancement of Science
- A PPPL scientist received the Award for Outstanding Doctoral Thesis in Plasma Physics, Division of Plasma Physics, American Physical Society, (Oct. 2000)
- A University of California, San Diego professor received the APS 2000 Nicholson Medal for Humanitarian Assistance

PROGRAM SHIFTS

The budget requested for FY 2002 is reduced below the FY 2001 adjusted appropriation level. Reductions across most program elements have been made to cover this reduction, as well as to provide additional funds to LANL necessary for tritium clean up at the TSTA facility before it can be turned over to Environmental Management for Decontamination and Decommissioning.

Workforce Development

The FES program, the Nation's primary sponsor of research in plasma physics and fusion science, supports development of the R&D workforce by funding undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed as a part of this program provides new scientific talent to areas of fundamental research. It also provides talented people to a wide variety of technical and industrial fields that require finely honed thinking and problem solving abilities and computing and technical skills. Scientists trained through association with the FES program are employed in related fields such as plasma processing, space plasma physics, plasma electronics, and accelerator/beam physics as well as in other fields as diverse as biotechnology and investment and finance.

In FY 2000, the FES program supported 365 graduate students and post-doctoral investigators. Of these, 50 conducted research at the DIII-D tokamak at General Atomics, the C-Mod tokamak at MIT, or the NSTX at PPPL.

Two of the first five participants in the Junior Faculty in Plasma Physics Development Program have been granted tenure by their institutions.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Fusion Energy Sciences					
Science	130,326	139,820	-3,508	136,312	133,440
Facility Operations	73,706	79,812	-1,916	77,896	71,994
Enabling R&D	34,228	35,368	-1,083	34,285	33,061
Subtotal, Fusion Energy Sciences	238,260 [a]	255,000	-6,507	248,493	238,495
General Reduction	0	-2,596	2,596	0	0
General Reduction for Safeguards and Security	0	-3,363	3,363	0	0
Omnibus Rescission	0	-548	548	0	0
Total, Fusion Energy Sciences	238,260 [b] [c]	248,493	0	248,493	238,495 [d]

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 $5,748,000, which has been transferred to the SBIR program and $345,000 which has been transferred to the STTR program.

[b] Includes $2,984,000 for Waste Management activities at Princeton Plasma Physics Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $3,317,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[d] In addition, $10,000,000 will be transferred to this activity in a Budget Amendment to be submitted shortly. Details will be provided at that time.

Funding By Site

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	6,741	6,826	7,629	+803	+11.8%
National Renewable Energy Laboratory ..	50	0	0	0	0.0%
Sandia National Laboratories	3,249	3,181	2,996	-185	-5.8%
Total, Albuquerque Operations Office	10,040	10,007	10,625	+618	+6.2%
Chicago Operations Office					
Argonne National Laboratory	2,321	2,406	2,009	-397	-16.5%
Princeton Plasma Physics Laboratory	65,784	70,589	66,702	-3,887	-5.5%
Chicago Operations Office.....................	45,718	43,712	41,803	-1,909	-4.4%
Total, Chicago Operations Office..................	113,823	116,707	110,514	-6,193	-5.3%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	1,568	2,210	2,082	-128	-5.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory ..	5,534	5,171	4,767	-404	-7.8%
Lawrence Livermore National Laboratory	14,894	14,714	14,189	-525	-3.6%
Stanford Linear Accelerator Center	49	0	0	0	0.0%
Oakland Operations Office	71,631	69,547	65,483	-4,064	-5.8%
Total, Oakland Operations Office	92,108	89,432	84,439	-4,993	-5.6%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education .	821	835	798	-37	-4.4%
Oak Ridge National Laboratory	18,369	16,116	16,412	+296	+1.8%
Oak Ridge Operations Office	17	39	0	-39	-100.0%
Total, Oak Ridge Operations Office	19,207	16,990	17,210	+220	+1.3%
Ohio Field Office...	8	0	0	0	0.0%
Richland Operations Office					
Pacific Northwest National Laboratory	1,369	1,427	1,317	-110	-7.7%
Washington Headquarters	137	11,720	12,308	+588	+5.0%
Total, Fusion Energy Sciences	238,260 [abc]	248,493	238,495 [d]	-9,998	-4.0%

[a] Excludes $5,748,000, which has been transferred to the SBIR program and $345,000 which has been transferred to the STTR program.

[b] Includes $2,984,000 for Waste Management activities at Princeton Plasma Physics Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $3,317,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

[d] In addition, $10,000,000 will be transferred to this activity in a Budget Amendment to be submitted shortly. Details will be provided at that time.

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. Argonne's Fusion Energy Sciences program contributes to a variety of enabling R&D program activities. Argonne has a lead role internationally in analytical models and experiments for liquid metal cooling in fusion devices. Studies of the interaction of flowing liquid metals with magnetic fields are conducted in the ALEX facility. Studies of corrosion in candidate structural alloy materials are conducted in a liquid lithium flow loop. Argonne's capabilities in the engineering design of fusion energy systems have contributed to the design of components, as well as to analysis supporting the studies of fusion power plant concepts. Argonne also contributes to materials research with its unique capabilities in vanadium alloy testing in fission reactors and post-irradiation examinations.

Idaho National Engineering and Environmental Laboratory

Idaho National Engineering and Environmental Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. Since 1978, INEEL has been the Fusion Energy Sciences program's lead laboratory for fusion safety. As the lead laboratory, it has helped to develop the fusion safety database that will demonstrate the environmental and safety characteristics of both nearer term fusion devices and future fusion power plants. Research at INEEL focuses on the safety aspects of both magnetic and inertial fusion concepts for existing and planned domestic experiments, and developing further our domestic safety database using existing collaborative arrangements to conduct work on international facilities. In addition, with the shutdown of the Tritium Systems Test Assembly (TSTA) facility at LANL, INEEL will expand their research and facilities capabilities to include tritium science activities.

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. For the Fusion Energy Sciences program, the laboratory's mission is to study and apply the physics of heavy ion beams and to advance related technologies for the U.S. Inertial Fusion Energy program.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821-acre site in Livermore, California. LLNL works with the Lawrence Berkley National Laboratory on the Heavy Ion Fusion program. The LLNL program also includes collaborations with General Atomics on the DIII-D tokamak, construction of an innovative concept experiment, the Sustained Spheromak Physics Experiment (SSPX) at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D.

Los Alamos National Laboratory

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000-acre site in Los Alamos, New Mexico. The budget supports the creation of computer codes for modeling the stability of plasmas, as well as work in diagnostics, innovative fusion plasma confinement concepts such as Magnetized Target Fusion, and the removal of most of the recoverable tritium in FY 2002 from the Tritium Systems Test Assembly facility.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE), operated by Oak Ridge Associated Universities (ORAU) through a management and operating contract with DOE, is located on a 150-acre site in Oak Ridge, Tennessee. Established in 1946, ORAU is a consortium of 88 colleges and universities. The institute undertakes national and international programs in education, training, health, and the environment. For the FES program, ORISE supports the operation of the Fusion Energy Sciences Advisory Committee. It also acts as an independent and unbiased agent to administer the Fusion Energy Sciences Graduate and Postgraduate Fellowship Programs, in conjunction with FES, the Oak Ridge Operations Office, participating universities, DOE laboratories, and industries.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Multiprogram Laboratory located on a 24,000-acre site in Oak Ridge, Tennessee. ORNL develops a broad range of components that are critical for improving the research capability of fusion experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. The laboratory is a leader in the theory of heating of plasmas by electromagnetic waves, antenna design, and design and modeling of pellet injectors to fuel the plasma and control the density of plasma particles. Research is also done in the area of turbulence and its effect on the transport of heat through plasmas. Computer codes developed at the laboratory are also used to model plasma processing in industry. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies. ORNL leads the advanced fusion structural materials science program, contributes to research on all materials systems of fusion interest, coordinates experimental collaborations for two U.S.-Japan programs, and coordinates materials activities for the Virtual Laboratory for Technology.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a Multiprogram Laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The Fusion Energy Sciences program at PNNL is focused on research on materials that can survive in a fusion neutron environment. The available facilities used for this research include mechanical testing and analytical equipment, including state-of-the-art electron microscopes, that are either located in radiation shielded hot cells or have been adapted for use in evaluation of radioactive materials after exposure in fission test reactors. Experienced scientists and engineers at PNNL provide leadership in the evaluation of ceramic matrix composites for fusion applications and support work on vanadium, copper and ferritic steels as part of the U.S. fusion materials team. PNNL also plays a leadership role in a fusion materials collaboration with Japan, with Japanese owned test and analytical equipment located in PNNL facilities and used by both PNNL staff and up to ten Japanese visiting scientists per year.

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. PPPL is the only U.S. Department of Energy (DOE) laboratory devoted primarily to plasma and fusion science. It hosts experimental facilities used by multi-institutional research teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the National Spherical Torus Experiment (NSTX), which is an innovative toroidal confinement device closely related to the tokamak, and is currently working on the conceptual design of another innovative toroidal concept, the compact stellarator. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks in the U.S. and the large JET (Europe) and JT-60U (Japan) tokamaks abroad. This research is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. PPPL, through its association with Princeton University, provides high quality education in fusion-related sciences, having produced more than 175 Ph.D. graduates since its founding in 1951.

Sandia National Laboratory

Sandia National Laboratory is a Multiprogram Laboratory, located on a 3,700 acre site in Albuquerque, New Mexico, with other sites in Livermore, California, and Tonopah, Nevada. Sandia's Fusion Energy Sciences program plays a lead role in developing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interface of plasmas and the walls of fusion devices. Sandia selects, specifies, and develops materials for components exposed to high heat and particles fluxes and conducts extensive analysis of prototypes to qualify components before their use in fusion devices. Materials samples and prototypes are tested in Sandia's Plasma Materials Test Facility, which uses high-power electron beams to simulate the high heat fluxes expected in fusion environments. Materials and components are exposed to tritium-containing plasmas in the Tritium Plasma Experiment. Tested materials are characterized using Sandia's accelerator facilities for ion beam analysis. Sandia supports a wide variety of domestic and international experiments in the areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing.

All Other Sites

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

Science

Mission Supporting Goals and Objectives

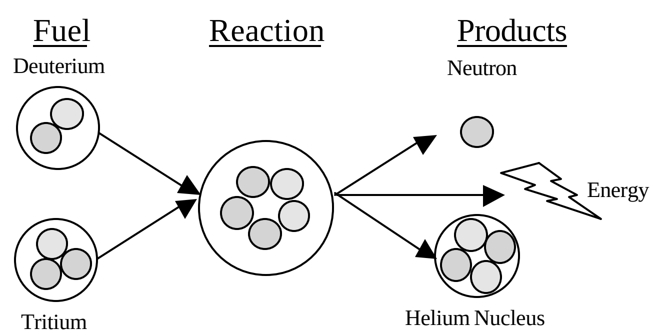
The goals of the Science subprogram are to understand the elementary physical processes that occur in plasmas and to use this knowledge to develop innovative approaches for confining fusion plasmas. These goals are accomplished by conducting:

- theory and modeling programs to develop the fundamental principles for understanding the complex behavior of plasmas
- research programs on fusion-relevant plasma experiments
- diagnostic development programs that provide improved instruments to measure plasma parameters such as temperature, density, and magnetic field strengths, and their fluctuations, over a wide range of parameters and time scales in a variety of experimental configurations, making possible rigorous comparisons between experiment and theory/modeling

A companion goal of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma science. Two activities, an NSF/DOE partnership in plasma physics and engineering and development grants for junior members of university plasma physics faculties, have been the major contributors to this objective.

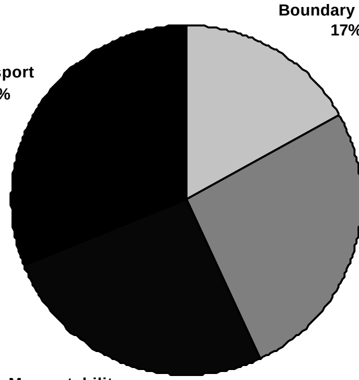
Plasma science is the study of the ionized matter that makes up 99 percent of the observable universe, ranging from neon lights to stars. It includes not only plasma physics but also other physical phenomena in ionized matter, such as atomic, molecular, radiation-transport, excitation and ionization processes. These phenomena can play significant roles in partially ionized media and in the interaction of plasmas with material walls. Plasma science contributes not only to fusion research, but also to many other fields of science and technology, such as astrophysics and industrial processing, and to national security.

Fusion science is focused primarily on describing the fundamental processes taking place in plasmas where the temperatures (greater than 100 million degrees Celsius) and densities permit hydrogenic nuclei that collide to fuse together, releasing energy and producing the nucleus of a helium atom and a neutron.



The Fusion Process

Fusion science shares many scientific issues with plasma science. For MFE, these scientific issues include: (1) wave-particle interaction and plasma heating; (2) chaos, turbulence, and transport; (3) sheaths and boundary layers; and (4) stability, magnetic reconnection, and dynamos. Progress in all of these research issues is likely to be required for ultimate success in achieving a practical fusion energy source.



Science subprogram estimated funding allocation to address the MFE science issues.

For IFE, the two science issues are: (1) high energy density physics, such as laser-plasma and beam-plasma interactions, and (2) non-neutral plasmas.

The largest component of the Science subprogram is research that focuses on gaining a predictive understanding of the behavior of the high temperature, high-density plasmas typically required for fusion energy applications. The tokamak magnetic confinement concept has thus far been the most effective approach for confining plasmas with stellar temperatures within a laboratory environment. Many of the important issues in fusion science are being studied in an integrated program on the two major U.S. tokamak facilities, DIII-D at General Atomics and Alcator C-Mod at the Massachusetts Institute of Technology. Both DIII-D and Alcator C-Mod are operated as national science user facilities with research programs established through public research forums, program advisory committee recommendations, and peer review.

DIII-D has extensive diagnostic instrumentation to measure what is happening in the plasma. It also has unique capabilities to shape the plasma, which, in turn, affects particle transport in the plasma and the stability of the plasma. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layer physics using a "magnetic divertor" to control magnetic field configuration at the edge of the plasma. (The divertor is produced by magnet coils that bend the magnetic field at the edge of the tokamak out into a region where plasma particles following the field are neutralized and pumped away.)

Alcator C-Mod is a unique, compact tokamak facility that uses intense magnetic fields to confine high temperature, high-density plasmas. It is also unique in the use of metal (molybdenum) walls to accommodate the high power densities in this compact device. Alcator C-Mod has made significant contributions to the world fusion program in the area of ion-cyclotron frequency wave-particle interaction and plasma heating.

In the future, both DIII-D and Alcator C-Mod will focus on using their flexible plasma shaping and dynamic control capabilities to attain good confinement and stability by controlling the distribution of current in the plasma with radio wave current drive and the interface between the plasma edge and the material walls of the confinement vessel with a “magnetic divertor.” Achieving these high performance regimes for longer pulse duration will require simultaneous advances in all of the scientific issues listed above.

In addition to the advanced toroidal research on DIII-D and Alcator C-Mod, exploratory work will continue on two university tokamak experiments. The goal of the High Beta Tokamak (HBT) at Columbia University is to demonstrate the feasibility of stabilizing high plasma pressure within a tokamak configuration by a combination of a close-fitting conducting wall, plasma rotation, and active feedback. This work will be closely coordinated with the DIII-D program, and promising advances will be applied on DIII-D. The Electric Tokamak (ET) at UCLA will explore several new approaches to toroidal magnetic confinement; emphasizing radio wave driven plasma rotation and the achievement of very high plasma pressure relative to the applied magnetic field to produce a deep magnetic well.

The next largest research component is work on alternative concepts, aimed at extending fusion science and identifying concepts that may have favorable stability or transport characteristics that could improve the economic and environmental attractiveness of fusion energy sources. The largest element of the alternative concepts program is the National Spherical Torus Experiment (NSTX) at Princeton Plasma Physics Laboratory, which began its first full year of operation in FY 2000. Like DIII-D and Alcator C-Mod, NSTX is also operated as a national scientific user facility.

NSTX has a unique, nearly spherical plasma shape that complements the doughnut shaped tokamak and provides a test of the theory of toroidal magnetic confinement as the spherical limit is approached. Its favorable stability properties allow confinement at high plasma pressure relative to the applied magnetic field, and its high rate of shear for the flowing plasma should stabilize turbulence and lead to very good confinement. An associated issue for spherical torus configurations is the challenge of driving plasma current via radio-frequency waves or biasing electrodes. New computational and experimental techniques will be needed for the unique geometry and field configuration of the NSTX.

Exploratory research will continue, using more than a dozen small-scale, alternative concept devices and basic science experiments, to study only one or two scientific topics for which each experiment is optimized. For example, the Madison Symmetric Torus at the University of Wisconsin is a toroidal configuration with high current but low toroidal magnetic field that reverses direction near the edge of the discharge. The magnetic dynamo effect, which results from turbulent processes inside the plasma, spontaneously generates the field reversal at the plasma edge. This innovative experiment is investigating the dynamo mechanism, which is of interest in several fields of science including space and astrophysics, and turbulent transport, which is of interest in fusion science. The Levitated Dipole Experiment, a joint Massachusetts Institute of Technology/Columbia University program is exploring plasma confinement in a novel magnetic dipole configuration (similar to the magnetic fields constraining plasma in the earth’s magnetosphere). At Princeton Plasma Physics Laboratory, the Magnetic Reconnection Experiment addresses fundamental questions in magnetic reconnection, the process by which currents and flows in a plasma can induce changes in the topology of the magnetic field by breaking and reconnecting magnetic field lines. Magnetic reconnection is important not only in fusion experiments but also in phenomena like the solar flares, the solar wind and astrophysical plasmas.

A different set of insights into stability properties of plasmas should be developed from investigations into new stellarator configurations taking advantage of advances in stellarator theory, new computational capabilities, and insights from recent tokamak research. These stellarator configurations are nearly axisymmetric (like a tokamak) but do not require an externally driven current to produce an equilibrium. Thus, they should have the transport properties similar to a tokamak but should have different stability properties. A national team is completing work on the design of a medium-size National Compact Stellarator Experiment (NCSX) that would be used to study plasma turbulence, energy and particle transport, and stability in this novel geometry. It will also strengthen U.S. involvement in the much larger world stellarator program.

An entirely different set of science explorations is being carried out in the area of high energy density plasma physics, the underlying field for Inertial Fusion Energy (IFE). In pursuing this science, the IFE activity is exploring an alternate path for fusion energy that would capitalize on the major R&D effort in inertial confinement fusion (ICF) carried out for stockpile stewardship purposes within the National Nuclear Security Agency (NNSA) Office of Defense Programs. The IFE program depends on the ICF program for experimental research into the high energy density physics required for the design of energy producing targets and for future testing of the viability of IFE targets in the National Ignition Facility at LLNL. Efforts in IFE focus on understanding the physics of systems that will be needed to produce a viable inertial fusion energy source. These include heavy ion beam systems for heating and compressing a target pellet to fusion conditions, the experimental and theoretical scientific basis for modeling target chamber responses, and the physics of high-gain targets. The physics of intense heavy ion beams and other non-neutral plasmas is both rich and subtle, due to the kinetic and nonlinear nature of the systems and the wide range in spatial and temporal scales involved. For these reasons, heavy ion beam physics is of interest to the larger accelerator and beam physics community. The modeling of the fusion chamber environment is very complex and must include multi-beam, neutralization, stripping, beam and plasma ionization processes, and return current effects.

The theory and modeling program provides the conceptual underpinning for the fusion sciences program. Theory efforts are challenged to describe complex non-linear plasma systems at the most fundamental level. These descriptions are modeled through highly sophisticated computer codes that are used to analyze data from current experiments, guide future experiments, design future experimental devices, and assess projections of their performance. Such codes represent a growing knowledge base that, in the end, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and manipulated.

An important element of the theory and modeling program is the FES portion of the Office of Science's Scientific Discovery Through Advanced Computing program. Major scientific challenges exist in many areas of plasma and fusion science that can best be addressed through advances in scientific supercomputing, e.g., understanding and controlling plasma turbulence, investigating the physics of heavy ion accelerators, or understanding and controlling magnetohydrodynamic instabilities in magnetically confined plasmas.

The general plasma science program supports basic plasma science and engineering research and advances the discipline of plasma physics. Topics explored include a broad range of fundamental research efforts in wave-plasma physics, dusty plasmas, non-neutral plasmas, and boundary layer effects. Important elements of this program include the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Junior Faculty in Plasma Physics Development Program, and the basic and applied plasma physics program at DOE laboratories.

In FY 2000, the NSF/DOE Partnership funded more than 30 principal investigators who were chosen in a competitive peer review process from over 160 proposals to receive awards totaling about $4,000,000. Three new Junior Faculty in Plasma Physics were also awarded via competitive review.

The recent National Academy of Science assessment of the Fusion Energy Sciences program recommended the establishment of frontier plasma science centers. DOE would seek joint funding from other agencies to establish these centers through a competitive solicitation process that would include cost sharing by the participating institutions. The centers would involve multidisciplinary teams from universities and national labs, and provide the opportunities to broaden the program's institutional base and encourage participation by the wider scientific community. Possible focus topics for the centers include turbulence and transport, magnetic reconnection, plasma dynamics, energetic particle dynamics, and fusion materials modeling. In FY 2001, the solicitation for proposals in advanced scientific computing seeks proposals for topical centers. Those selected, through competitive peer review, will be continued in FY 2002.

In addition to their work on domestic experiments, scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad. The Fusion Energy Sciences program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. Collaboration avoids duplication of facilities that exist abroad. These include the world's highest performance tokamaks (JET in England and JT-60 in Japan), a stellarator (the Large Helical Device) in Japan, a superconducting tokamak (Tore Supra) in France, and several smaller devices. In addition, the U.S. is collaborating with South Korea on the design of a long-pulse, superconducting, advanced tokamak (KSTAR). These collaborations provide a valuable link with the 80% of the world's fusion research that is conducted outside the U.S.

Finally, development of improved diagnostic tools for analyzing plasma behavior continues to provide new insights into fusion plasmas and enables the detailed comparison of fusion theory and experiments. Non-perturbing measurements of the dynamic temperatures, densities, and electromagnetic fields in the core of near-burning plasma presents a formidable challenge. Nonetheless, considerable progress in obtaining quantitative measurements has been made over the last decade. Balanced progress in theory and modeling, experimental operation, and the development of improved measurement systems has provided an excellent formula for scientific progress in fusion.

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
Tokamak Experimental Research	46,546	44,980	45,014	+34	+0.1%
Alternative Concept Experimental Research	51,380	50,274	48,336	-1,938	-3.9%
Theory	24,270	27,275	25,975	-1,300	-4.8%
General Plasma Science	8,130	8,408	8,026	-382	-4.5%
SBIR/STTR	0	5,375	6,089	+714	+13.3%
Total, Science	130,326	136,312	133,440	-2,872	-2.1%

Detailed Program Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Tokamak Experimental Research	**46,546**	**44,980**	**45,014**
▪ **DIII-D Research**	**23,532**	**22,740**	**22,723**

The DIII-D tokamak facility provides the largest, well-diagnosed, high temperature experimental magnetic fusion facility in the U.S. The DIII-D experimental program is structured along the four key MFE fusion topical science areas — energy transport, stability, plasma-wave interactions, and boundary physics. In FY 2002, the level of participation by the collaborators and on site staff in physics research and data analysis will be decreased. Research in all four topical science areas will be pursued using the new microwave heating hardware modifications, a new diagnostic for current profile measurements, and enhanced computational tools. In particular, emphasis on testing different transport theories by comparison of experimental results and physics based computer models will increase. Control of stability limits, which has gone through an initial phase of experiments, will be further investigated by modification of current profiles with electron cyclotron waves. These studies are closely coupled to the theoretical basis for the instabilities. The installation of equipment that will allow 6 MW of electron cyclotron heating power to be injected into the plasma will be completed in the first quarter of FY 2002 at a cost of about $8,000,000; this heating power will be used to further verify the predicted current drive physics. The understanding and control of boundary physics is very critical for the control of energy transport in the plasma core. New diagnostics for current profile measurement are being installed in FY 2001, which will enhance the study of boundary physics, especially as to the nature of edge currents that lead to instabilities at the plasma edge. In FY 2002, **performance will be measured by** successful use of the recently upgraded plasma microwave heating system and new sensors on DIII-D to study feedback stabilization of disruptive plasma oscillations. This understanding could permit substantial increases in the effective containment of plasma pressure with a given magnetic field.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Alcator C-Mod Research**..	**7,969**	**7,305**	**7,488**

The Alcator C-Mod facility, by virtue of its very high magnetic field, is particularly well suited to operate in plasma regimes that are relevant to future, much larger fusion tokamaks as well as to compact, high field burning plasma physics tokamaks. The approach to ignition and sustained burn of a plasma is an important integrating science topic for fusion. In FY 2002, the level of participation by the collaborators and on site staff in physics research and data analysis will be maintained at its current level. Research will be pursued to examine the physics of the plasma edge, power and particle exhaust from the plasma, mechanisms of self-generation of flows in the plasma, and the characteristics of the advanced confinement modes that appear in the plasma when currents are driven by radio waves. It will also focus on exploring physics techniques for radiating away the large parallel heat flow encountered in the plasma exhaust at high densities and on visualization diagnostics for turbulence in the edge and core of high density plasmas. A new diagnostic neutral beam, commissioned in FY 2000, will allow for improved comparisons between theory and experimental results on the characteristic behavior of the plasma.

▪ **International Collaborations and Education**......................	**7,642**	**7,784**	**7,987**

International collaboration provides the opportunity for U.S. scientists to work with their colleagues on unique foreign tokamaks (JET, Tore Supra, TEXTOR, and ASDEX-UG in Europe, JT-60U in Japan, and KSTAR in Korea). These collaborations produce complementary and comparative data to those obtained on the U.S. tokamaks to further the scientific understanding of fusion physics and enhance the pace of fusion energy development. In FY 2002, the collaboration with these programs will focus on ways of using the unique aspects of these facilities to make progress on the four key MFE issues cited in the FES Program Mission. Funding for educational activities in FY 2002 will support research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, general science literacy programs for teachers and students, and broad outreach efforts related to fusion science and technology.

▪ **Experimental Plasma Research (Tokamaks)**......................	**7,403**	**7,151**	**6,816**

Funding provided in this category supports research on innovative tokamak experiments at universities and the development of diagnostic instruments.

Several unique, innovative tokamak experiments are supported. In FY 2002, the High Beta Tokamak at Columbia will continue work on feedback stabilization of magnetohydrodynamic instabilities. Experiments in the Electric Tokamak at UCLA will continue to be directed at developing an understanding of the effects of plasma rotation at progressively higher levels of radio frequency heating power.

Development of unique measurement capabilities (diagnostic systems) that provide an understanding of the plasma behavior in fusion research devices will continue. This research provides the necessary information for analysis codes and theoretical interpretation. Some key areas of diagnostic research include the development of: (1) techniques to measure the cause of heat and particle loss from the core to the edge of magnetically confinement plasmas, including techniques aimed at understanding how barriers to heat loss can be formed in plasmas; (2) methods to measure the production, movement, and loss/retention of the particles that are needed to ignite and sustain a burning plasma; (3) new approaches that are required to measure plasma parameters in alternate magnetic configurations, which provide unique constraints due to magnetic field configuration and strength, and limited lines of sight into the plasma. The requested funding level in FY 2002 supports the highest-rated proposals of this multiyear diagnostic development research, as well as any new research programs that are recommended for funding as a result of a competitive peer review of the diagnostics development program.

	FY 2000	FY 2001	FY 2002
Alternative Concept Experimental Research..............................	**51,380**	**50,274**	**48,336**
▪ **NSTX Research**...	**12,379**	**12,125**	**12,000**

The NSTX is the one of the world's two largest embodiments of the spherical torus confinement concept. Plasmas in spherical tori have been predicted to be stable even when high ratios of plasma-to-magnetic pressure and self-driven current fraction exist simultaneously in the presence of a nearby conducting wall bounding the plasma. If these predictions are verified in detail, it would indicate that spherical tori use applied magnetic fields more efficiently than most other magnetic confinement systems and, could therefore, be expected to lead to more cost-effective fusion power systems in the long term.

Large plasma current can be produced by use of the magnetic reconnection technique called Coaxial Helicity Injection (CHI) which uses an innovative application of direct-voltage and current from the plasma edge to create the plasma. Scientists are investigating whether this technique can be integrated at plasma startup with the normal ohmic driven current. This could open up the additional possibility of integrating the CHI with other current drive techniques such as radio frequency waves and neutral beam injection. The intriguing physics properties of this innovative non-inductive startup technique have already been studied in small university size experiments in FY 2001. The basic mechanism is being systematically investigated in NSTX using improved control techniques. To date plasma currents of up to 200 kilo amps (kA) have just been successfully achieved. In FY 2002, **performance will be measured by** a successful demonstration of innovative techniques for initiating and maintaining the current in a spherical torus.

In FY 2002, the level of participation by the collaborators and on site staff in physics research and data analysis will be reduced. The NSTX research team will focus on evaluating the plasma stability limits with auxiliary heating. Procedures for operating NSTX while using an improved control system will be developed. This will include development of techniques for applying neutral beam heating early in the startup phase to permit stability studies and an assessment of the resulting plasma oscillations. In preparation for longer-term objectives, the fusion science research activities will concentrate on developing higher current capability (up to 500 kA) and further buildup of plasmas started in this way using conventional plasma heating methods to assess the potential of using CHI to extend NSTX plasma pulse length. Goals in FY 2002 include identifying the mechanisms for transporting plasma across the magnetic field at low aspect ratio over a wide range of plasma pressure as a fraction of magnetic pressure. One focus will be on comparing the measured dependence of energy and particle fluxes on background plasma variations including the twist of the magnetic field lines, and comparing these fluxes with theoretical predictions.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Experimental Plasma Research (Alternatives)**..................	**24,799**	**24,357**	**23,184**

This budget category includes most of the experimental research on plasma confinement configurations outside of the three major national facilities described above. Funds in this category are provided for twelve small experiments, one intermediate level proof-of-principle experiment, and one large study program that is focused on obtaining a design for a compact stellarator proof-of-principle experiment.

The majority of the research is directed toward toroidal configurations (the toroidal direction is the long way around a magnetic "doughnut"). For configurations with a large toroidal magnetic field, the research is focused on stellarators with special combinations of confining magnetic fields. The Helically Symmetric Torus is the world's first stellarator designed using one simplified combination of such magnetic fields. As discussed above, there is also a significant effort underway that is studying the design of a larger stellarator similar to the tokamak, but with rotational transform generated by either external coils or externally driven plasma current (a hybrid). This pre-conceptual design effort for a National Compact Stellarator Experiment (NCSX) is using computer simulations to develop very compact stellarator configurations that appear to overcome some of the stability problems that have faced the tokamak design, at the cost of some complexity in coil design.

Two small spherical tori, the Helicity Injection Tokamak at the University of Washington and the Pegasus Experiment at the University of Wisconsin, are used in the experimental study of the physics of these compact toroidal shapes. Of particular interest for many of these small-scale experiments are methods used to form the magnetic shapes and to sustain them by injection of additional current in a controlled manner so that the configuration is not de-stabilized and destroyed.

Research on high energy density configurations in which the toroidal field is less than the poloidal (the short way around the magnetic "doughnut") field concentrates on pulse sustainment, confinement, and magnetic field reconnection (formation) processes. Many of these innovative experiments have relatively short pulses in comparison to tokamak discharges, and these experiments are investigating means of sustaining the pulse. These programs include the Madison Symmetric Torus (University of Wisconsin), a spheromak experiment at LLNL, and a small experiment at the California Institute of Technology designed to study the basic physics of the reconnection (formation) process itself.

Research on toroidal systems with the highest energy density includes systems with no toroidal magnetic field and relatively small poloidal magnetic fields. The field reversed configuration (FRC) experiment at the University of Washington, the world's most advanced experiment of this type, focuses on sustaining the relatively short pulses of these plasmas through novel electrical and plasma processes. The ion ring experiment at Cornell University seeks gross stabilization of the FRC through the use of large particle orbits in the magnetic fields (charged particles tend to move in circles in magnetic fields, hence the "orbit"). The levitated dipole experiment (LDX) at MIT will be studying a variant where the confining poloidal magnetic fields are generated by a superconducting magnetic ring located within the plasma itself. Dipole confinement is of great scientific interest in many solar and astrophysical plasma systems.

	(dollars in thousands)	
FY 2000	FY 2001	FY 2002

The magnetized target fusion program (funded by the FES program) at LANL and the Air Force Research Laboratory will study the possibility that a FRC plasma can be compressed to multi-keV temperatures using fast liner compression technology developed by the DOE Defense Programs.

In FY 2002, research efforts on most of these exploratory activities will continue. New concepts will be funded as appropriate through peer review.

	FY 2000	FY 2001	FY 2002
▪ **Inertial Fusion Energy Experiments**	**14,202**	**13,792**	**13,152**

The inertial fusion energy program has research components that encompass many of the scientific and technical elements that form the basis of an inertial fusion energy system. Heavy ion accelerators continue to be the leading IFE driver candidate. Understanding the physics of the intense heavy ion beam (Bi+4, for example), a non-neutral plasma, is one of the outstanding scientific issues. Considerable progress has been made on developing a predictive physics model for intense heavy ion beams. This model, which includes aspects of the accelerator system, has the goal of providing an "end to end" simulation of a heavy ion accelerator. Future developments will include final focusing and transport in the target chamber. The close interplay between scaled experiments and theory and calculation assures that the model has been validated against experiment. Technical elements of the program include the continuing development of experimental systems to study beam formation by high current ion sources, beam acceleration and focusing. The high current experiment under construction will be the primary experimental facility for heavy ion beam transport studies. The 500 kV test stand will be used to study the physics of intense ion sources. Physics experiments carried out on NNSA-funded facilities including the National Ignition Facility (NIF) will provide high energy density physics data to be used in the design of targets for IFE experiments. NIF will provide validation of target design for actual model targets. The IFE science program will be focused on scientific and technical elements that will allow progress toward future integrated experiments. In FY 2002, **performance will be measured by** successfully bringing into operation the recently completed 500 kV Ion Source Test Stand at LLNL, and by starting experiments to explore new ion source configurations to discover improved ways of producing heavy ion driver beam currents.

Performance will be measured by completing a preliminary technical assessment of technology issues and approaches for inertial fusion energy concepts in the areas of the high energy density plasma chambers, target fabrication and tracking, and target chamber interfaces, including studies of safety issues.

	FY 2000	FY 2001	FY 2002
Theory	**24,270**	**27,275**	**25,975**

The goal of the theory and computation program is to achieve a quantitative understanding of the behavior of fusion plasmas for interpreting experiments and for guiding the design of future devices. Considerable progress has been made in areas of macroscopic equilibrium and stability of magnetically confined plasmas and turbulence and transport in tokamak plasmas.

The theory and modeling development program is a broad-based program with researchers located at national laboratories, universities, and industry. The main thrust of the work in tokamak theory is aimed at developing predictive understanding of advanced tokamak operating modes. These tools will later be extended to innovative confinement geometries. In alternate concept theory, the emphasis is on

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

understanding the fundamental processes determining equilibrium, stability, and confinement in each concept. The generic theory work supports the development of basic plasma theory and atomic physics theory that is applicable to fusion research and to basic plasma science. A separate modeling effort is dedicated to developing computational tools to assist in the analysis of experimental data.

In FY 2002 the theory and computation program will continue to emphasize advanced computing and will make use of rapid developments in computer hardware to attack complex problems involving a large range of scales in time and space. These problems were beyond the capability of computers in the past, but advancements in computation are allowing a new look at problems that once seemed almost intractable. The objective of the advanced computing activities, including the Scientific Discoveries through Advanced Computing program, is to promote the use of modern computer languages and advanced computing techniques to bring about a qualitative improvement in the development of models of plasma behavior. This will ensure that advanced modeling tools are available to support a set of innovative national experiments and fruitful collaboration on major international facilities. Specific performance measures include the addition of electron dynamics in turbulence calculations and the inclusion of the plasma's self-generated currents in gross stability simulations. These additions will improve the fidelity of the simulations and provide an enhanced predictive understanding of fusion plasmas.

General Plasma Science	**8,130**	**8,408**	**8,026**

The general plasma science program is directed toward basic plasma science and engineering research. This research strengthens the fundamental underpinnings of the discipline of plasma physics, which makes contributions in many basic and applied physics areas, one of which is fusion energy. Principal investigators at universities, laboratories and private industry carry out the research. A critically important element is the education of plasma physicists. Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Junior Faculty in Plasma Physics Development Program and the basic and applied plasma physics program at DOE laboratories. In FY 2002, the program will continue to fund proposals that have been peer reviewed. Basic plasma physics user facilities will be supported at both universities and laboratories. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases.

SBIR/STTR	**0**	**5,375**	**6,089**

In FY 2000, $4,861,000 and $292,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 and FY 2002 amounts are the estimated requirements for the continuation of these programs. In the past, funding requirements for SBIR/STTR had been split between the Science and Enabling R&D subprograms. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.

Total, Science	**130,326**	**136,312**	**133,440**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Tokamak Experimental Research	
▪ Funding for DIII-D research is slightly reduced..	-17
▪ Funding for Alcator C-Mod research is increased by shifting funds from Alcator C-Mod operations to optimize the scientific productivity of the Alcator C-Mod program. .	+183
▪ An increase in funding for such support activities as education and HBCUs is partially offset by a decrease in international collaborations.	+203
▪ The level of funding for Tokamak Experimental Plasma Research is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-335
Total, Tokamak Experimental Research	+34
Alternative Concept Experimental Research	
▪ Funding for NSTX research is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-125
▪ Funding for alternate concept experiments at universities is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-1,173
▪ Funding for IFE science is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs	-640
Total, Alternative Concept Experimental Research	-1,938
Theory	
▪ Funding for theory and modeling to support experiments is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs	-1,300
Total, Theory	-1,300
General Plasma Science	
▪ The funds available for the NSF/DOE partnership is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-382
Total, General Plasma Science	-382

	FY 2002 vs. FY 2001 ($000)
SBIR/STTR	
▪ Support for SBIR/STTR is mandated at 2.65 percent. In the past, funding requirements for SBIR/STTR had been split between the Science and Enabling R&D subprograms. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.	+714
Total Funding Change, Science	-2,872

Facility Operations

Mission Supporting Goals and Objectives

This activity provides mainly for the operation and maintenance of major fusion research facilities; namely, DIII-D at GA, Alcator C-Mod at MIT, and NSTX at PPPL. These user facilities enable U.S. scientists from universities, laboratories, and industry, as well as visiting foreign scientists, to conduct the world-class research funded in the Science and Enabling R&D subprograms. The facilities consist of magnetic plasma confinement devices, plasma heating and current drive systems, diagnostics and instrumentation, experimental areas, computing and computer networking facilities, and other auxiliary systems. These funds pay for operating and maintenance personnel, electric power, expendable supplies, replacement parts, system modifications and facility enhancements. Capital equipment funding for upgrading and enhancing the research capability of DIII-D and C-Mod is also included.

Funding is included in this subprogram for several activities at PPPL, including continuing the Decontamination and Decommissioning (D&D) and ongoing care taking for the tritium systems and other radioactive components at TFTR, site-wide waste management activities, and General Plant Projects (GPP) and General Purpose Equipment (GPE). GPP and GPE funding supports essential facility renovations and other necessary capital alterations and additions to buildings and utility systems.

The principal objective of the Facility Operations subprogram is to operate the facilities in a safe, environmentally sound manner for the number of weeks shown in the table below. Operating in this manner will maximize the quantity and quality of data collected at the major fusion research facilities while building a culture of operational excellence and complying with all applicable safety and environmental requirements. Funding included for these facilities provides a modest reduction in operating time relative to FY 2001.

The table below summarizes the scheduled weeks of operations for DIII-D, C-Mod, and NSTX.

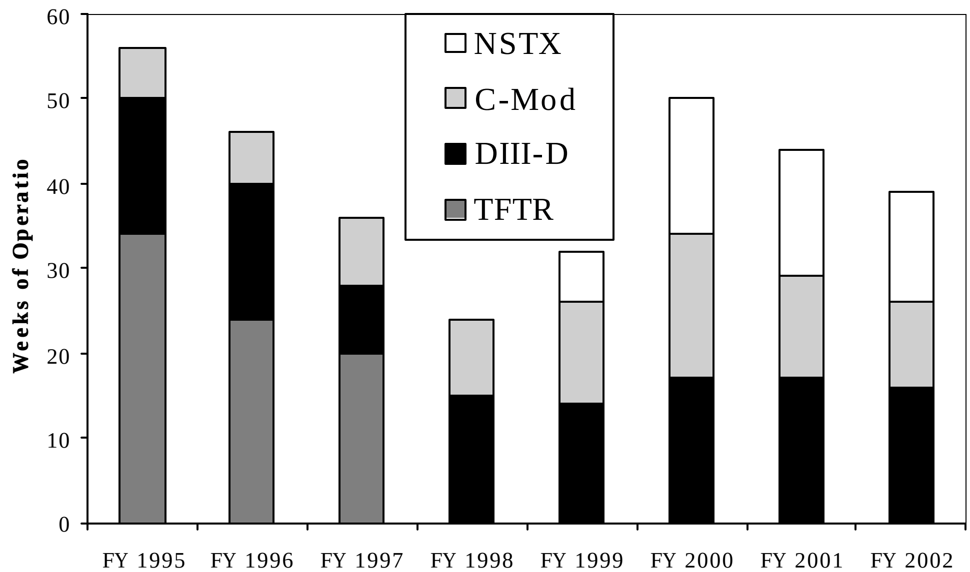
Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence, and relevance; quality; and safety and health.

Weeks of Fusion Facility Operation

(Weeks of Operations)

	FY 2000	FY 2001	FY 2002
DIII-D*	17	17	14
Alcator C-Mod	17	12	8
NSTX	16	15	11

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



Recent operating history of major fusion experimental facilities

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
TFTR	12,969	19,031	18,000	-1,031	-5.4%
DIII-D	30,523	29,249	26,706	-2,543	-8.7%
Alcator C-Mod	10,657	10,636	9,600	-1,036	-9.7%
NSTX	15,161	14,366	13,200	-1,166	-8.1%
General Plant Projects/Other	1,412	1,464	1,464	0	0.0%
Waste Management	2,984	3,150	3,024	-126	-4.0%
Total, Facility Operations	73,706	77,896	71,994	-5,902	-7.6%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
TFTR	**12,969**	**19,031**	**18,000**

In FY 2002, **performance will be measured by** successfully completing in a safe manner TFTR D&D ($14,500,000). This activity will provide for the removal and disposal of the tokamak and remaining radioactive components from the test cell and the basement. In addition, during the D&D, $3,500,000 is necessary to maintain and keep the facility safe. The original plan to provide a total of $21,000,000 in FY 2002 has been modified, based on recent project reviews, to defer $3,000,000 of management reserve expenditures into FY 2003 with the expectation that the project will be completed in FY 2002 without the need to spend the $3,000,000.

	FY 2000	FY 2001	FY 2002
DIII-D	**30,523**	**29,249**	**26,706**

Provide support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems, such as the Electron Cyclotron Heating (ECH) systems. In FY 2002, these funds support 14 weeks of plasma operation (dependent upon electrical power availability in California).

	FY 2000	FY 2001	FY 2002
Alcator C-Mod	**10,657**	**10,636**	**9,600**

Provide support for operation, maintenance, major inspection of the fusion device, and minor machine improvements. In FY 2002, these funds support 8 weeks of plasma operation. Fabrication of a plasma heating and current drive system for Alcator C-Mod will be continued in FY 2002 and the system will be operational in 2003. This enhancement is a Major Item of Equipment with a TEC of $5,200,000 and a FY 2002 request of $1,167,000.

	FY 2000	FY 2001	FY 2002
NSTX	**15,161**	**14,366**	**13,200**
▪ **NSTX**	**12,661**	**14,366**	**13,200**

Provide support for operation, maintenance, and improvement of the NSTX facility and installation of planned diagnostic upgrades. In FY 2002, these funds support 11 weeks of plasma operation.

	FY 2000	FY 2001	FY 2002
▪ **NSTX Neutral Beam**	**2,500**	**0**	**0**

The NSTX neutral beam modification was completed in FY 2000 and was integrated into the NSTX research facility for use in FY 2001 research programs.

	FY 2000	FY 2001	FY 2002
General Plant Projects/General Purpose Equipment	**1,412**	**1,464**	**1,464**

These funds provide primarily for general infrastructure repairs and upgrades for the PPPL site based upon quantitative analysis of safety requirements, equipment reliability and research needs.

	FY 2000	FY 2001	FY 2002
Waste Management	**2,984**	**3,150**	**3,024**

These funds support necessary waste management activities at the PPPL site.

	FY 2000	FY 2001	FY 2002
Total, Facility Operations	**73,706**	**77,896**	**71,994**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
TFTR	
▪ The management reserve is reduced, increasing the risk that completion of the work will be deferred until FY 2003. The hope is that the work will be completed in FY 2002..	-1,031
DIII-D	
▪ Funding for DIII-D operations is decreased to provide funding to meet programmatic responsibilities to clean up the TSTA facility, and for other programmatic needs.	-2,543
Alcator C-Mod	
▪ Funding for Alcator C-Mod operations is decreased to provide funding to meet programmatic responsibilities to clean up the TSTA facility, and for other programmatic needs	-1,036
NSTX	
▪ Funding for NSTX operations is decreased to provide funding to meet programmatic responsibilities to clean up the TSTA facility, and for other programmatic needs.	-1,166
Waste Management	
▪ Funding for Waste Management is decreased to provide for other programmatic needs.	-126
Total Funding Change, Facility Operations	-5,902

Enabling R&D

Mission Supporting Goals and Objectives

The Enabling Research and Development subprogram provides for sustained progress toward fusion research goals through continuing innovation of technologies used in experimental fusion research facilities. The Enabling R&D subprogram provides such innovations for both magnetic and inertial fusion research facilities. This subprogram is divided into two elements: Engineering Research and Materials Research.

The Engineering Research element has completed a major restructuring following the U.S. withdrawal from the International Thermonuclear Experimental Reactor (ITER) project. The scope of activities has been substantially broadened to address more fully the diversity of domestic interests in enabling R&D for both magnetic and inertial fusion energy systems. These activities now focus on critical technology needs for enabling U.S. plasma experiments to achieve their full performance capability. Also, international technology collaborations allow the U.S. to access plasma experimental conditions not available domestically. These activities also include investigation of the scientific foundations of innovative technology concepts for future experiments. Another activity is advanced design of the most scientifically challenging systems for next-step fusion research facilities, i.e. facilities that may be needed in the immediate future. Also included are analysis and studies of critical scientific and technological issues, the results of which will provide guidance for optimizing future experimental approaches and for understanding the implications of fusion research on applications to fusion energy.

The Materials Research element continues to focus on the key science issues of materials for practical and environmentally attractive uses in fusion research and facilities while taking steps to implement the FESAC recommendations of 1998 that fusion materials research become more strongly oriented toward modeling and theory activities. This has made this element more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded elsewhere, as well as more capable of contributing to broader materials research in niche areas of materials science. In addition, materials research of interest to both magnetic and inertial fusion energy systems has now been included in this element.

Management of the diverse and distributed collection of fusion enabling R&D activities is being accomplished through a Virtual Laboratory for Technology, with community-based coordination and communication of plans, progress, and results.

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
Engineering Research	27,176	26,723	26,461	-262	-1.0%
Materials Research	7,052	6,664	6,600	-64	-1.0%
SBIR/STTR	0	898	0	-898	-100.0%
Total, Enabling R&D	34,228	34,285	33,061	-1,224	-3.6%

Detailed Justification

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
Engineering Research	**27,176**	**26,723**	**26,461**
▪ **Plasma Technology**	**12,124**	**11,613**	**10,930**

Plasma Technology efforts will be focused on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for use in future magnetic and inertial fusion experiments. Nearer-term experiment support efforts will be oriented toward plasma facing components and plasma heating and fueling technologies. A feasibility assessment for deploying a first-generation liquid metal system that interacts with the plasma to permit direct control of plasma particle densities and temperatures in NSTX will be completed. Development will continue to ensure the needed robustness of the current 1.0 million watt microwave generator that will efficiently heat plasmas to temperatures needed to verify computer models; development will also address critical issues on an advanced 1.5 million watt generator. Funds will be provided to continue superconducting magnet research and innovative technology research in the area of plasma-surface interaction sciences that will enable fusion experimental facilities to achieve their major scientific research goals and full performance potential.

	FY 2000	FY 2001	FY 2002
▪ **Fusion Technology**	**9,574**	**9,800**	**10,500**

Fusion Technology efforts will be focused on technology innovations and model improvements needed to resolve critical issues faced by both inertial and magnetic fusion concepts. These issues include identifying innovative approaches to fusion reaction chamber design as well as tritium and safety-related aspects of these chambers. In FY 2002, funding for Fusion Technologies is increased to permit the tritium inventory reduction needed to place this facility in a stabilized condition in preparation for transfer of this excess facility to EM. Funding for TSTA is increased by $1,137,000 to $3,300,000. In FY 2002, **performance will be measured by** completing a preliminary technical assessment of technology issues and approaches for inertial fusion energy concepts in the areas of the high energy density plasma chambers, target fabrication and tracking, and target-chamber interfaces, including studies of safety issues. Funds will continue to be provided for the US/Japan collaboration on innovative chamber technology research at a level that allows the US to more fully exploit investments made to enable this collaboration in tritium, coolant flow, and heat transfer research facilities.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
▪ **Advanced Design**	**5,478**	**5,310**	**5,031**

Funding for this element will focus on design studies of systems for next-step plasma science experiment options. Initial systems science studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics and the prospects of possible inertial fusion energy systems will be conducted in an iterative fashion with the experimental community.

Materials Research	**7,052**	**6,664**	**6,600**

Materials Research remains a key element of establishing the scientific foundations for safe and environmentally attractive uses of fusion. Through a wide variety of modeling and experiment activities aimed at the science of materials behavior in fusion environments, research on candidate materials for the structural elements of fusion chambers will continue. Priorities for this work are based on the innovative approaches to evaluating materials and improved modeling of materials behavior that were adopted as a result of recommendations from the FESAC review completed in1998. Research includes materials and conditions relevant to inertial fusion systems as well as magnetic systems. Investigations will be conducted on the limits of strength and toughness of materials based on dislocation propagation and interactions with crystalline matrix obstacles, and the changes to thermal and electrical conductivity in materials based on electron and photon transport and scattering at the atomic level.

SBIR/STTR	**0**	**898**	**0**

In FY 2000, $887,000 and $53,000 were transferred to the SBIR and STTR programs, respectively. The FY 2001 amount is the estimated requirement for the continuation of these programs. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.

Total, Enabling R&D	**34,228**	**34,285**	**33,061**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Engineering Research	
▪ Funding for plasma technologies is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-683
▪ Funding for TSTA is increased by $1,137,000 to $3,300,000 to permit activities to clean up the facility prior to turning it over to the Office of Environmental Management for Decontamination and Decommissioning. Funding for all other fusion technologies activities is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	+700
▪ Funding Advanced Design and Analysis is reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility and for other programmatic needs.	-279
Total, Engineering Research	-262
Materials Research	
▪ The level of material research effort will be slightly reduced to provide funding to meet programmatic responsibilities to clean up the TSTA facility.	-64
SBIR/STTR	
▪ In the past, funding requirements for SBIR/STTR had been split between the Science and Enabling R&D subprograms. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.	-898
Total Funding Change, Enabling R&D	-1,224

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	1,062	1,369	1,369	0	0.0%
Capital Equipment	16,114	7,243	4,318	-2,925	-40.4%
Total, Capital Operating Expenses	17,176	8,612	5,687	-2,925	-34.0%

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
DIII-D Upgrade	27,203	21,460	4,900	843	0	FY 2001
NSTX – Neutral Beam	5,950	3,450	2,500	0	0	FY 2000
Alcator C-Mod LH Modification	5,200 [a]	0	1,133	1,833	1,167	FY 2003
Total, Major Items of Equipment		24,910	8,533	2,676	1,167	

[a] Includes increase in TEC of $1,067,000 to be provided in FY 2003, and six-month delay based upon results of completion of the design. Such a change would normally be accommodated by contingency funds, but for this relatively modest MIE, such funds were not included in the original cost estimate.

Science

FY 2002 Budget Amendment

(B/A in thousands of dollars)

	(dollars in thousands)		
	FY 2002 Pending Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
Science			
Basic Energy Sciences	1,004,705		1,004,705
Advanced Scientific Computing Research	165,750	-2,700 [a]	163,050
Biological and Environmental Research	442,970		442,970
Fusion Energy Sciences	238,495	+10,000	248,495
High Energy Physics	721,100	-5,000 [a]	716,100
Nuclear Physics	360,510		360,510
Energy Research Analyses	1,300	-300 [a]	1,000
Multiprogram Energy Laboratories – Facilities Support	30,175		30,175
Science Program Direction	144,385	-2,000 [a]	142,385
Subtotal, Science	3,109,390	0	3,109,390
Safeguards and Security	55,412		55,412
Reimbursable Safeguards and Security	-4,912		-4,912
Total, Safeguards and Security	50,500		50,500
Total Science	3,159,890	0	3,159,890

[a] The pending detailed budget justification for the FY 2002 Science account currently reflects the proposed reductions of $2,700,000 from Advanced Scientific Computing Research; $5,000,000 from High Energy Physics; $300,000 from Energy Research Analyses; and $2,000,000 from Science Program Direction to the proposed $10,000,000 Amended Request for Fusion Energy Sciences. The Pending Request does not include the proposed $10,000,000 increase to Fusion Energy Sciences.

Fusion Energy Sciences

Program Mission

The pending FY 2002 Congressional Budget Request is $10,000,000 less than the FY 2001 Appropriation. This amendment will restore funding for the Fusion Energy Sciences (FES) program to the FY 2001 level, consistent with the Department's budget principle to continue basic research and the operation of important scientific facilities in support of the DOE mission. This amendment will limit the impact on the research program and the researchers in FY 2002 to that resulting from the increase in the cost of living from FY 2001 to FY 2002.

The amendment will allocate an additional $1,000,000 to the management reserve for the Tokamak Fusion Test Reactor (TFTR) Decontamination and Decommissioning (D&D) activity at the Princeton Plasma Physics Laboratory (PPPL). This additional funding will increase the probability that the project will be completed on schedule in a safe and environmentally acceptable manner by the end of FY 2002. The remaining $9,000,000 was removed from the other elements of the program, on a *pro rata* basis, to maintain the level of effort in all tasks to the extent possible, given the impact of an increasing cost of conducting scientific research.

This amendment proposes to restore the $1,000,000 to TFTR and the remaining $9,000,000 to the other program elements on the same *pro rata* basis. Thus, this will continue important fusion research tasks involving 75 experienced personnel that would otherwise be lost from the program, and the major fusion facilities will be able to operate at levels that are only slightly below the FY 2001 level.

Funding Profile

	(dollars in thousands)		
	FY 2002 Pending Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
Fusion Energy Sciences			
Science	133,440	+5,560	139,000
Facility Operations	71,994	+3,250	75,244
Enabling R&D	33,061	+1,190	34,251
Total, Fusion Energy Sciences	238,495	+10,000	248,495

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

Funding By Site

	(dollars in thousands)		
	FY 2002 Pending Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
Albuquerque Operations Office			
Los Alamos National Laboratory	7,629	+203	7,832
Sandia National Laboratories	2,996	+152	3,148
Total, Albuquerque Operations Office	10,625	+355	10,980
Chicago Operations Office			
Argonne National Laboratory	2,009	+71	2,080
Princeton Plasma Physics Laboratory	66,702	+2,903	69,605
Chicago Operations Office	41,803	+1,838	43,641
Total, Chicago Operations Office	110,514	+4,812	115,326
Idaho Operations Office			
Idaho National Engineering and Environmental Laboratory	2,082	+108	2,190
Oakland Operations Office			
Lawrence Berkeley National Laboratory	4,767	+198	4,965
Lawrence Livermore National Laboratory	14,189	+617	14,806
Oakland Operations Office	65,483	+2,859	68,342
Total, Oakland Operations Office	84,439	+3,674	88,113
Oak Ridge Operations Office			
Oak Ridge Inst. for Science & Education	798	+32	830
Oak Ridge National Laboratory	16,412	+504	16,916
Total, Oak Ridge Operations Office	17,210	+536	17,746
Richland Operations Office			
Pacific Northwest National Laboratory	1,317	+3	1,320
Washington Headquarters	12,308	+512	12,820
Total, Fusion Energy Sciences	238,495	+10,000	248,495

Science

Mission Supporting Goals and Objectives

The amended budget request supports the mission, goals, and objectives of the Science subprogram. Funds are added to each program element on a *pro rata* basis to limit the number of personnel that will be lost and the reduction in the research effort. There will still be reductions resulting from an increasing cost of conducting scientific research.

Funding Schedule

(dollars in thousands)

	FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
Tokamak Experimental Research	45,014	+1,872	46,886
Alternative Concept Experimental Research	48,336	+2,014	50,350
Theory	25,975	+1,082	27,057
General Plasma Science	8,026	+334	8,360
SBIR/STTR	6,089	+258	6,347
Total, Science	133,440	+5,560	139,000

Detailed Program Justification

(dollars in thousands)

	FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
Tokamak Experimental Research	**45,014**	**+1,872**	**46,886**
▪ **DIII-D Research**	**22,723**	**+947**	**23,670**

The increased funding will be used to reduce the projected staff reduction and increase experiment preparation and the analysis of experimental results in the four key MFE fusion topical science areas — energy transport, stability, plasma-wave interactions, and boundary physics.

▪ **Alcator C-Mod Research**	**7,488**	**+312**	**7,800**

The increased funding will be used to reduce the projected staff reduction and increase experiment preparation and the analysis of experimental results in the areas of the physics of the plasma edge, power and particle exhaust from the plasma, mechanisms of self-generation of flows in the plasma, and the characteristics of the advanced confinement modes that appear in the plasma when currents are driven by radio waves, techniques for radiating away the large parallel heat flow encountered in the plasma exhaust at high densities, and on visualization diagnostics for turbulence in the edge and core of high density plasmas.

	FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
	(dollars in thousands)		
▪ **International Collaborations and Education**	**7,987**	**+329**	**8,316**

The increased funding will be used to reduce the projected staff reduction and increase experiment preparation and the analysis of experimental results in the program's international collaboration activities that focus on ways of using the unique aspects of the international facilities to make progress on the four key MFE issues. Increased funding for educational activities in FY 2002 will allow support to be maintained for research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, general science literacy programs for teachers and students, and broad outreach efforts related to fusion science and technology.

▪ **Experimental Plasma Research (Tokamaks)**	**6,816**	**+284**	**7,100**

The increased funding will be used to reduce the projected staff reduction and increase experiment preparation and the analysis of experimental results in the innovative tokamak experiments at universities and the development of diagnostic instruments.

Alternative Concept Experimental Research	**48,336**	**+2,014**	**50,350**
▪ **NSTX Research**	**12,000**	**+500**	**12,500**

The increased funding will be used to reduce the projected staff reduction both on-site and at collaborating institutions and to reduce the projected slowdown in experiment preparation and the analysis of experimental results. Research will be in the areas of the magnetic reconnection technique called Coaxial Helicity Injection (CHI) which uses an innovative application of direct-voltage and current from the plasma edge to create the plasma; the plasma stability limits with auxiliary heating; and comparing the measured dependence of energy and particle fluxes on background plasma variations, including the twist of the magnetic field lines, and comparing these fluxes with theoretical predictions.

▪ **Experimental Plasma Research (Alternatives)**	**23,184**	**+966**	**24,150**

The increased funding will be used to reduce the projected staff reduction and increase experiment preparation and the analysis of experimental results in twelve small experiments, one intermediate level proof-of-principle experiment, and one large study program that is focused on obtaining a design for a compact stellarator proof-of-principle experiment.

▪ **Inertial Fusion Energy Experiments**	**13,152**	**+548**	**13,700**

The increased funding will be used to reduce the projected staff reduction and increase experiment preparation and the analysis of experimental results in the inertial fusion energy program. This will allow the continuing development of experimental systems to study beam formation by high current ion sources, beam acceleration and beam focusing.

	(dollars in thousands) FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
Theory	**25,975**	**+1,082**	**27,057**

The increased funding will be used to reduce the projected staff reduction and increase theoretical research on the behavior of fusion plasmas. This will allow the theorists to continue emphasizing advanced computing and make effective use of rapid developments in computer hardware to attack complex problems involving a large range of scales in time and space. It will promote the use of modern computer languages and advanced computing techniques to bring about a qualitative improvement in the development of models of plasma behavior. This will ensure that advanced modeling tools are available to support a set of innovative national experiments and fruitful collaboration on major international facilities.

General Plasma Science	**8,026**	**+334**	**8,360**

The increased funding will be used to reduce the projected reduction of university research scientists working on basic plasma science and engineering.

SBIR/STTR	**6,089**	**+258**	**6,347**

Funding for the SBIR and STTR programs has been increased to meet the requirement for the continuation of those programs consistent with the increase in the total FES budget.

Total, Science	**133,440**	**+5,560**	**139,000**

Facility Operations

Mission Supporting Goals and Objectives

The amended budget request supports the mission, goals, and objectives of the Facility Operations subprogram. Funds are added to each program element on a *pro rata* basis to limit the number of personnel that will be lost and to minimize the impact on the operation of the facilities resulting from an increasing cost of conducting scientific research.

Weeks of Fusion Facility Operation

(Weeks of Operations)

	FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
DIII-D*	14	2	16
Alcator C-Mod	8	2	10
NSTX	11	2	13

Funding Schedule

(dollars in thousands)

	FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
TFTR	18,000	+1,000	19,000
DIII-D	26,706	+1,174	27,880
Alcator C-Mod	9,600	+400	10,000
NSTX	13,200	+550	13,750
General Plant Projects/Other	1,464	0	1,464
Waste Management	3,024	+126	3,150
Total, Facility Operations	71,994	+3,250	75,244

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

Detailed Program Justification

	(dollars in thousands)		
	FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
TFTR	**18,000**	**+1,000**	**19,000**

The additional $1,000,000 will be used to increase the management reserve to increase the likelihood that the project will be completed in FY 2002.

DIII-D	**26,706**	**+1,174**	**27,880**

The increased funding will be used to reduce the projected staff reduction and increase the operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems, such as the Electron Cyclotron Heating (ECH) systems. With this FY 2002 amendment, these funds will support an additional 2 weeks of plasma operation (dependent upon electrical power availability in California).

Alcator C-Mod	**9,600**	**+400**	**10,000**

The increased funding will be used to reduce the projected staff reduction and increase the operation and maintenance of C-Mod. With this FY 2002 amendment, these funds will support an additional 2 weeks of plasma operation.

NSTX	**13,200**	**+550**	**13,750**

The increased funding will be used to reduce the projected staff reduction and increase the operation and maintenance of the NSTX facility. With this FY 2002 amendment, these funds will support an additional 2 weeks of plasma operation.

General Plant Projects/General Purpose Equipment	**1,464**	**0**	**1,464**

There is no change in this program element.

Waste Management	**3,024**	**+126**	**3,150**

The increased funding will be used to reduce the projected staff reduction in the waste management activities at the PPPL site.

Total, Facility Operations	**71,994**	**+3,250**	**75,244**

Enabling R&D

Mission Supporting Goals and Objectives

The amended budget request supports the mission, goals, and objectives of the Enabling Research and Development subprogram. Funds are added to each program element on a *pro rata* basis to limit the number of personnel that will be lost and to minimize the impact on the research activities resulting from an increasing cost of conducting scientific research.

Funding Schedule

(dollars in thousands)

	FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
Engineering Research	26,461	+1,190	27,651
Materials Research	6,600	0	6,600
Total, Enabling R&D	33,061	+1,190	34,251

Detailed Justification

(dollars in thousands)

	FY 2002 Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
Engineering Research	**26,461**	**+1,190**	**27,651**
▪ **Plasma Technology**	**10,930**	**+570**	**11,500**

The increased funding will be used to reduce the projected staff reduction and increase plasma technology efforts focused on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for use in future magnetic and inertial fusion experiments.

▪ **Fusion Technology**	**10,500**	**+371**	**10,871**

The increased funding will be used to reduce the projected staff reduction and increase fusion technology efforts focused on technology innovations and model improvements needed to resolve critical issues faced by both inertial and magnetic fusion concepts.

▪ **Advanced Design**	**5,031**	**+249**	**5,280**

The increased funding will be used to reduce the projected staff reduction in design studies research.

Materials Research	**6,600**	**0**	**6,600**
Total, Enabling R&D	**33,061**	**+1,190**	**34,251**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000 Pending Request	FY 2002 Proposed Amendment	FY 2002 Revised Request
General Plant Projects	1,369	0	1,369
Capital Equipment.....................................	4,318	+162	4,480
Total, Capital Operating Expenses..............	5,687	+162	5,849

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000 Request	FY 2002 Proposed Amend	FY 2002 Revised Request	Accept-ance Date
DIII-D Upgrade.................................	27,203	27,203	0	0	0	FY 2001
NSTX – Neutral Beam......................	5,950	5,950	0	0	0	FY 2000
Alcator C-Mod LH Modification.........	5,200 [a]	2,966	1,167	+49	1,216	FY 2003
Total, Major Items of Equipment		36,119	1,167	+49	1,216	

[a] Includes increase in TEC of $1,018,000 to be provided in FY 2003, and six-month delay based upon results of completion of the design. Such a change would normally be accommodated by contingency funds, but for this relatively modest MIE, such funds were not included in the original cost estimate.

Safeguards and Security

Program Mission

The mission of the Office of Science (SC) Safeguards and Security program is to ensure appropriate levels of protection against: unauthorized access, theft, diversion, loss of custody, or destruction of Department of Energy (DOE) assets and hostile acts that may cause adverse impacts on fundamental science, national security or the health and safety of DOE and contractor employees, the public or the environment. Each site has a tailored protection program as analyzed and defined in each site's Security Plan (SP) or other appropriate plan.

Security at SC sites is primarily focused on the protection of the DOE personnel, facilities, and equipment. Security interests include multi-million dollar, world-class research and development equipment and facilities, technical and administrative buildings, warehouses, and maintenance facilities. While some sites perform national security activities, the nature of the work typically involves limited issuance of individual security clearances and minimal classified information or material. Very small amounts of nuclear material are stored at a majority of sites. Particular emphasis is placed upon cyber security to provide hardware, software, communication, and data protection.

Protection policies, procedures, and operations at SC sites are equivalent to or greater than the level of security at university research facilities or private sector/commercial industrial facilities. The majority of these sites are located in a college campus-style setting with security assuming a low visibility posture. Site protective forces are generally unarmed and consist of less than 20 personnel. These security officers are utilized in stationary guard posts and mobile security patrols within the confines of the sites. Use is made of security fences, barriers, lighting, intrusion detection systems, and closed-circuit television.

Program Goal

The goal of the Office of Science Safeguards and Security program is to provide appropriate protection of research facilities and property, personnel, information and nuclear materials in a technically sound and cost-effective manner.

Program Objectives

- To provide laboratories and research facilities with adequate safeguards and security measures.
- To provide levels of protection in a tailored manner in accordance with potential risks.
- To correct any identified safeguards and security inadequacies.
- To anticipate evolving threats and provide protective measures.
- To maintain a balance between security and SC research mission.

The following is a brief description of the type of activities performed:

Physical Protection Protective Forces

The Physical Protection Protective Forces activity provides for security guards, management, and or supervision, training and equipment needed for effective performance of protection tasks during normal and emergency conditions.

Physical Security Protective Systems

The Physical Security Protective Systems activity provides for equipment to protect vital security interests and government property per the local threat. Equipment and hardware includes fences, barriers, lighting, sensors, entry control devices, etc. This hardware and equipment is generally operated and used to support the protective guard mission as well.

Information Security

The Information Security activity ensures that materials and documents, that may contain sensitive or classified information, are accurately and consistently identified, properly reviewed for content, appropriately marked and protected from unauthorized disclosure, and ultimately destroyed in an appropriate manner.

Cyber Security

The Cyber Security activity ensures that sensitive and classified information that is electronically processed or transmitted is properly identified, protected, and tested and that all electronic systems have an appropriate level of infrastructure reliability and integrity.

Personnel Security

The Personnel Security activity includes clearance program, security education and awareness for employees, and visitor control. This is accomplished through initial and termination briefings, re-orientations, computer based training, special workshops, publications, signs, and posters.

Material Control and Accountability

The Material Control and Accountability activity provides for the control and accountability of special nuclear materials, including training and development for assessing the amounts of material involved in packaged items, process systems and wastes. Additionally, this activity documents that a theft, diversion or operational loss of special nuclear material has not occurred. Also included is on-site and off-site transport of special nuclear materials in accordance with mission, environmental and safety requirements.

Program Management

The Program Management activity includes the development and updating of security plans, assessments and approvals to determine if assets are at risk, and policy oversight. Also encompassed are contractor management and administration, planning and integration of security activities into facility operations.

Significant Accomplishments and Program Shifts

Beginning in FY 2001, Safeguards and Security activities are direct funded in the "Science" appropriation. Previously these activities were generally funded as a site overhead function. For FY 2001, the Department submitted an amended budget request to consolidate and direct fund safeguards and security in the Office of Security and Emergency Operations. Congress directed that the direct responsibility for safeguards and security must be united and integrated with the responsibility of line operations. This FY 2002 request directly funds safeguards and security activities in accordance with congressional guidance. Increased program emphasis is being provided to cyber security commensurate with increased threats and technology advances.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Science Safeguards and Security					
Protective Forces	22,609	22,211	-60	22,151	26,540
Security Systems	3,725	4,786	-13	4,773	6,956
Transportation	0	262	-262 [a]	0	0
Information Security	696	694	-3	691	940
Cyber Security	5,523	6,450	-16	6,434	10,364
Personnel Security	1,733	1,705	-4	1,701	2,202
Material Control and Accountability	5,083	2,307	+255	2,562	3,169
Program Management	3,200	3,265	-8	3,257	5,241
Program Direction	0	13,260	-13,260	0	0
Subtotal, Science Safeguards and Security	42,569	54,940	-13,371	41,569	55,412
Less Security Charge for Reimbursable Work	-5,266	-5,122	0	-5,122	-4,912
Subtotal, Science Safeguards and Security	37,303	49,818	-13,371	36,447	50,500
Omnibus Rescission	0	-110	110	0	0
Total, Science Safeguards and Security	37,303	49,708	-13,261 [b]	36,447	50,500

Public Law Authorization:

Public Law 95-91, “Department of Energy Organization Act”
Public Law 103-62, “Government Performance and Results Act of 1993”

[a] Funding in the amount of $262,000 is transferred from Transportation to Material Control and Accountability.

[b] Excludes $13,261,000 in FY 2001 transferred to other DOE programs in FY 2002 for program direction related safeguards and security activities.

Funding By Site

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Chicago Operations Office					
Ames Laboratory	254	264	397	+133	+50.4%
Argonne National Laboratory	10,678	11,807	15,355	+3,548	+30.0%
Brookhaven National Laboratory	9,585	9,428	10,986	+1,558	+16.5%
Fermi National Accelerator Laboratory	2,294	2,490	2,765	+275	+11.0%
Princeton Plasma Physics Laboratory	1,680	1,735	1,829	+94	+5.4%
Total, Chicago Operations Office	24,491	25,724	31,332	+5,608	+21.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	3,612	3,492	4,709	+1,217	+34.9%
Stanford Linear Accelerator Center	1,774	1,814	2,152	+338	+18.6%
Oakland Operations Office	2,478	0	0	0	0.0%
Total, Oakland Operations Office	7,864	5,306	6,861	+1,555	+29.3%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education	764	885	1,248	+363	+41.0%
Oak Ridge National Laboratory	8,970	9,162	15,024	+5,862	+64.0%
Thomas Jefferson National Accelerator Facility	480	492	947	+455	+92.5%
Total, Oak Ridge Operations Office	10,214	10,539	17,219	+6,680	+63.4%
Total, Science Safeguards and Security	42,569	41,569	55,412	+13,843	+33.3%
Less Security Charge for Reimbursable Work	-5,266	-5,122	-4,912	+210	+4.1%
Total, Science Safeguards and Security	37,303	36,447	50,500	+14,053	+38.6%

Site Description

Safeguards and Security activities are conducted to meet the requirements of the following program elements: Physical Protection Protective Forces, Physical Security Protective Systems, Information Security, Cyber Security, Personnel Security, Material Control and Accountability, and Program Management. A summary level description of each activity is provided in the preceding Program Mission narrative. These activities ensure adequate protection for DOE security interests.

The attainment of the Safeguards and Security program goals and objectives are measured by progress made towards established performance measures. The technical excellence of the field security program is continually re-evaluated through field and Headquarters reviews. **Performance will be measured** at all sites by accomplishing the following:

- SC will prevent 99% of all unauthorized intrusions to systems that process sensitive unclassified information.
- Physical Security Systems will prevent all unauthorized access to security areas at SC labs.
- Protective Forces will prevent all unauthorized access to security areas at SC labs.

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Ames Laboratory	**254**	**264**	**397**

The Ames Laboratory Safeguards and Security program coordinates planning, policy, implementation and oversight in the areas of physical security, protective forces, personnel security, material control and accountability and cyber security. Access control management, maintaining uninterrupted power supply systems, and investigating and reporting incidents are also critical ongoing efforts. A protective force to protect Ames Laboratory and DOE assets is maintained. Ames actively carries out ongoing efforts to install and maintain cyber security software, hardware, and system configurations within the Ames Laboratory network, that is receiving increased attention (+110,000). The nuclear materials control program prevents or deters the loss or misuse of nuclear materials. Reimbursable work is included in the numbers above. The amount for FY 2002 is $34,000.

Argonne National Laboratory	**10,678**	**11,807**	**15,355**

The Argonne National Laboratory Safeguards and Security program provides protection of nuclear materials, classified matter, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, espionage, or other hostile acts that may cause risks to national security or the health and safety of DOE and contractor employees, the public, or the environment. Program activities include physical security (+795,000), material control and accountability, operational security, transportation safeguards, information and cyber security (that is receiving increased emphasis) (+856,000), physical security, and personnel security. In addition, a protective force is maintained. These activities ensure that the facility, personnel, and assets remain safe from potential threats. Reimbursable work is included in the numbers above. The amount for FY 2002 is $840,000.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Brookhaven National Laboratory	**9,585**	**9,428**	**10,986**

Brookhaven National Laboratory (BNL) Safeguards and Security program activities are focused on information security, cyber security, physical security, and material control and accountability. Information security pertains primarily to information protection and declassification/classification activities. Cyber security efforts are focused on unclassified and classified computer security and cyber infrastructure, that is receiving increased attention (+174,000). BNL operates a transportation division to move special nuclear materials around the site. The personnel security program focuses on badging and clearance investigations. Material control and accountability efforts focus on accurately accounting for and protecting the sites special nuclear materials. In addition, protective forces (+1,018,000) are employed to ensure the protection of the Laboratory and national assets. Reimbursable work is included in the numbers above. The amount for FY 2002 is $806,000.

Fermi National Accelerator Laboratory	**2,294**	**2,490**	**2,765**

Fermi National Accelerator Laboratory Safeguards and Security program efforts are directed at maintaining protective force staffing and operations to protect personnel and the facility as well as continue cyber security, physical security, and a material control and accountability program to accurately account for and protect the facilities special nuclear materials. Both cyber security (+269,000) and protective force (+5,000) are receiving increased attention.

Lawrence Berkeley National Laboratory	**3,612**	**3,492**	**4,709**

The Lawrence Berkeley National Laboratory Safeguards and Security program provides physical protection of personnel and laboratory facilities. This is accomplished with protective forces, cyber security, personnel security and material control and accountability. Access controls utilizing physical security upgrades (+464,000), cyber security (+434,000) and protective forces are receiving increased attention. Reimbursable work is included in the numbers above. The amount for FY 2002 is $830,000.

Oakland Operations Office	**2,478**	**0**	**0**

This activity provides for direct funded material control and accountability functions in FY 2000 only. Funding responsibility transferred to NNSA in FY 2001; in accord with DOE realignment of responsibilities.

Oak Ridge Institute for Science and Education............	**764**	**885**	**1,248**

The Oak Ridge Institute for Science and Education (ORISE) Safeguards and Security program provides physical protection/protective force services by employing unarmed security officers. The facilities are designated as property protection areas for the purpose of protecting government owned assets. In addition to the government owned facilities and personal property, ORISE possesses small quantities of nuclear materials that must be protected. The program includes information security, personnel security, protective forces, physical security, and cyber security. Cyber security (+188,000) and protective forces (+75,000) are receiving increased attention. Reimbursable work is included in the numbers above. The amount for FY 2002 is $319,000.

Oak Ridge National Laboratory	**8,970**	**9,162**	**15,024**

The Oak Ridge National Laboratory (ORNL) Safeguards and Security program includes protective forces, physical security systems, information security, cyber security, personnel security, material

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

control and accountability, and program management. Program planning functions at the Laboratory provide for short and long range strategic planning, and special safeguards plans associated with both day-to-day protection of site-wide security interests and preparation for contingency operations. Additionally, ORNL is responsible for provision of overall Laboratory policy direction and oversight in the security arena, for conducting recurring programmatic self-assessments; for assuring a viable ORNL Foreign Ownership, Control or Influence (FOCI) program is in place; and for identifying, or tracking, and obtaining closure on findings or deficiencies noted during inspections, surveys, or assessments of safeguards and security programs. Increased attention is being given to protective forces (+2,372,000), security systems (+712,000), and cyber security (+1,413,000). Reimbursable work is included in the numbers above. The amount for FY 2002 is $1,945,000.

Princeton Plasma Physics Laboratory	**1,680**	**1,735**	**1,829**

The Princeton Plasma Physics Laboratory Safeguards and Security program provides for protection of nuclear materials, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, or other hostile acts. These activities result in reduced risk to national security and the health and safety of DOE and contractor employees, the public, and the environment. Efforts are primarily focused on cyber security (+61,000) and protective forces (+30,000). Reimbursable work is included in the numbers above. The amount for FY 2002 is $54,000.

Stanford Linear Accelerator Center................................	**1,774**	**1,814**	**2,152**

The Stanford Linear Accelerator Center Safeguards and Security program focuses on reducing the threat to DOE national facilities and assets. The program consists primarily of physical protection protective forces and cyber security program elements. Increased attention is being given to cyber security (+271,000). Reimbursable work is included in the numbers above. The amount for FY 2002 is $84,000.

Thomas Jefferson National Accelerator Facility............	**480**	**492**	**947**

Thomas Jefferson National Accelerator Facility has a guard force which provides 24-hour services for the accelerator site and after-hours property protection security for the entire site. There is increased funding for electronic card access. Increased attention has been given to the Security Program Management (+144,000). Additionally, the security program provides for cyber security protection (that is receiving increased attention) (+154,000), and recording of after-hours personnel accessing the site (+115,000).

Subtotal, Science Safeguards and Security.....................	**42,569**	**41,569**	**55,412**
Less Security Charge for Reimbursable Work	**-5,266**	**-5,122**	**-4,912**
Total, Science Safeguards and Security	**37,303**	**36,447**	**50,500**

Detailed Funding Profile

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Ames Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	94	98	111	+13	+13.3%
Training	1	1	1	0	0.0%
Other	28	28	28	0	0.0%
Total, Protective Forces	123	127	140	+13	+10.2%
Security Systems					
Physical Security	23	24	26	+2	+8.3%
Cyber Security					
Unclassified Computer Security	6	6	129	+123	+2,050.0%
Communications Security	18	19	6	-13	-68.4%
Total, Cyber Security	24	25	135	+110	+440.0%
Personnel Security					
Clearance Program and Visit Control	36	38	42	+4	+10.5%
Material Control and Accountability					
Material Control and Accounting	6	6	6	0	0.0%
Program Management					
Planning	11	12	12	0	0.0%
Professional Training and Development	7	7	7	0	0.0%
Policy Oversight and Administration	24	25	29	+4	+16.0%
Total, Program Management	42	44	48	+4	+9.1%
Total, Ames Laboratory	254	264	397	+133	+50.4%
Argonne National Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	5,321	5,066	5,631	+565	+11.2%
Training	50	50	50	0	0.0%
Other	827	825	827	+2	+0.2%
Total, Protective Forces	6,198	5,941	6,508	+567	+9.5%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Security Systems					
Physical Security	554	1,921	2,716	+795	+41.4%
Explosive Detection	65	65	65	0	0.0%
Escorts	4	4	4	0	0.0%
Total, Security Systems	623	1,990	2,785	+795	+39.9%
Information Security					
Information Protection	164	163	182	+19	+11.7%
Declassification/Classification	44	44	56	+12	+27.3%
Information Assurance	16	16	16	0	0.0%
Technical Surveillance Countermeasures	21	21	16	-5	-23.8%
Operations Security	93	93	88	-5	-5.4%
Total, Information Security	338	337	358	+21	+6.2%
Cyber Security					
Unclassified Computer Security	309	316	838	+522	+165.2%
Classified Computer Security	29	37	70	+33	+89.2%
Communications Security	0	6	6	0	0.0%
TEMPEST	1	4	8	+4	+100.0%
Cyber Infrastructure	697	701	998	+297	+42.4%
Total, Cyber Security	1,036	1,064	1,920	+856	+80.5%
Personnel Security					
Clearance Program and Visit Control	516	514	548	+34	+6.6%
Security Awareness Program	69	69	69	0	0.0%
Total, Personnel Security	585	583	617	+34	+5.8%
Material Control and Accountability					
Material Control and Accounting	1,159	1,155	1,234	+79	+6.8%
Transportation	124	124	124	0	0.0%
Total, Material Control and Accountability	1,283	1,279	1,358	+79	+6.2%
Program Management					
Planning	158	158	737	+579	+366.5%
Professional Training and Development	90	90	90	0	0.0%
Policy Oversight and Administration	367	365	982	+617	+169.0%
Total, Program Management	615	613	1,809	+1,196	+195.1%
Total, Argonne National Laboratory	10,678	11,807	15,355	+3,548	+30.0%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Brookhaven National Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	5,225	4,811	5,667	+856	+17.8%
Training	112	105	109	+4	+3.8%
Other	336	315	473	+158	+50.2%
Total, Protective Forces	5,673	5,231	6,249	+1,018	+19.5%
Security Systems					
Physical Security	1,323	943	1,052	+109	+11.6%
Explosive Detection	19	20	0	-20	-100.0%
Escorts	19	20	0	-20	-100.0%
Total, Security Systems	1,361	983	1,052	+69	+7.0%
Information Security					
Information Protection	116	98	115	+17	+17.3%
Declassification/Classification	17	14	15	+1	+7.1%
Information Assurance	8	7	37	+30	+428.6%
Technical Surveillance Countermeasures	8	7	0	-7	-100.0%
Operations Security	17	14	0	-14	-100.0%
Total, Information Security	166	140	167	+27	+19.3%
Cyber Security					
Unclassified Computer Security	520	1,273	1,438	+165	+13.0%
Classified Computer Security	227	205	214	+9	+4.4%
Communications Security	14	13	13	0	0.0%
TEMPEST	6	5	5	0	0.0%
Cyber Infrastructure	9	8	8	0	0.0%
Total, Cyber Security	776	1,504	1,678	+174	+11.6%
Personnel Security					
Clearance Program and Visit Control	20	20	22	+2	+10.0%
Security Awareness Program	2	2	2	0	0.0%
Total, Personnel Security	22	22	24	+2	+9.1%
Material Control and Accountability					
Material Control and Accounting	439	367	502	+135	+36.8%
Transportation	132	138	138	0	0.0%
Total, Material Control and Accountability	571	505	640	+135	+26.7%

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Program Management					
Planning	305	313	328	+15	+4.8%
Professional Training and Development	102	105	109	+4	+3.8%
Policy Oversight and Administration	609	625	739	+114	+18.2%
Total, Program Management	1,016	1,043	1,176	+133	+12.7%
Total, Brookhaven National Laboratory	9,585	9,428	10,986	+1,558	+16.5%
Fermi National Accelerator Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	1,414	1,468	1,355	-113	-7.7%
Training	64	67	76	+9	+13.4%
Other	104	108	217	+109	+100.9%
Total, Protective Forces	1,582	1,643	1,648	+5	+0.3%
Security Systems					
Physical Security	257	266	267	+1	+0.4%
Cyber Security					
Unclassified Computer Security	313	434	703	+269	+62.0%
Material Control and Accountability					
Material Control and Accounting	35	36	36	0	0.0%
Program Management					
Planning	29	30	30	0	0.0%
Professional Training and Development	30	30	42	+12	+40.0%
Policy Oversight and Administration	48	51	39	-12	-23.5%
Total, Program Management	107	111	111	0	0.0%
Total, Fermi National Accelerator Laboratory	2,294	2,490	2,765	+275	+11.0%
Lawrence Berkeley National Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	791	802	1,000	+198	+24.7%
Other	121	123	125	+2	+1.6%
Total, Protective Forces	912	925	1,125	+200	+21.6%
Security Systems					
Physical Security	868	896	1,360	+464	+51.8%
Cyber Security					
Unclassified Computer Security	1,299	1,122	1,556	+434	+38.7%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Personnel Security					
Clearance Program	106	109	134	+25	+22.9%
Security Awareness Program	12	12	13	+1	+8.3%
Total, Personnel Security	118	121	147	+26	+21.5%
Material Control and Accountability					
Material Control and Accounting	64	66	80	+14	+21.2%
Program Management					
Planning	105	109	113	+4	+3.7%
Professional Training and Development	18	18	19	+1	+5.6%
Policy Oversight and Administration	228	235	309	+74	+31.5%
Total, Program Management	351	362	441	+79	+21.8%
Total, Lawrence Berkeley National Laboratory	3,612	3,492	4,709	+1,217	+34.9%
Oakland Operations Office					
Material Control and Accountability					
Material Control and Accounting	2,478	0	0	0	0.0%
Oak Ridge Institute for Science and Education					
Protective Forces					
Salaries, Wages, and Benefits	100	108	181	+73	+67.6%
Training	4	4	4	0	0.0%
Other	60	70	72	+2	+2.9%
Total, Protective Forces	164	182	257	+75	+41.2%
Security Systems					
Physical Security	69	73	98	+25	+34.2%
Information Security					
Information Protection	30	34	61	+27	+79.4%
Declassification/Classification	10	12	12	0	0.0%
Technical Surveillance Countermeasures	8	6	6	0	0.0%
Operations Security	16	29	30	+1	+3.4%
Total, Information Security	64	81	109	+28	+34.6%
Cyber Security					
Unclassified Computer Security	140	189	373	+184	+97.4%
Classified Computer Security	50	117	119	+2	+1.7%
Communications Security	15	35	36	+1	+2.9%
TEMPEST	10	12	12	0	0.0%
Cyber Infrastructure	50	59	60	+1	+1.7%
Total, Cyber Security	265	412	600	+188	+45.6%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Personnel Security					
Clearance Program and Visit Control	98	113	159	+46	+40.7%
Security Awareness Program............................	104	24	25	+1	+4.2%
Total, Personnel Security....................................	202	137	184	+47	+34.3%
Total, Oak Ridge Institute for Science and Education.	764	885	1,248	+363	+41.0%
Oak Ridge National Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	3,365	3,684	5,841	+2,157	+58.6%
Training..	471	489	152	-337	-68.9%
Other	1,432	1,171	1,723	+552	+47.1%
Total, Protective Forces	5,268	5,344	7,716	+2,372	+44.4%
Security Systems					
Physical Security	436	451	1,185	+734	+162.7%
Escorts..	21	22	0	-22	-100.0%
Total, Security Systems	457	473	1,185	+712	+150.5%
Information Security					
Information Protection	59	62	185	+123	+198.4%
Declassification/Classification	0	0	31	+31	+100.0%
Technical Surveillance Countermeasures	35	36	30	-6	-16.7%
Operations Security	34	35	60	+25	+71.4%
Total, Information Security	128	133	306	+173	+130.1%
Cyber Security					
Unclassified Computer Security	549	570	1,876	+1,306	+229.1%
Classified Computer Security............................	185	193	300	+107	+55.4%
Total, Cyber Security..	734	763	2,176	+1,413	+185.2%
Personnel Security					
Clearance Program and Visit Control	743	772	1,135	+363	+47.0%
Security Awareness Program............................	27	28	53	+25	+89.3%
Total, Personnel Security....................................	770	800	1,188	+388	+48.5%
Material Control and Accountability					
Material Control and Accounting	646	670	1,049	+379	+56.6%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Program Management					
Planning	758	762	1,001	+239	+31.4%
Professional Training and Development	0	0	47	+47	+100.0%
Policy Oversight and Administration	209	217	356	+139	+64.1%
Total, Program Management	967	979	1,404	+425	+43.4%
Total, Oak Ridge National Laboratory	8,970	9,162	15,024	+5,862	+64.0%
Princeton Plasma Physics Laboratory					
Protective Forces					
Salaries, Wages, and Benefits	670	694	723	+29	+4.2%
Training	82	83	84	+1	+1.2%
Other	94	97	97	0	0.0%
Total, Protective Forces	846	874	904	+30	+3.4%
Security Systems					
Physical Security	62	63	58	-5	-7.9%
Escorts	5	5	10	+5	+100.0%
Total, Security Systems	67	68	68	0	0.0%
Cyber Security					
Unclassified Computer Security	665	688	749	+61	+8.9%
Program Management					
Planning	31	32	32	0	0.0%
Professional Training and Development	8	8	8	0	0.0%
Policy Oversight and Administration	63	65	68	+3	+4.6%
Total, Program Management	102	105	108	+3	+2.9%
Total, Princeton Plasma Physics Laboratory	1,680	1,735	1,829	+94	+5.4%
Stanford Linear Accelerator Center					
Protective Forces					
Salaries, Wages, and Benefits	220	227	229	+2	+0.9%
Other	1,243	1,265	1,330	+65	+5.1%
Total, Protective Forces	1,463	1,492	1,559	+67	+4.5%
Cyber Security					
Unclassified Computer Security	311	322	593	+271	+84.2%
Total, Stanford Linear Accelerator Center	1,774	1,814	2,152	+338	+18.6%

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Thomas Jefferson National Accelerator Facility					
Protective Forces					
Salaries, Wages, and Benefits	336	346	387	+41	+11.8%
Other	44	46	47	+1	+2.2%
Total, Protective Forces	380	392	434	+42	+10.7%
Security Systems					
Physical Security	0	0	115	+115	+100.0%
Cyber Security					
Unclassified Computer Security	100	100	216	+116	+116.0%
Cyber Infrastructure	0	0	38	+38	+100.0%
Total, Cyber Security	100	100	254	+154	+154.0%
Program Management					
Policy Oversight and Administration	0	0	144	+144	+100.0%
Total, Thomas Jefferson National Accelerator Facility	480	492	947	+455	+92.5%
Subtotal, Science Safeguards and Security	42,569	41,569	55,412	+13,843	+33.3%
Less Security Charge for Reimbursable Work	-5,266	-5,122	-4,912	+210	+4.1%
Total, Science Safeguards and Security	37,303	36,447	50,500	+14,053	+38.6%

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Ames Laboratory	
▪ Increase mainly in cyber security.	+133
Argonne National Laboratory	
▪ Increases mainly in cyber security protection requirements (+856,000) and program management needs (+1,196,000). Oversight reviews identified significant vulnerabilities in the cyber security programs at Argonne National Laboratory that required enhanced protection measures. Also an increase in physical security for upgrades to aging systems at Argonne National Laboratory – West (+631,000).	+3,548
Brookhaven National Laboratory	
▪ Increases mainly in protective forces and cyber security protection requirements.	+1,558
Fermi National Accelerator Laboratory	
▪ Increase mainly in cyber security.	+275
Lawrence Berkeley National Laboratory	
▪ Increases mainly in physical security and cyber security	+1,217
Oakland Operations Office	
▪ No activities in FY 2001 or FY 2002; in accord with DOE realignment of responsibilities, transferred to NNSA.	0
Oak Ridge Institute for Science and Education	
▪ Minor changes in funding requirements.	+363
Oak Ridge National Laboratory	
▪ The increases are mainly in protective force services (+2,372,000), physical security system upgrades (+712,000) and cyber security (+1,413,000). Independent oversight inspectors identified vulnerabilities in the protection of sensitive unclassified information that required enhanced physical and cyber security protection.	+5,862
Princeton Plasma Physics Laboratory	
▪ Minor changes in funding requirements.	+94
Stanford Linear Accelerator Center	
▪ Minor changes in funding requirements.	+338

	FY 2002 vs. FY 2001 ($000)
Thomas Jefferson National Accelerator Facility	
▪ Increases mainly in Security Systems (+115,000), Cyber Security (+116,000), and Program Management (+144,000).	+455
Subtotal Funding Change, Science Safeguards and Security	+13,843
Less Security Charge for Reimbursable Work	+210
Total Funding Change, Science Safeguards and Security	+14,053

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects......................	0	1,369	2,000	+631	+46.1%
Total, Capital Operating Expenses	0	1,369	2,000	+631	+46.1%

Science Program Direction

Program Mission

Science Program Direction consists of three subprograms: Program Direction, Science Education, and Field Operations. Program Direction is the funding source for the Office of Science (SC) Federal staff that directs and administers a broad spectrum of scientific disciplines and provides technical and administrative support directly related to Science in Headquarters, the Chicago and Oak Ridge Operations Offices, and the Berkeley and Stanford Site Offices. Science Education sponsors programs that enable college and university students and faculty to take advantage of fellowship and research opportunities at the National Laboratories and user facilities, all designed to promote interest in science, math, engineering, and technology fields. Field Operations is the centralized funding source for the day-to-day operations, management and administrative functions, and the core Federal staff responsible for providing these services to the many different Departmental programs at the Chicago and Oak Ridge Operations Offices.

The **Program Direction** subprogram supports the overall direction of technical and scientific activities in the Basic Energy Sciences; Nuclear Physics; High Energy Physics; Biological and Environmental Research; Advanced Scientific Computing Research; and Fusion Energy Sciences programs and for managing laboratory infrastructure; security, environment, safety and health; administrative resources; policy; and planning. It provides funding for salaries and benefits, travel, support services, and other related expenses, including the Working Capital Fund.

The **Science Education** subprogram supports four educational human resource development programs. The Department is committed to math, science, engineering, and technology education programs to help provide a technically trained and diverse workforce for the Nation.

- The *Energy Research Undergraduate Laboratory Fellowship Program (ERULF)*, formerly known as the Laboratory Cooperative Program, is designed to provide educational training and research experiences at DOE laboratories for highly motivated undergraduate students. These opportunities complement academic programs and introduce students to the unique intellectual and physical resources present at the DOE laboratories. Appointments are available during the spring, summer, and fall terms. These research opportunities have also been extended in a pilot pre-service teacher program (PST) with the National Science Foundation, to undergraduate students who are preparing for careers in math, science, engineering or technology teaching.
- The *National Science BowlÒ Program* is a highly publicized academic competition among high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, computer and general science. This program was created to encourage high school students across the Nation to excel in math and science and to pursue careers in those fields. Since its inception, more than 60,000 high school students have participated in regional tournaments leading up to the national finals. This program provides the students, and teachers who have prepared them, a forum to receive national recognition for their talent and hard work.
- The *Albert Einstein Distinguished Educator Fellowship Program* supports outstanding science and mathematics teachers, who provide insight, extensive knowledge, and practical experience to the Legislative and Executive branches. This program is in compliance with the Albert Einstein Distinguished Educator Act of 1994 (signed into law in November 1994). The law gives DOE

responsibility for administering the program of distinguished educator fellowships for elementary and secondary school mathematics and science teachers.

- The *DOE Community College Institute (CCI) of Biotechnology, Environmental Science, and Computing* provides educational human resource development experiences at several DOE National Laboratories for highly motivated community college students. Each laboratory offers a 10-week summer experience for selected students from a regional consortium of community colleges collaborating with DOE and that laboratory. This experience is a collaboration among DOE National Laboratories and the American Association of Community Colleges.

The **Field Operations** subprogram enables the Chicago and Oak Ridge Operations Offices to manage programs, projects, laboratories, facilities, grants and contracts in support of science and technology, energy research, and environmental management activities under their purview. Field Operations provides the salaries and benefits, travel, and support services for the core administrative staff that perform managerial, business, fiduciary, contractual, and technical support functions and the day-to-day requirements of operating an office, i.e., rent, utilities, communications, information technology, office equipment, etc. The Oakland Operations Office, previously funded in this subprogram, is now funded in the National Nuclear Security Administration (NNSA) consistent with the field restructuring management reform initiated on October 1, 2000.

Program Goals

- Fund Federal staff and related expenses necessary to provide overall management direction of SC's scientific research and technology programs.
- Enable the Director of SC to serve as the Department's science advisor for formulation and implementation of basic and fundamental research policy.
- Sustain U.S. leadership in math, science, technology, and engineering by leveraging DOE resources in partnership with laboratories and facilities, other Federal agencies, academia and industry that contribute to the development of a diverse scientific and technical workforce for the 21st century.
- Provide management and administrative services that enable the Operations Offices to continue environmental cleanups; support the national laboratories and research facilities; institute environment, safety and health initiatives; maintain communications with stakeholders; create public and private partnerships; and take advantage of reindustrialization opportunities.

Program Objectives

Program Direction

- To develop, direct, and administer a complex and broadly diversified program of mission-oriented, basic and applied research and development designed to support new and improved energy, environmental, and health technologies.
- To manage the design, construction, and operation of forefront scientific research facilities for use by the Nation's scientific community, including the Spallation Neutron Source Project.
- To conduct independent technical assessments; peer reviews; and evaluate research proposals, programs, and projects.
- To enhance international collaboration and leverage the U.S. investment in research and development.

- To review, analyze, and where appropriate, champion the recommendations of SC's Federally-chartered advisory committees: the Fusion Energy Sciences Advisory Committee; High Energy Physics Advisory Panel; Department of Energy/National Science Foundation (DOE/NSF) Nuclear Science Advisory Committee; Basic Energy Sciences Advisory Committee; Biological and Environmental Research Advisory Committee; and the Advanced Scientific Computing Advisory Committee.

Science Education

- To provide opportunities and effective mechanisms for a diverse group of students and faculty to participate in research at the Department's laboratories related to SC's research programs, with a focus on undergraduates.
- To provide opportunities for participants to improve their communications skills through oral and written presentations of their research experience.

Field Operations

- To provide the day-to-day managerial, business, fiduciary, contractual, and technical foundation necessary to support programmatic missions in the areas of science and technology, energy research, and environmental management.
- To improve the operational efficiency through the development and implementation of integrated business management systems.
- To maintain the field infrastructure in an environment that is safe and hazard free.
- To improve communications with customers, stakeholders, and the public.

Significant Accomplishments and Program Shifts

SCIENCE ACCOMPLISHMENTS

Program Direction

- Achieved technical excellence in SC programs despite managing one of the largest, most diversified, and complex basic research portfolios in the Federal Government with a relatively small Federal and contractor support staff.
- Based on results of genomics and structural biology research, redirected resources to the "Genomes to Life" research program and implemented this research as recommended by the Biological and Environmental Research Advisory Committee, incorporating and expanding the Microbial Cell Project.
- Concluded the international agreement for U.S. participation in the Large Hadron Collider project. Signatories include the Secretary of Energy and the Director of the National Science Foundation. Execution of the project is ongoing.
- Transferred management responsibility for newly generated wastes at Ames Laboratory, Argonne National Laboratory/East, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, and Princeton Plasma Physics Laboratory from the Office of Environmental Management to SC.
- Planned and managed a complex, scientific R&D program to advance the knowledge base needed for an attractive fusion energy source.

- Refined the framework of appropriate international arrangements needed to carry out SC programs in a most cost-effective manner.
- Responded to recommendations from the Secretary of Energy Advisory Board and chartered a working group to prepare an Integrated Program Plan for fusion energy sciences. The Plan will be available early in 2001 and will describe the technical activities necessary for fusion program success and the relationships among these activities.
- Delivered the procurement module of the Information Management for Science (IMSC) system, a major business management corporate system within SC.
- Provided multiple information technology (IT) improvements as requested by the SC Headquarters business customers to assist them in carrying out the SC mission, e.g., refreshed 33 percent of laptops and customer workstations, made Internet Explorer 5.01 available, etc.
- Developed and initiated the implementation of SC's Cyber Security Plan.
- Implemented an "Information Architecture" process at the Chicago Operations Office, in accordance with the Information Technology Management Reform Act of 1996, that is compatible with the Information Architecture already implemented in SC Headquarters.
- Integrated direct safeguards and security responsibilities with line operations.
- Made organizational changes consistent with the principles established by Secretarial direction and subsequent management restructuring reforms unfolding as part of implementing the National Nuclear Security Administration (NNSA), including aligning the Berkeley and Stanford Site Offices under SC and relinquishing the Oakland Operations Office and the Y-12 Area Office to NNSA.

Science Education

- The Energy Research Undergraduate Laboratory Fellowship Program has implemented an innovative, interactive Internet system to receive and process hundreds of student applications for summer, fall, and spring semester research appointments at participating DOE laboratories. The automated system is virtually paperless and provides an excellent example of how the Internet can be used to streamline the operation of the Department's research participation programs. The on-line application system now has pre- and post-surveys that quantify student knowledge, performance and improvement, and allows SC to measure program effectiveness and track students in their career path.
- Through special recruitment efforts, the Energy Research Undergraduate Laboratory Fellowship Program has attracted a diverse group of students using the electronic application. Nearly 20 percent of those submitting applications were from under-represented ethnic groups. Approximately 40 percent of the applications were females, and more than 25 percent were from low-income families. In the summer of 1999, more than 400 appointments were made through the new application process and in the summer of 2000 more than 500 appointments were made through the new application process.
- Five additional regional competitions were held in conjunction with DOE's National Science BowlÒ. More than 9,000 high school students participated in the 53 regional science bowl tournaments.
- The Albert Einstein Distinguished Educator Fellowship Program placed 4 outstanding K-12 science, math, and technology teachers in Congressional offices and 1 at DOE, as directed by legislation. The

National Aeronautics and Space Administration and the National Science Foundation contributed funds to place 7 additional Einstein Fellows in those agencies.

- In FY 2000, SC piloted for the second year, its DOE Community College Institute of Biotechnology, Environmental Science, and Computing. In the summer of 2000, 118 community college students attended a 10-week scientific research experience at 6 DOE multipurpose laboratories. Almost 60 percent of the participating students came from under-represented groups in math, science, engineering, and technology; many were "non-traditional" students.
- The Community College Institute of Biotechnology, Environmental Science, and Computing received recognition as a semifinalist in the Harvard "Innovations in American Government Awards Program 2000." It was one of 96 semifinalists out of an original applicant pool of 1,300.

Field Operations

- Implemented the reorganization, resulting from the establishment of the NNSA required by the FY 2000 Defense Authorization and subsequent management reforms.
- In support of the Energy and Water Development Appropriations Act requirement under Section 310(A) and Section 311 of Public Law 106-60, Laboratory Funding Plans were prepared and overhead reviews of prime contractors were accomplished.
- Closed 400 contracts and grants.
- Improved contracting practices to become more competitive in the award process by holding contractors more accountable in the execution of Government contracts and moved to a performance-based contracting strategy.
- Successfully awarded the new contract to UT-Battelle, LLC, for the management of Oak Ridge National Laboratory (ORNL) at Oak Ridge.
- Awarded the new protective services contract to Wackenhut Services, Inc., which provides uniformed guards for the safeguards and security functions at the Y-12 Plant, Oak Ridge National Laboratory, East Tennessee Technology Park (ETTP), Federal Building, and Office of Scientific and Technical Information.

FACILITY ACCOMPLISHMENTS

Program Direction

- Completed the B-factory and its detector at the Stanford Linear Accelerator Center within scope and budget, and on schedule.
- Strengthened integrated safety and security management and infrastructure management at the national laboratories.
- Enhanced neutron science capability at the Los Alamos Neutron Science Center.
- Designed and continued construction of the Neutrinos at the Main Injector project at the Fermi National Accelerator Laboratory.
- Began construction of the Spallation Neutron Source at the Oak Ridge National Laboratory in FY 2000.

Field Operations

- Successfully tested, validated, and completed all critical computer systems at the Operations Offices and major laboratories for Y2K with no glitches.

PROGRAM SHIFTS

- In FY 1999, SC became the Lead Program Secretarial Office (LPSO) for Chicago, Oak Ridge, and Oakland Operations Offices. Then in October 2000, DOE changed the field structure and realigned work performed on behalf of NNSA under NNSA organizations.
- The FY 2001 Energy and Water Development Appropriations Act (H.R. 4733-23, Public Law 106-907), prohibited the Department from using appropriated funds to pay personnel engaged in concurrent service or duties in DOE and NNSA. As a result, the Oakland Operations Office is now part of NNSA and reports directly to the Deputy Administrator for Defense Programs (DP) instead of SC. The Oakland Operations Office Manager and staff, other than those who work on behalf of SC programs, are designated as NNSA employees.
- The Berkeley and Stanford Site Offices have oversight responsibilities for the Lawrence Berkeley National Laboratory and the Stanford Linear Accelerator Center, respectively, and report directly to the SC Director instead of the Oakland Operations Office Manager. The Y-12 Area Office reports to DP instead of to the Oak Ridge Operations Office Manager.
- A portion of SC's Program Direction budget, in the "Field Operations" subprogram, funded the administrative and management functions at Oakland. With the October 2000 realignment, this subprogram will not fund Oakland activities beginning in FY 2002.
- The FY 2001 Energy and Water Development Appropriations Act (H.R. 4733-23, Public Law 106-907) directed the Department to integrate safeguards and security responsibilities with line operations. Beginning in FY 2002, SC will support the safeguards and security federal staffing functions at the Oak Ridge Operations Office within the Program Direction subprogram.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Science Program Direction					
Program Direction	57,505 [a]	51,438	+9,642[a]	61,080	72,525
Science Education	4,472 [b]	4,500	-40[b]	4,460	5,460
Field Operations	58,514 [c] [d]	83,307	-21,941 [d]	61,366	64,400
Subtotal, Science Program Direction	120,491	139,245	-12,339	126,906	142,385
General Reduction for Safeguards and Security	0	-408	408	0	0
Omnibus Rescission	0	-305	305	0	0
Subtotal, Science Program Direction	120,491	138,532	-11,626	126,906	142,385
Pending Budget Amendment	0	0	0	0	2,000 [e]
Total, Science Program Direction	120,491	138,532	-11,626	126,906	144,385
Staffing (FTEs)					
Headquarters (FTEs)	259	284	0	284	284
Field (FTEs)	94	62	+43	105	107
Field Operations (FTEs)	555	732	-176	556	551
Total, FTEs	908	1,078	-133	945	942

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 $603,000 in FY 2000 for Waste Management activities transferred from the Office of Environmental Management in FY 2001. Includes $1,901,000 in FY 2000 and $2,661,000 in FY 2001 transferred from Field Operations to Program Direction for SC site offices. Includes $7,141,000 in FY 2000 and $7,094,000 in FY 2001 for Program Direction related Safeguards and Security (S&S) activities transferred from consolidated S&S program in FY 2002.

[b] Excludes $28,000 in FY 2000 and $30,000 in FY 2001 for S&S activities transferred to consolidated S&S program in FY 2001.

[c] Excludes $362,000 in FY 2000 for S&S activities transferred to consolidated S&S program in FY 2001.

[d] Excludes $19,872,000 in FY 2000 and $21,381,000 in FY 2001 for transfer of Oakland Operations Office to NNSA in FY 2002. Excludes $378,000 in FY 2001 for S&S activities transferred to consolidated S&S program in FY 2001.

[e] A Budget Amendment transferring $2,000,000 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					
National Renewable Energy Laboratory	0	120	100	-20	-16.7%
Chicago Operations Office					
Ames National Laboratory	0	0	50	+50	+100.0%
Argonne National Laboratory	602	430	750	+320	+74.4%
Brookhaven National Laboratory	558	420	650	+230	+54.8%
Fermi National Laboratory Laboratory	0	50	100	+50	+100.0%
Princeton Plasma Physics Laboratory	0	110	100	-10	-9.1%
Chicago Operations Office............................	29,488	31,774	33,046	+1,272	+4.0%
Total, Chicago Operations Office........................	30,648	32,784	34,696	+1,912	+5.8%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	0	40	100	+60	+150.0%
Idaho Operations Office................................	0	35	0	-35	-100.0%
Total, Idaho Operations Office............................	0	75	100	+25	+33.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	613	445	750	+305	+68.5%
Stanford Linear Accelerator Center................	0	125	150	+25	+20.0%
Berkeley and Stanford Site Offices	2,985	3,130	3,262	+132	+4.2%
Oakland Operations Office	548	0	0	0	0.0%
Total, Oakland Operations Office	4,146	3,700	4,162	+462	+12.5%
Oak Ridge Operations Office					
Oak Ridge Institute for Science and Education	1,120	704	950	+246	+34.9%
Oak Ridge National Laboratory	642	0	0	0	0.0%
Thomas Jefferson National Accelerator Facility...	0	45	100	+55	+122.2%
Oak Ridge Operations Office	41,304	43,960	47,265	+3,305	+7.5%
Total, Oak Ridge Operations Office	43,066	44,709	48,315	+3,606	+8.1%
Richland Operations Office					
Pacific Northwest National Laboratory	293	0	100	+100	+100.0%
Richland Operations Office	308	650	800	+150	+23.1%
Total, Richland Operations Office.......................	601	650	900	+250	+38.5%

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Washington Headquarters	42,030	44,868	54,112	+9,244	+20.6%
Subtotal, Science Program Direction	120,491[a] [b]	126,906	142,385	+15,479	+12.2%
Pending Budget Amendment	0	0	2,000 [c]	+2,000	--
Total, Science Program Direction	120,491	126,906	144,385	+17,479	+1.4%

[a] Includes $603,000 in FY 2000 for Waste Management activities transferred from the Office of Environmental Management in FY 2001. Also includes $7,141,000 in FY 2000 and $7,094,000 in FY 2001 for Program Direction related S&S activities transferred from consolidated S&S program in FY 2002. Excludes $362,000 in FY 2000 for S&S activities transferred to consolidated S&S program in FY 2001. Also excludes $17,971,000 in FY 2000 and $18,720,000 in FY 2001 for transfer of Oakland Operations Office to NNSA in FY 2002.

[b] Excludes $28,000 in FY 2000 for S&S activities transferred to consolidated S&S program in FY 2001.

[c] A Budget Amendment transferring $2,000,000 from this program will be submitted shortly. The narrative description for this program has already been adjusted to reflect the revised levels.

Site Description

Ames National Laboratory

Ames Laboratory (Ames), located in Ames, Iowa, is an integrated part of Iowa State University. Ames was formally established in 1947, by the Atomic Energy Commission, because of its successful development and efficient process in producing high-purity uranium metal in large quantities for atomic energy. Today, Ames pursues a broad range of priorities in the chemical, materials, engineering, environmental, mathematical and physical sciences. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a multi-program laboratory located on a 1,700-acre site in suburban Chicago. Argonne research falls into 4 broad categories: basic science, scientific facilities, energy resources, and environmental management. ANL has a satellite site located in Idaho Falls, Idaho. This site occupies approximately 900 acres and is the home of most of Argonne's major nuclear reactor research facilities. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Berkeley Site Office

The Berkeley Site Office provides institutional program management oversight in the execution of science programs contracted through Lawrence Berkeley National Laboratory and with US industries and universities.

Brookhaven National Laboratory

Brookhaven National Laboratory is a multi-program laboratory located on a 5,200-acre site in Upton, New York. Brookhaven creates and operates major facilities available to university, industrial, and government personnel for basic and applied research in the physical, biomedical, and environmental sciences, and in selected energy technologies. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Chicago Operations Office

Chicago is responsible for the integrated management of its five performance-based contractor laboratory sites--Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, and Ames Laboratory; and two government-owned and government-operated federal laboratories--Environmental Measurements Laboratory and New Brunswick Laboratory. Chicago has oversight responsibility for more than 10,000 contractor employees located at various site offices across the Nation. This responsibility includes ensuring the security and environmental safety of the taxpayer's investment--approximately 16,000 acres of land with a physical plant worth approximately $5.8 billion. Chicago is often noted as a leader in both intellectual property matters and management of more than 2,000 active procurement instruments. Several Departmental programs rely on these patent services and the expertise within this Center of Excellence for Acquisitions and Assistance.

Idaho National Engineering and Environmental Laboratory

The Idaho National Engineering and Environmental Laboratory (INEEL) is located on 890 square miles in the southeastern Idaho desert. Other INEEL research and support facilities are located in nearby Idaho Falls. Within the laboratory complex are nine major applied engineering, interim storage and research and development facilities, operated by Bechtel, B&W Idaho for the U.S. Department of Energy. Today, INEEL is solving critical problems related to the environment, energy production and use, U.S. economic competitiveness, and national security. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory is a multi-program laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. The Laboratory is dedicated to performing leading-edge research in the biological, physical, materials, chemical, energy, and computer sciences. The Laboratory also operates unique user facilities available to qualified investigators. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) is located on a 300-acre campus at the foot of South Table Mountain in Golden, Colorado. It is the world leader in renewable energy technology development. Since its inception in 1977, NREL's sole mission has been to develop renewable energy and energy efficiency technologies and transfer these technologies to the private sector. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a multi-program laboratory located on a 24,000-acre site in Oak Ridge, Tennessee. Scientists and engineers at ORNL conduct basic and applied research and development to create scientific knowledge and technological solutions that strengthen the nation’s leadership in key areas of science; increase the availability of clear, abundant energy; restore and protect the environment; and contribute to national security. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Oak Ridge Operations Office

Oak Ridge has oversight responsibility for ORNL, East Tennessee Technology Park (ETTP), Paducah Gaseous Diffusion Plant, Portsmouth Gaseous Diffusion Plant, Y-12 Plant, and the government owned and operated Oak Ridge Institute for Science and Education (ORISE). Oak Ridge has oversight responsibility for more than 15,000 contractor employees located at these sites, as well as responsibility for over 43,000 acres of land and approximately 46,000,000 square feet of facility space, valued at over $12 billion. ORNL has responsibility for the Spallation Neutron Source project (construction began in FY 2000). The Y-12 Plant has recently resumed weapons production operations, and the ETTP is responsible for utilizing DOE assets by recycling metals, the sale of precious metals, and the disposition of uranium. Other major initiatives at Oak Ridge include reducing environmental risk; reducing the Y-12 weapons footprint; re-industrializing the ETTP and some parts of the Y-12 Plant for commercial use; the revitalization of the scientific infrastructure; and creating public and private partnerships for regional economic development. Oak Ridge is also recognized as one of the Department's three Financial Centers of Excellence.

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. ORISE conducts research into modeling radiation dosages for novel clinical, diagnostic, and therapeutic procedures. In addition, ORISE coordinates several research fellowship programs and the peer review of all Basic Energy Sciences funded research. ORISE will now manage and administer ORNL undergraduate research opportunities for students and faculty.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a multi-program laboratory located on 640 acres at the Department's Hanford site in Richland, Washington. The Laboratory conducts research in the area of environmental science and technology and carries out related national security, energy, and human health programs. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

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 primary mission of PNNL is to develop the scientific understanding and the innovations, which will lead to an attractive fusion energy source. Associated missions include conducting world-class research along the broad frontier of plasma science and providing the highest quality of scientific education. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Richland Operations Office

Richland is responsible for and manages all environmental cleanup and science and technology development at the 560 square mile Hanford Site, coordinating closely with contractor companies hired to manage and complete the work of the world's largest cleanup project. The primary contractors are Fluor Daniel Hanford and its subcontractors, the Bechtel Hanford, Inc, the Hanford Environmental

Health Foundation, and the Battelle Memorial Institute, which serves as the contractor for Laboratory operations of the Pacific Northwest National Laboratory. Richland also manages the cooperative agreement with Associated Western Universities to administer research appointments at National Laboratories and universities, for undergraduate students and faculty, as part of the Office of Science funded Education Programs.

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 is a national basic research laboratory, probing the structure of matter at the atomic scale with x-rays and at much smaller scales with electron and positron beams. SLAC scientists perform experimental and theoretical research in elementary particle physics using electron beams, plus a broad program of research in atomic and solid state physics, chemistry, biology, and medicine using synchrotron radiation. There are also active programs in the development of accelerators and detectors for high-energy physics research and of new sources and instrumentation for synchrotron radiation research. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate students and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Stanford Site Office

The Stanford Site Office provides institutional program management oversight in the execution of basic research at the Stanford Linear Accelerator Center, a national laboratory operated under a contract with Stanford University.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility (Jefferson Lab) is a program-dedicated laboratory (Nuclear Physics) located on 273 acres in Newport News, Virginia. Jefferson Lab is a basic research laboratory built to probe the nucleus of the atom to learn more about the quark structure of matter. The Laboratory gives scientists a unique and unprecedented probe to study quarks, the particles that make up protons and neutrons in an atom's nucleus. Educational activities supported at the laboratory are directed towards providing hands-on research experiences for undergraduate student and faculty participants on state-of-the-art equipment while engaging them in important issues at the forefront of scientific inquiry.

Program Direction

Mission Supporting Goals and Objectives

Program Direction provides the Federal staffing resources and associated costs required for overall direction and execution of SC program and advisory responsibilities. Program Direction supports staff in the High Energy Physics, Nuclear Physics, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, Advanced Scientific Computing Research, Multiprogram Energy Laboratories-Facilities Support, and Energy Research Analyses programs, including management, resource, policy, and technical support staff. The staff includes scientific and technical personnel as well as program support personnel in the areas of budget and finance; general administration; grants and contracts; information technology management; policy review and coordination; infrastructure management; construction management; safeguards and security; and environment, safety and health. This program also provides staffing resources at the Chicago and Oak Ridge Operations Offices directly involved in executing SC programs.

Program Direction also includes resources to cover the costs of centrally provided goods and services procured through the Working Capital Fund at Headquarters, such as supplies, rent, telecommunications, desktop infrastructure, etc.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	3,790	3,826	4,036	+210	+5.5%
Travel	214	227	227	0	0.0%
Support Services	160	240	240	0	0.0%
Other Related Expenses	195	309	309	0	0.0%
Total, Chicago Operations Office	4,359	4,602	4,812	+210	+4.6%
Full Time Equivalents	31	37	37	0	0.0%
Berkeley and Stanford Site Offices					
Salaries and Benefits	2,310	2,400	2,532	+132	+5.5%
Travel	121	130	130	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	554	600	600	0	0.0%
Total, Berkeley and Stanford Site Offices	2,985	3,130	3,262	+132	+4.2%
Full Time Equivalents	26	26	26	0	0.0%

	(dollars in thousands, whole FTEs)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Oak Ridge Operations Office					
Salaries and Benefits	2,820	3,633	4,050	+417	+11.5%
Travel	151	163	163	0	0.0%
Support Services	3,446	4,134	5,340	+1,206	+29.2%
Other Related Expenses	1,796	976	976	0	0.0%
Total, Oak Ridge Operations Office	8,213	8,906	10,529	+1,623	+18.2%
Full Time Equivalents	37	42	44	+2	+4.8%
Headquarters					
Salaries and Benefits	30,334	32,878	35,953	+3,075	+9.4%
Travel	1,449	1,514	1,514	0	0.0%
Support Services	5,992	5,350	7,250	+1,900	+35.5%
Other Related Expenses	4,173	4,700	9,205	+4,505	+95.9%
Total, Headquarters	41,948	44,442	53,922	+9,480	+21.3%
Full Time Equivalents	259	284	284	0	0.0%
Total Science					
Salaries and Benefits	39,254	42,737	46,571	+3,834	+9.0%
Travel	1,935	2,034	2,034	0	0.0%
Support Services	9,598	9,724	12,830	+3,106	+31.9%
Other Related Expenses	6,718	6,585	11,090	+4,505	+68.4%
Total, Science Program Direction	57,505	61,080	72,525	+11,445	+18.7%
Total, Full Time Equivalents	353	389	391	+2	+0.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Salaries and Benefits	**39,254**	**42,737**	**46,571**

Supports 391 Full Time Equivalents (FTEs). Enables the Federal staff to provide program guidance and administrative and technical support for a broad spectrum of scientific disciplines and support the Berkeley and Stanford Site Offices and safeguards and security functions at the Oak Ridge Operations Office. In FY 2002, SC will continue to focus on human capital management and planning with the goal of building and sustaining a talented and diverse workforce, offsetting existing and projected shortfalls in the scientific and technical areas, and manage programs and grants in a safe, efficient, and effective manner. **Performance will be measured** based on SC receiving, processing, and coordinating merit peer reviews on 2,000 research proposals; issuing 2,500 procurement actions; and managing 3,500 existing research grants. The funding increase provides for the salary pay raise, increases in personnel benefits, recruitment incentives to attract and encourage scientific and technical experts to accept positions in SC, and 2 FTEs aligned with security responsibilities at the Oak Ridge Operations Office (+$3,834,000).

Travel..	**1,935**	**2,034**	**2,034**

Travel includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with Federal travel regulations.

Support Services...	**9,598**	**9,724**	**12,830**

Provides funding for general administrative and technical expertise (16 percent), information technology (IT) (40 percent), and safeguards and security support (37 percent) within SC and corporate project management efforts in the Department (7 percent). The $3,106,000 increase supports maintaining the current IT infrastructure in Headquarters (+$1,000,000), providing adequate safeguards and security resources at the Oak Ridge Operations Office (+$1,206,000), and SC's contribution to the development of metrics and processes that will improve project management within DOE (+$900,000).

- Continue day-to-day operations within SC, e.g., mailroom operations; travel management; environment, safety and health support; and administering the Small Business Innovation Research program.
- Standardize, integrate, and invest in IT that will best support improved mission accomplishment and promote IT efficiencies consistent with the provisions of the Information Technology Management Reform Act of 1996. SC provides a real-time computer Helpdesk, incorporates new technologies and maintains corporate systems that support grants management, other major business functions, and research setting applications. SC was able to accommodate IT enhancements within existing funding without having to seek new budget authority for improving the electronic operating environment until FY 2002. To continue current operations, an increase of $1,000,000 is requested in FY 2002, for a total of $4,334,000 IT support in Headquarters. The increase enables SC to improve Internet tools and make information and corporate systems accessible from any location around the world; enhance cyber security capabilities; continue planned enhancements; and retire legacy systems – all as outlined in SC's 5-Year Information Management Strategic Plan.

Performance will be measured monthly through joint review by the business customer(s), Information Management Board, and the Information Management staff responsible for delivering the clearly defined and prioritized products and services. Specifically,

- At least 50 percent of the information management services available through the desktop will be available through remote access.
- Email capability and network systems will be operational and available 99 percent, 24 hours a day.
- Through customer assessments, attain a 75 percent or more rating on productivity improvements directly related to information management enhancements.

■ Support security functions at the Oak Ridge Operations Office, e.g., classifying/declassifying records, processing personnel clearances, securing and handling classified and unclassified information, and providing protective forces to safeguard assets, property, and human resources. The $1,206,000 increase will enable the Oak Ridge Operations Office to acquire the services necessary to maintain a secured environment within the Federal Building and across the Oak Ridge Reservation.

■ Provide funding for the corporate Facility Information Management System (FIMS). FIMS is a web-based application that manages the inventory of the DOE infrastructure management analysis effort. It is one of the many tools used to support the Department's efforts in re-engineering processes and metrics to ensure that facilities and infrastructure are being managed adequately. In FY 2002, funding will support the maintenance and operation of the web-based application, hardware, software, and programmer services. The increase of $200,000 is SC's contribution to maintaining this system.

■ Provide contract support to develop processes, tools, and metrics to ensure that projects are managed adequately. In FY 2002, emphasis will be placed on reforming processes for project management and the acquisition of large facilities throughout the Department to better adhere to project schedules and budgets. The Office of Engineering and Construction Management, within the Office of Chief Financial Officer, will manage a Departmental Project Management Tracking and Control System to monitor the status of projects in terms of cost, schedule, and technical performance. The $700,000 increase is SC's contribution to this corporate effort.

Other Related Expenses	**6,718**	**6,585**	**11,090**

Provides funds for a variety of tools, goods, and services that support the Federal workforce, including acquisitions made through the Working Capital Fund (WCF), computer and office equipment, publications, training, etc. The $4,505,000 increase will support WCF consumption (+$505,000), and Corporate Research & Development (R&D) Portfolio Management Environment (PME) efforts (+$4,000,000).

■ SC will incur new assessments under the WCF. The $505,000 increase will support the increase in cost for rental space, projected increments in usage, and new services, e.g., DOEnet infrastructure, email/video conference capabilities, and more users taking advantage of remote access capabilities.

	FY 2000	FY 2001	FY 2002

(dollars in thousands)

- In FY 2002, $4,000,000 is requested to support PME. SC will modernize and streamline the Department's R&D management processes by supporting the design, development and testing of the R&D tracking and reporting module and start defining the specifications for the program execution module. The full PME implementation is to occur in stages over a three-year period. DOE funds a vast amount of energy-related research in several areas and currently lacks a central reliable source to extract the research data. The R&D facilities performing the work follow their own research management processes tailored to their expertise and methods of operation. The information collected and stored to support their management process is often in different formats and at different levels of resolution. This makes the overall management of DOE-funded research a difficult challenge. The PME will become the technology infrastructure, providing information integration methodologies, and process enhancement that will enable electronic cradle-to-grave tracking of research projects, information sharing across programs, and snapshots of the department's R&D. In the end, DOE will improve its management of R&D data, provide a corporate view across the complex, align with applicable laws and report information to Congress.

	FY 2000	FY 2001	FY 2002
Total, Program Direction	**57,505**	**61,080**	**73,525**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2001 vs. FY 2002 ($000)
Salaries and Benefits	
■ Supports the increase in cost-of-living, locality pay, within grades, promotions, and awards for 391 FTEs.	+3,834
Support Services	
■ Maintain the current information technology infrastructure in Headquarters, e.g., Internet tools, cyber security; data recovery, password protection, major business and research setting functions, remote access, etc.	+1,000
■ Provides adequate protection within the Federal Building and across the Reservation in Oak Ridge, Tennessee in line with the work scope and services to be rendered through protective forces, processing personnel clearances, and classifying documents.	+1,206
■ Support the Department's Facility Information Management System.	+200
■ Support the Department's efforts in developing processes, tools, and metrics to insure that projects are being managed adequately.	+700

	FY 2001 vs. FY 2002 ($000)
Other Related Expenses	
■ Supports incremental cost and projected usage of goods and services provided by the Working Capital Fund, e.g., office space, supplies, printing/graphics, DOEnet, email/televideo conferencing, remote access, etc.	+505
■ Support Corporate Research & Development (R&D) Portfolio Management Environment (PME)	+4,000
Total Funding Change, Program Direction	+11,445

Support Services

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Technical Support Services					
Test and Evaluation Studies	800	526	1,426	+900	+171.1%
Total, Technical Support Services............	800	526	1,426	+900	+171.1%
Management Support Services					
ADP Support	3,798	4,074	5,074	+1,000	+24.5%
Administrative Support	5,000	5,124	6,330	+1,206	+23.5%
Total, Management Support Services	8,798	9,198	11,404	+2,206	+24.0%
Total, Support Services	9,598	9,724	12,830	+3,106	+31.9%

Other Related Expenses

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Training..	105	115	115	0	0.0%
Working Capital Fund.............................	3,545	3,700	4,205	+505	+13.6%
Information Technology Hardware and Software/Maintenance Acquisitions	1,649	1,220	1,220	0	0.0%
Other	1,419	1,550	5,550	+4,000	+258.1%
Total, Other Related Expenses	6,718	6,585	11,090	+4,505	+68.4%

Science Education

Mission Supporting Goals and Objectives

For over 50 years, the Department of Energy and its predecessor agencies have supported science and engineering education programs involving university faculty as well as pre-college teachers and students. In the past, the Department has provided support for university students, pre-college teachers, and college faculty through hands-on research experiences at the Department's National Laboratories and research facilities.

The involvement of DOE's National Laboratories in faculty/student research is perhaps the most distinguishing feature of the agency's participation over the years in math, science, and engineering education. No other Federal agency has an extensive network of research laboratories and facilities as DOE does with its unique physical and human resources. These laboratories and facilities have been the key to the Department's contribution over time to the Nation's math, science, and engineering education goals.

As we enter the new century, the Nation continues to face important challenges related to recruiting and retaining students who have historically been underrepresented (e.g., women, disabled persons, African Americans, Hispanic Americans, and Native Americans) in science and engineering fields. Guided by recent reports such as the National Research Council on Undergraduate Education Achievement Trends in Science and Engineering, the Office of Science will continue to design an undergraduate research fellowship program that couples academic study with extensive hands-on research experiences in a variety of DOE national laboratory settings. This program is intended to enhance the likelihood that underrepresented students will successfully complete their undergraduate studies and progress to graduate school. Historically, over two-thirds of undergraduates who have participated in DOE programs such as this have gone on to graduate school in disciplines directly relevant to the DOE science and technology missions.

Funding Schedule

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Energy Research Undergraduate Laboratory Fellowships	3,002	2,500	2,910	+410	+16.4%
National Science BowlÒ Program	550	550	550	0	0.0%
Albert Einstein Distinguished Educator Fellowship Program	204	810	500	-310	-38.3%
Community College Institute of Biotechnology, Environmental Science, and Computing	716	600	1,500	+900	+150.0%
Total, Science Education	4,472	4,460	5,460	+1,000	+22.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Energy Research Undergraduate Laboratory Fellowships	**3,002**	**2,500**	**2,910**

The Energy Research Undergraduate Laboratory Fellowship Program (ERULF) is the oldest of the Science Education programs. The ERULF program supports a diverse group of students at our National Laboratories in individually mentored research experiences. Through these unique and highly focused experiences these students will comprise a repository of talent to help the DOE meet its science mission goals. The paradigms of the program are: 1) students apply on a competitive basis and are matched with mentors working in the students' fields of interest; 2) students spend an intensive 10-16 weeks working under the individual mentorship of resident scientists; 3) students must each produce an abstract and formal research report; 4) students attend seminars that broaden their view of career options and help them understand how to become members of the scientific community; 5) program goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was recently created which publishes selected full research papers and all abstracts of students in the program. The National Science Foundation (NSF) has begun a collaboration with this program as of FY 2001.

The program will ensure a steady flow of students with technical expertise into the Nation's pipeline of workers in both academia and industry. A system is being created to track students in their academic career paths.

A sub-component of the ERULF Program is the Pre-Service Teacher Pilot Program, performed in partnership with the National Science Foundation (NSF). This program brings undergraduate students, who are preparing to become K-12 math, science or technology teachers to the National Laboratories to learn about the world of scientific research through hands-on experiences. Students' performance is measured in the same ways as ERULF students, with the additional component of developing an educational module, under the guidance of a master teacher, which connects their research experiences to the classroom setting.

National Science Bowl Ò Program	**550**	**550**	**550**

SC will manage and support the National Science BowlÒ for high school students from across the country for DOE. Since its inception, more than 60,000 high school students have participated in this event. The National Science BowlÒ is a highly publicized academic competition among teams of high school students who answer questions on scientific topics in astronomy, biology, chemistry, mathematics, physics, earth, computer, and general science. In 1991, DOE developed the National Science BowlÒ to encourage high school students from across the Nation to excel in math and science and to pursue careers in those fields. The National Science BowlÒ provides the students and teachers a forum to receive national recognition for their talent and hard work. Saturday seminars in the latest scientific topics have been added to the National Science BowlÒ weekend. Students participating in the National Science Bowl Ò will be tracked to see the long term impact on their academic and career choices.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Albert Einstein Distinguished Educator Fellowship Program	**204**	**810**	**500**

The Albert Einstein Fellowship Awards for outstanding K-12 science, math, and technology teachers continues to be a strong pillar of the program for bringing real classroom and education expertise to our education programs and outreach activities. This Congressional initiative, established by the Albert Einstein Distinguished Educator Fellowship Act of 1994, has enabled the Department to maintain an enriching relationship with the Triangle Coalition for Science and Technology Education. The Triangle Coalition administers the program for the Department of Energy through the recruitment, application, selection and placement of the Einstein Fellows and evaluation of the program.

DOE Community College Institute of Biotechnology, Environmental Science, and Computing	**716**	**600**	**1,500**

The DOE Community College Institute (CCI) of Biotechnology, Environmental Science, and Computing was originally a collaborative effort between DOE and its National Laboratories with the American Association of Community Colleges and specified member institutions. Through a recent Memorandum of Understanding with the NSF, students in NSF programs are participating in this program. This program is designed to address shortages, particularly at the technician and paraprofessional levels, in the rapidly expanding areas of biotechnology, environmental science, and computing, that will help develop the human resources needed to continue building the Nation's capacity in these critical areas for the next century. The Institute provides a ten-week research fellowship for highly qualified community college students at a DOE National Laboratory. The paradigms of the program are: 1) students apply on a competitive basis and are matched with mentors working in the students' field of interest; 2) students spend an intensive 10 weeks working under the individual mentorship of resident scientists; 3) students must each produce an abstract and formal research report; 4) students attend professional enrichment activities, workshops and seminars that broaden their view of career options, help them understand how to become members of the scientific community, and enhance their communication and other professional skills; and 5) program goals and outcomes are measured based on students' research papers, students' abstracts, surveys and outside evaluation. An undergraduate student journal was recently created which publishes selected full research papers and all abstracts of students in the program. The National Science Foundation has begun a collaboration with this program as of FY 2001. This will allow NSF's undergraduate programs to include a DOE community college internship in their opportunities provided to students.

Total, Science Education	**4,472**	**4,460**	**5,460**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
■ Under the ERULF, additional students and faculty, including undergraduate students who are preparing to teach math, science or technology, can be supported. The participants will perform research at a DOE National Laboratory or with an industry/business partner. The DOE, through a new Memorandum of Understanding, is partnering with the NSF to provide human resource development through opportunities in DOE National Laboratories.	+410
■ This decrease brings the funding for Einstein Fellowships to the level required to support the on-going level of effort. One-time needs in FY 2001 resulted in an increase in funding not needed in FY 2002 for Einstein Fellowships.	-310
■ Expands the Community College Institute program to more students, including faculty student teams. The DOE is partnering with the NSF in a new Memorandum of Understanding, to provide human resource development through opportunities in DOE National Laboratories for students and faculty participating in NSF programs. These programs will help increase the diversity in the science, math, engineering, and technology fields and serve as a model to other Federal agencies wishing to expand the scientific/technical workforce of the Nation.	+900
Total Funding Changes, Science Education..	+1,000

Field Operations

Mission Supporting Goals and Objectives

The Field Operations subprogram pays the salaries and benefits of the Federal personnel located at the Chicago and Oak Ridge Operations Offices. Consistent with the field restructuring effective October 1, 2000, as part of implementing NNSA, the Oakland Operations Office that was funded in this subprogram in FY 2001, is funded by NNSA in FY 2002. The Chicago and Oak Ridge staff are responsible for managing the daily business, administrative and technical services that support Science and other DOE program-specific work performed within the field and laboratory structure. The following administrative and technical services are provided by this core matrix staff: financial stewardship, personnel management, contract and procurement acquisition, labor relations, legal counsel, public and congressional liaison, intellectual property and patent management, environmental compliance, safety and health management, infrastructure operations maintenance, information systems development and support, and reindustrialization.

In addition, this subprogram provides funding for the fixed requirements associated with rent, utilities, and telecommunications. Other requirements such as information systems support, administrative support, mail services, printing and reproduction, travel, certification training, vehicle acquisition and maintenance, equipment, classified/unclassified data handling, records management, health care services, guard services, and facility and ground maintenance are also included. These infrastructure requirements are relatively fixed. The offices are also responsible for supplying office space and materials for the Office of Inspector General located at each site.

Other operational requirements funded include occasional contractor support to perform ecological surveys, cost validations, and environmental assessments; ensure compliance with Defense Nuclear Facilities Safety Board safety initiatives; abide by site preservation laws and regulations; and perform procurement contract closeout activities. Departmental and programmatic initiatives, as well as regional and congressional constituents, influence these requirements.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	20,121	20,917	22,067	+1,150	+5.5%
Travel	350	400	400	0	0.0%
Support Services	1,500	1,589	1,650	+61	+3.8%
Other Related Expenses	2,954	3,456	3,617	+161	+4.7%
Total, Chicago Operations Office	24,925	26,362	27,734	+1,372	+5.2%
Full Time Equivalents	233	236	236	0	0.0%
Oakland Operations Office					
Salaries and Benefits	548	0	0	0	0.0%
Travel	0	0	0	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	0	0	0	0	0.0%
Total, Oakland Operations Office	548	0	0	0	0.0%
Full Time Equivalents	7	0	0	0	0.0%
Oak Ridge Operations Office					
Salaries and Benefits	26,173	27,704	28,777	+1,073	+3.9%
Travel	200	321	321	0	0.0%
Support Services	2,866	3,004	3,125	+121	+4.0%
Other Related Expenses	3,802	3,975	4,443	+468	+11.8%
Total, Oak Ridge Operations Office	33,041	35,004	36,666	+1,662	+4.7%
Full Time Equivalents	315	320	315	-5	-1.6%
Total Field Operations					
Salaries and Benefits	46,842	48,621	50,844	+2,223	+4.6%
Travel	550	721	721	0	0.0%
Support Services	4,366	4,593	4,775	+182	+4.0%
Other Related Expenses	6,756	7,431	8,060	+629	+8.5%
Total, Field Operations	58,514	61,366	64,400	+3,034	+4.9%
Full Time Equivalents	555	556	551	-5	-0.9%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Salaries and Benefits	**46,842**	**48,621**	**50,844**

Supports 551 FTEs at the Chicago and Oak Ridge Operations Offices. Provides the Federal staff that is responsible for management and administrative functions and services in support of the many different programs, projects, laboratories, facilities, contracts, and grants under their purview. The funding increase supports the Federal pay raise (+$2,223,000). The FTE level is 5 less than appropriated in FY 2001. The FTE reduction is directly related to aligning safeguards and security functions with line management organizations (NNSA and Science) at the Oak Ridge Operations Office.

Travel	**550**	**721**	**721**

Enables field staff to participate on task teams, work various issues, conduct compliance reviews, and perform contractor oversight to ensure implementation of DOE orders and regulatory requirements at the facilities under their purview. Also provides for attendance at conferences and training classes, and permanent change of station relocation, etc.

Support Services	**4,366**	**4,593**	**4,775**

Chicago and Oak Ridge use a variety of administrative and technical assistance services that are critical to their success in meeting the local customer needs. These services include information technology (IT) and routine computer maintenance support, operating communications centers, processing/distributing mail, travel management centers, contract close-out activities, copy centers, trash removal, facility and grounds maintenance, filing and retrieving records, etc. Cost of living for these general administrative services represents an increase of $182,000.

Other Related Expenses	**6,756**	**7,431**	**8,060**

Funds day-to-day requirements associated with operating a viable office, including fixed costs associated with occupying office space, utilities, telecommunications and other costs of doing business, e.g., postage, printing and reproduction, copier leases, site-wide health care units, assessments including records storage, etc. Employee training and development and the supplies and furnishings used by the Federal staff are also included. The $629,000 increase supports several items.

- Fund incremental cost for utility bills and renting the Federal Building in Oak Ridge and the space occupied by the Chicago Operations Office (+$209,000).
- Acquire compatible computer hardware and software at both Chicago and Oak Ridge to support cyclical desktop replacement, standardize and synchronize equipment with SC's operating systems, and IT investment and remote access capability solutions (+$45,000).
- Fund goods and services provided through Working Capital Fund (WCF) (+$46,000).
- Reimbursement for records stored at the National Archives Records storage facility (+$329,000).

Total, Field Operations	**58,514**	**61,366**	**64,400**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2001 vs. FY 2002 ($000)
Salaries and Benefits	
■ Supports the increase in cost-of-living, locality pay, within grades, promotions, and awards, etc., for 551 FTEs. The FTE level is 5 less than FY 2001. The FTE reduction is directly related to aligning safeguards and security functions with line management organizations (NNSA and Science) at the Oak Ridge Operations Office.	+2,223
Support Services	
■ Provides cost of living for general administrative and technical support services	+182
Other Related Expenses	
■ The increase reflects the cost of living associated with essential day-to-day operations, i.e., rent and utility bills, telecommunications bills, computer and office equipment, goods and services under Working Capital Fund, and reimbursement for records stored at the National Archives, etc.	+629
Total Funding Change, Field Operations	+3,034

Support Services

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Technical Support Services					
Economic and Environmental Analysis	0	0	0	0	0.0%
Total, Technical Support Services	0	0	0	0	0.0%
Management Support Services					
ADP Support	1,825	1,915	1,988	+73	+3.8%
Administrative Support	2,541	2,678	2,787	+109	+4.1%
Total, Management Support Services	4,366	4,593	4,775	+182	+4.0%
Total, Support Services	4,366	4,593	4,775	+182	+4.0%

Other Related Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
Training	475	695	695	0	0.0%
Printing and Reproduction	225	436	436	0	0.0%
Rent & Utilities & Telecommunication	4,350	4,625	4,834	+209	+4.5%
Information Technology Hardware, Software, and Maintenance	620	525	570	+45	+8.6%
Working Capital Fund	154	154	200	+46	+29.9%
Other	932	996	1,325	+329	+33.0%
Total, Support Services	6,756	7,431	8,060	+629	+8.5%