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.

<u>IFE Program Goals</u>

- 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

<u>Management Objectives</u>

- 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.

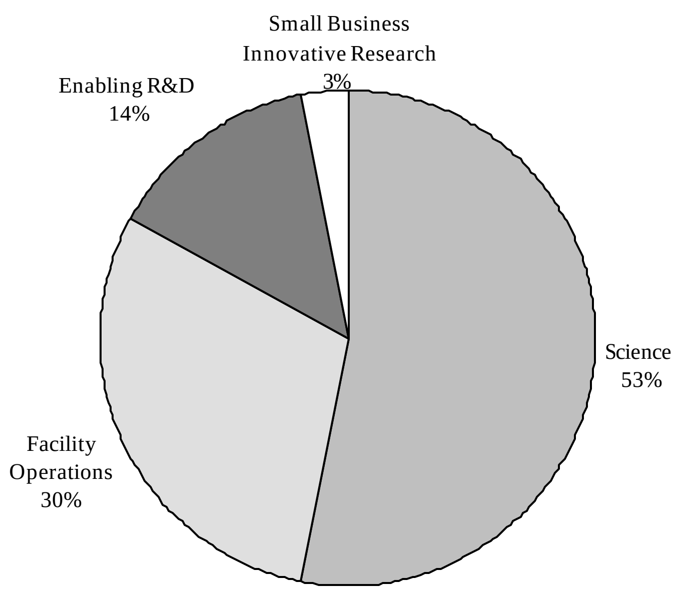
Program Organization

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.

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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

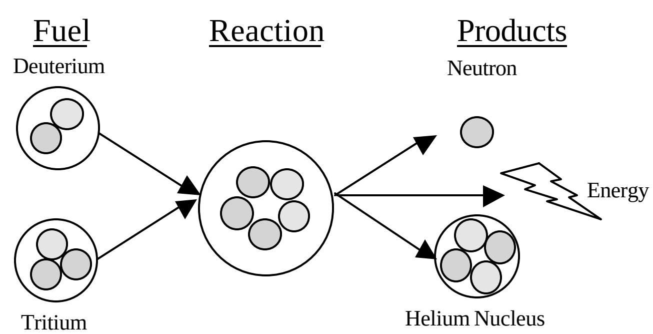
The goals of the Science subprogram are to understand the elementary physical processes that occur in plasmas and to use this knowledge to develop innovative approaches for confining fusion plasmas. These goals are accomplished by conducting:

- 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.

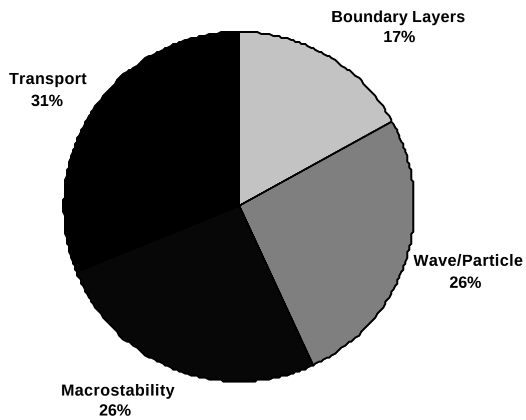
Plasma science is the study of the ionized matter that makes up 99 percent of the observable universe, ranging from neon lights to stars. It includes not only plasma physics but also other physical phenomena in ionized matter, such as atomic, molecular, radiation-transport, excitation and ionization 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.

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.

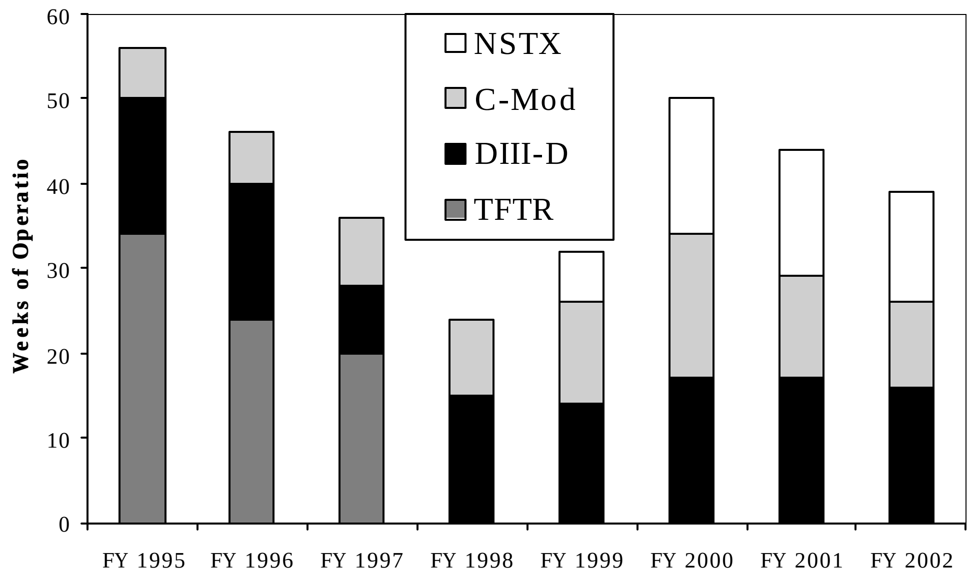
Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence, and relevance; quality; and safety and health.

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.

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).

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.

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.

▪ **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.

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.

Waste Management	**2,984**	**3,150**	**3,024**

These funds support necessary waste management activities at the PPPL site.

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.

▪ **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.

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

	FY 2000	FY 2001	FY 2002
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.

	FY 2000	FY 2001	FY 2002
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.

	FY 2000	FY 2001	FY 2002
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.