Fusion Energy Sciences

Program Mission

The Fusion Energy Sciences (FES) program leads the national research effort to advance plasma science, fusion science, and fusion technology—the knowledge base needed for an economically and environmentally attractive fusion energy source. Fusion offers the potential for abundant, safe, environmentally attractive, affordable energy. The science and the technology of fusion have progressed to the point that the next major research step is the exploration of the physics of a self-sustained plasma reaction in a burning plasma physics experiment. The Office of Science (SC) will fund research that supports such an experiment. In addition, SC will fund the exploration of innovative approaches to confining, heating, and fueling plasmas. In order to develop a predictive capability to design future fusion experiments and energy systems, unique, state-of-the-art experiments and theoretical models benchmarked against those experiments will be funded by SC. The characteristics of the materials used in the construction of fusion power plants will determine the environmental impact that those power plants will have on the environment. SC will support scientific research aimed at developing materials for fusion applications in coordination with its basic materials science program that will ensure that fusion-generated power will have a minimal environmental impact. SC will support and sustain basic plasma science research as the vital scientific core of the fusion program.

Strategic Objectives

SC6: 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; for Magnetic Fusion Energy (MFE), resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic confinement configurations; advance understanding and innovation in high-performance plasmas, optimizing for projected power-plant requirements; develop enabling technologies to advance fusion science, pursue innovative technologies and materials to improve the vision for fusion energy; and apply systems analysis to optimize fusion development; for Inertial Fusion Energy (IFE), leveraging from the Inertial Confinement Fusion (ICF) program sponsored by the National Nuclear Security Agency's (NNSA) Office of Defense Programs, advance the fundamental understanding and predictability of high energy density plasmas for IFE.

SC7: Provided major advanced scientific user facilities where scientific excellence is validated by external review; average operational downtime does not exceed 10% of schedule; construction and upgrades are within 10% of schedule and budget; and facility technology research and development programs meet their goals.

Progress toward accomplishing these Strategic Objectives will be measured by Program Strategic Performance Goals, Indicators and Annual Targets, as follows:

Program Strategic Performance Goals

SC6-1: Develop the basis for a reliable capability to predict the behavior of magnetically confined plasma and use the advances in the Tokamak concept to enable the start of the burning plasma physics phase of the U.S. fusion sciences program. (Science subprogram)

Performance Indicator

The range of parameter space over which theoretical modeling and experiments agree.

Performance Standards

As discussed in Corporate Context/Executive Summary.

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Improved nonlinear magneto-hydrodynamics codes to be capable of computing the effect of realistic resistive walls and plasma rotation on advanced tokamak pressure limits. (met goal)	Use recently upgraded plasma microwave heating system and new sensors on DIII-D to study feedback stabilization of disruptive plasma oscillations.	Complete installation of internal coils for feedback control of plasma instabilities on DIII-D, and conduct a first set of experiments demonstrating the effectiveness of these coils in controlling plasma instabilities, and compare with theoretical predictions.
Evaluated first physics results from the innovative Electric Tokamak at UCLA, to study fast plasma rotation and associated radial electric fields due to radiofrequency-drive, in order to enhance plasma pressure in sustained, stable plasmas. (Exploratory Concept-Electric Tokamak) (met goal)	Successfully demonstrate innovative techniques for initiating and maintaining current in a spherical torus.	Produce high temperature plasmas with 5 Megawatts of Ion Cyclotron Radio Frequency (ICRF) power for pulse lengths of 0.5 seconds in Alcator C-Mod. Study the stability and confinement properties of these plasmas, which would have collisionalities in the same range as that expected for the burning plasma regime.

SC6-2: Develop the cutting edge technologies that enable FES research facilities to achieve their scientific goals and investigate innovations needed to create attractive visions of designs and technologies for fusion energy systems. (Enabling R&D subprogram)

Performance Indicator

Percentage of milestones met for installing components developed by the Enabling R&D program on existing experimental devices.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Completed the DOE-Japan Atomic Energy Research Institute collaboration on fusion plasma chamber exhaust processing in the Tritium Systems Test Assembly (TSTA) facility at LANL. (met goal)	Complete design and fabrication of the High-Power Prototype advanced ion-cyclotron radio frequency antenna that will be used at the Joint European Torus (JET).	Complete testing of the High-Power Prototype advanced ion-cyclotron radio frequency antenna that will be used at the Joint European Torus.
Initiated a new U.S.-Japan collaborative program for research on enabling technologies, materials, and engineering science for an attractive fusion energy source. (met goal)	Complete measurements and analysis of thermal creep of Vanadium Alloy (V-4Cr-4Ti) in vacuum and lithium environments, determine controlling creep mechanisms and access operating temperature limits.	Complete preliminary experimental and modeling investigations of nano-scale thermodynamic, mechanical, and creep-rupture properties of nanocomposited ferritic steels.

SC7-6: Manage all FES facility operations and construction to the highest standards of overall performance, using merit evaluation and independent peer review. (Facility Operations subprogram)

Performance Indicator

Percent on time/on budget, percent unscheduled downtime.

Performance Standards

As discussed in Corporate Context/Executive Summary.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Targets	FY 2003 Targets
Kept deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of approved baselines; achieved planned cost and schedule performance for dismantling, packaging, and offsite shipping of the Tokamak Fusion Test Reactor (TFTR) systems [Met Goal]	Keep deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of approved baselines; successfully complete within cost and in a safe manner all TFTR decontamination and decommissioning activities.	Keep deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of approved baselines; complete the National Compact Stellarator Experiment (NCSX) Conceptual Design and begin the Preliminary Design.
Kept deviations in weeks of operation for each major facility within 10 percent of the approved plan. [Met Goal]	Keep deviations in weeks of operation for each major facility within 10 percent of the approved plan.	Keep deviations in weeks of operation for each major facility within 10 percent of the approved plan.

Significant Accomplishments and Program Shifts

Science

SCIENCE ACCOMPLISHMENTS

Research funded by the Fusion Energy Sciences program in FY 2001 produced major scientific results over a wide range of activities. Examples of these results include:

- Enhanced Understanding of Electric Currents in a Plasma—Experiments on controlling electric currents in the plasma with high-power microwaves on DIII-D have demonstrated the predicted improvement in the efficiency of this process with increased plasma pressure, and achieved the efficiency that is required for future "advanced tokamak" experiments. The same microwave system was also used to eliminate a class of instabilities that otherwise limit the achievable plasma pressure in these "advanced" operating modes.
- Improvements in High Harmonic Fast Wave Heating—This heating technique has emerged as a powerful control tool on National Spherical Torus Experiment (NSTX). This form of wave heating now permits new operating scenarios with overall improvements in plasma heating effectiveness.
- Improvements in Controlling Plasma Heating—Researchers have continued to work on 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 have developed a technique known as "off-axis ion cyclotron radio frequency heating," which can produce a clean transport barrier in the core. Using multiple frequencies, it is now found that the evolution of the transport barrier can be controlled and the potential for steady-state operation has been demonstrated.
- Reduction in Energy Transport—Greatly reduced energy transport has been achieved in the Reversed Field Pinch (RFP), an innovative confinement concept experiment at the University of Wisconsin. Optimization of the current-profile has further improved confinement so that the global energy confinement time is now nine times that of a standard RFP plasma. This confinement significantly exceeds the empirical scaling that has characterized this fusion concept for several decades.
- Enhanced Plasma Control System on DIII-D — As plasma pressure increases, the plasma itself can cause deformations of the magnetic field configuration, which very rapidly destroy the plasma confinement. Theoretical predictions indicated that a perfectly conducting wall surrounding the plasma can improve its stability. It was also believed that when the plasma spins rapidly, an ordinary metallic wall should have the same stabilizing properties of a perfectly conducting wall. Recent experiments at DIII-D by a collaborative team of scientists from General Atomics, Columbia University and Princeton Plasma Physics Laboratory have made use of new plasma control systems to improve stability. The control system detects and opposes deformations of the plasma in much the same way that a superconducting wall would; it also automatically corrects small irregularities in the magnetic field, which would otherwise tend to have a "braking" effect on the rotation of the plasma. With the new control system, the plasma pressure was increased stably up to levels almost twice as high as allowed in absence of such control. These results are potentially important for the development of steady-state advanced tokamaks, and may allow these devices to operate stably well above the conventional pressure limit if plasma rotation can be maintained.

- A Novel Operating Mode on Alcator C-Mod—The Enhanced D-alpha (EDA) operating mode first seen on Alcator C-Mod exhibits many promising features, such as excellent energy confinement, while exhibiting neither accumulation of impurities nor the occurrence of large edge oscillations. New and very accurate measurements have revealed that the density and electric field fluctuations, from a quasi-coherent oscillation, drive particle transport across magnetic field lines. These results together with ongoing theoretical efforts provide insight with regard to the physics of this very promising mode of operation for future machines.
- Development of Turbulence Modeling Computer Codes—Simulation codes containing turbulence computer models, in which plasma is represented by charged particles, including an improved physics model for the behavior of electrons, have been developed. Calculations using the code show that electron dynamics affect plasma stability in the presence of variations in ion temperature along the plasma radius. Previously, the system was modeled by electrons with simplified physics. It was shown that electrons are also responsible for instabilities due to variations in electron temperature. This research permits much more realistic modeling of transport.
- Improvements in Computer Modeling of the Plasma Edge—Recent improvements in computer modeling of edge turbulence have made it possible to simulate the transition from low confinement mode to high confinement mode in a tokamak. The models not only reproduce the main aspects of the transition, but also reproduce the sizes and frequencies of the turbulent regions that are in agreement with the experimental data.
- Advances in Understanding IFE Beam Transport—How a heavy ion driver beam is transported and focused in a target chamber must be known with high confidence because of the impact this information has on both target requirements and the beam that must be produced by the accelerator. Initial efforts directed toward this problem, including beam neutralization, have been carried out by upgrading existing facilities at LBNL and beginning development of a new plasma source conceived at PPPL.
- A New Research Device for Addressing IFE Development—One of the scientific and technical challenges to development of heavy ion drivers for IFE is the production of intense beams. A new 500-kilovolt test-stand was completed at LLNL and will be used for experiments to provide better understanding of the physics that determines how the necessary beam intensities can be generated. These experiments will provide the basis for new ion sources to be used in future high current experiments.
- Operation of a New Plasma Source—A coaxial magnetized plasma gun (spheromak source) with unconventional design has been constructed at Caltech and is now operational. The new gun emphasizes geometric simplicity to provide insight into a novel startup mechanism and spheromak formation. This method allows one to dispense with the large, expensive high voltage insulators used in traditional designs.
- Initial Operation of an Advanced Stellarator—The Helical Symmetric Experiment (HSX), the first advanced stellarator in the world to test quasi-symmetry, is completing its first year of plasma operations at the University of Wisconsin. Well-formed nested magnetic surfaces have been observed, and a method has been developed and applied to experimentally measure the magnitude of the magnetic field.
- Initial Operation of a New Field Reversed Configuration Experiment—The Translation, Confinement, & Sustainment (TCS), Field Reversed Configuration (FRC) experiment became fully operational at the University of Washington. Rotating magnetic fields were applied using the Los Alamos National Laboratory-built power supply. Standard elongated, flux confined FRCs were

generated and sustained in steady state for as long as the power was supplied (up to 2.5 milliseconds). Both analytical and numerical models were developed to explain this unique current drive mechanism, which has many possible applications to fusion confinement.

Facility Operations

FACILITY ACCOMPLISHMENTS

In FY 2001, 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 DIII-D program continued to identify improved methods of operation of fusion facilities. DIII-D was operated with high plasma density, a key issue for future machine designs, and the operating methods were extended to the large JET tokamak in England in a collaborative program. Improved performance was achieved in both facilities. Also, DIII-D accomplished a small-scale test of magnetic field feedback controls, which have enabled improved plasma performance. Also, the new Electron Cyclotron Heating System performed very well.
- Improved plasma operating scenarios with long pulses and high reproducibility were developed at NSTX. These efforts include the development of elongation control algorithms, experimentation with plasma current ramp rates, boronization, and between-shots helium glow discharge cleaning. In addition, NSTX plasma operation has been improved by the full coverage of the plasma facing surfaces with carbon tiles, which reduced a significant source of metallic impurities. Further, the neutral beam system was successfully brought into operation.
- The Alcator C-Mod Lower Hybrid heating system improvement project, a combined MIT/PPPL collaboration, successfully completed the system final design, and procurement of components was initiated. The project is on track for completion in FY 2003.
- The TFTR decontamination and decommissioning (D&D) activities at PPPL proceeded on cost and schedule. There were a number of significant technical accomplishments during the year. In the first quarter, PPPL conducted the largest single lift of the project when they removed the 92-ton umbrella structure over the vacuum vessel. In addition, PPPL has filled the TFTR vacuum vessel with concrete and has initiated cutting the vessel into smaller pieces to be sent to a DOE waste repository for burial.

Enabling R&D

SCIENCE ACCOMPLISHMENTS

A number of technological advances were made in FY 2001 that enabled plasma experiments to achieve their research goals, allowed access to experimental regimes in devices not available domestically, and provided innovations in new technologies that improve the vision of fusion as an attractive energy source. Examples include:

- Scientists at Princeton Plasma Physics Lab, University of California San Diego, and Sandia National Lab conducted experiments in a toroidal plasma to investigate the phenomenon of plasma contact with liquid surfaces and to 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 Oak Ridge National Lab, University of California Los Angeles, University of California Santa Barbara, and Lawrence Livermore National Lab developed models for microstructural evolution in candidate fusion materials 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 fusion materials with significantly improved performance and lifetimes, and with elemental tailoring that minimizes radioactivity generation by neutron-induced transmutation. The ability to produce superior materials for fusion applications is critical to the viability of using fusion energy for practical applications with benign environmental impacts.
- Researchers at ORNL and PPPL began the design of the prototype of a high power radio frequency antenna that will enable increased levels of plasma heating. The prototype, which will be built in FY 2002 and tested in FY 2003, will validate the design, performance, and fabrication techniques of antennas to be built for use in the JET plasma experiment. These antennas, which will provide the world's most powerful radio frequency plasma heating capability, will permit investigation into advanced modes of fusion-relevant plasma performance.
- Work was initiated on the Safety and Tritium Applied Research (STAR) facility at INEEL, the site for all FES-funded tritium research following the shutdown of the Tritium Systems Test Assembly (TSTA) facility at Los Alamos National Lab. Tritium research at STAR will be focused on more fundamental studies than were conducted at TSTA and will use a small fraction of the tritium used at TSTA for fusion fuel cycle demonstration. In FY 2003, experiments will begin on tritium-related issues of candidate coolant materials for fusion energy systems and of plasma interaction with materials.

AWARDS

- An ORNL researcher received the American Nuclear Society's (ANL) Outstanding Lifetime Achievement Award from the ANS Fusion Energy Division.
- A Cal Tech research scientist has been selected to receive this year's Solar Physics division (SPD) Popular Writing Award to a professional scientist for an article "Simulating Solar Prominences in the Laboratory," which appeared in American Scientist. Each year the SPD Popular Writing Awards Committee awards one prize to a scientist for articles published in U.S. or Canadian newspapers, magazines, or semi-popular journals.
- An NSTX team member at PPPL received the "Engineer of the Year" Award from the New Jersey Society of Professional Engineers, in recognition of outstanding achievements in engineering, contributions to the development of fusion as a long-term energy source, and notable service in enhancing the prestige of the engineering profession.
- The 2001 American Physical Society, Division of Plasma Physics Award for Excellence in Plasma Physics was received by four researchers at three institutions - General Atomics, the University of California, Los Angeles, and the Princeton Plasma Physics Laboratory.
- A University of Maryland fusion theorist received the American Physical Society's James Clark Maxwell Prize for Plasma Physics.

- Eight fusion researchers were elected Fellows of the American Physical Society.
- One fusion researcher was elected a Fellow of the American Nuclear Society.

PROGRAM SHIFTS

The budget requested for FY 2003 is $9,830,000 higher than the FY 2002 Appropriation. The FY 2003 budget generally supports the program balance and priorities recommended by the Fusion Energy Sciences Advisory Committee and supported by the Secretary of Energy Advisory Board and the National Research Council (NRC).

Science

The General Plasma Science program is increased to reflect additional collaborative efforts with NSF. For the remainder of this subprogram, scientific efforts will continue at the pace established in FY 2002.

Facility Operations

Funds made available by the expected completion of the TFTR D&D activity, and an increase of $9.8 million to the overall FES budget are used to increase significantly the run times at each of the three major fusion experimental facilities. The remainder of the funds made available by the completion of the TFTR D&D activity is used to maintain base program research efforts at their FY 2002 level, and to initiate the design and fabrication of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment project at PPPL.

Enabling R&D

Materials research is increased to take advantage of advances in microstructural design of materials for fusion. Funding for Advanced Design and Analysis is reduced nearly $1,000,000 with the completion of a two-year study of possible IFE power plant systems. The remainder of the scientific efforts funded under this subprogram will continue at the pace established in FY 2002.

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 2001, 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 Alcator C-Mod tokamak at MIT, or the NSTX at PPPL.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes $111,037,000 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 a nearly $1,000,000,000 capital investment by the U.S. Government, in current year dollars.

The funding requested will provide research time for about 560 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.

Funding Profile

(dollars in thousands)

	FY 2001 Comparable Appropriation	FY 2002 Original Appropriation	FY 2002 Adjustments	FY 2002 Comparable Current Appropriation	FY 2003 Request
Fusion Energy Sciences					
Science	131,347	138,252	-592	137,660	142,565
Facility Operations	77,002	74,420	-269	74,151	78,653
Enabling R&D	33,608	35,823	-154	35,669	36,092
Subtotal, Fusion Energy Sciences	241,957	248,495	-1,015	247,480	257,310
General Reduction	0	-1,015	+1,015	0	0
Total, Fusion Energy Sciences	241,957 [a] [b]	247,480	0	247,480	257,310

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 $5,849,000 which has been transferred to the SBIR program and $351,000 which has been transferred to the STTR program.

[b] Excludes $336,000 transferred to Science Safeguards and Security program in an FY 2001 reprogramming.

Funding By Site

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	7,258	7,378	7,308	-70	-0.9%
Sandia National Laboratories	3,178	2,992	3,213	+221	+7.4%
Total, Albuquerque Operations Office	10,436	10,370	10,521	+151	+1.5%
Chicago Operations Office					
Argonne National Laboratory	2,404	1,661	1,522	-139	-8.4%
Princeton Plasma Physics Laboratory......	70,649	68,794	63,576	-5,218	-7.6%
Chicago Operations Office	44,975	44,569	49,317	+4,748	+10.7%
Total, Chicago Operations Office	118,028	115,024	114,415	-609	-0.5%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	2,210	2,326	2,392	+66	+2.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory ..	5,510	5,861	5,799	-62	-1.1%
Lawrence Livermore National Laboratory	14,586	14,255	14,411	+156	+1.1%
Oakland Operations Office	71,254	69,004	73,779	+4,775	+6.9%
Total, Oakland Operations Office	91,350	89,120	93,989	+4,869	+5.5%
Oak Ridge Operations Office					
Oak Ridge Inst. for Science & Education .	940	419	808	+389	+92.8%
Oak Ridge National Laboratory	17,024	17,884	19,258	+1,374	+7.7%
Oak Ridge Operations Office....................	39	0	0	0	--
Total, Oak Ridge Operations Office	18,003	18,303	20,066	+1,763	+9.6%
Richland Operations Office					
Pacific Northwest National Laboratory	1,427	1,328	1,556	+228	+17.2%
Richland Operations Office.......................	32	0	0	0	--
Total, Richland Operations Office	1,459	1,328	1,556	+228	+17.2%
Savannah River Operations Office					
Savannah River Laboratory......................	0	50	49	-1	-2.0%
Washington Headquarters	471	10,959	14,322	+3,363	+30.7%
Total, Fusion Energy Sciences..................... ..	241,957 [a] [b]	247,480	257,310	+9,830	+4.0%

[a] Excludes $5,849,000 which has been transferred to the SBIR program and $351,000 which has been transferred to the STTR program.

[b] Excludes $336,000 transferred to Science Safeguards and Security program in an FY 2001 reprogramming.

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 coatings for candidate structural alloy materials are conducted in a liquid lithium flow loop. Argonne's capabilities in the engineering design of fusion energy systems have contributed to the design of components, as well as to analysis supporting the studies of fusion power plant concepts.

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. LBNL, LLNL, and PPPL work together in advancing the physics of heavy ion drivers through the Heavy Ion Fusion Virtual National Laboratory.

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, operation of an innovative concept experiment, the Sustained Spheromak Physics Experiment (SSPX) at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D. LLNL, LBNL, and PPPL work together in advancing the physics of heavy ion drivers through the Heavy Ion Fusion Virtual National Laboratory.

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 the remainder of the recoverable tritium in FY 2003 from and completion of the stabilization of 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), 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 and administrative aspects of some FES program peer reviews. 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 is also a leader in stellarator theory and design, and is a major partner with PPPL in conceptual design of the NCSX. 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 fusion materials activities.

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 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 NCSX, a compact stellarator. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks in the U.S. and the large JET (Europe) and JT-60U (Japan) tokamaks abroad. This research is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. PPPL, through its association with Princeton University, provides high quality education in fusion-related sciences, having produced more than 175 Ph.D. graduates since it's founding in 1951. PPPL, LBNL, and LLNL work together in advancing the physics of heavy ion drivers through the Heavy Ion Fusion Virtual National Laboratory.

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

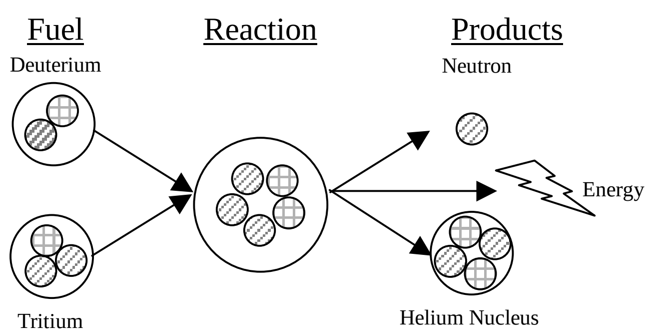
Mission Supporting Goals and Objectives

The Science subprogram develops the basis for a reliable capability to predict the behavior of plasma in a broad range of plasma confinement configurations and use advances in the Tokamak concept to enable the start of the burning plasma physics phase of the U.S. fusion sciences program. Over the next five years FES-funded research will advance the understanding of plasma, the fourth state of matter and enhance predictive capabilities, through comparison of experiments, theory and simulation. This integrated research will focus on well-defined plasma scientific issues including turbulence and transport, macroscopic stability, wave particle interactions and multiphase interfaces. Progress will be made on methods for sustaining and controlling high temperature, high density plasmas, based on improved understanding of fundamental issues. Advanced computational techniques will be integrated into research to provide significantly improved predictive capability for plasma behavior.

An additional objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma science. Two activities, an NSF/DOE partnership in plasma physics and engineering and development grants for junior members of university plasma physics faculties, have been the major contributors to this objective.

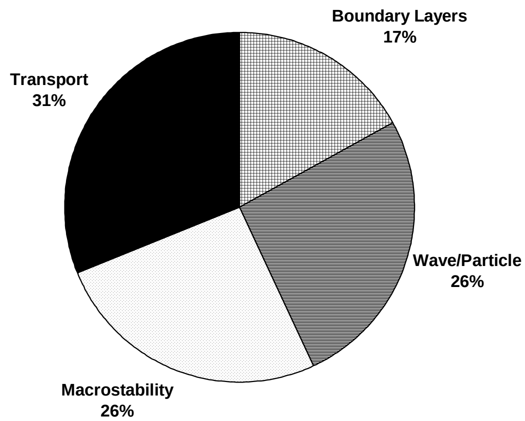
Plasma science is the study of the ionized matter that makes up 99 percent of the visible universe, ranging from neon lights to stars. It includes not only plasma physics but also other physical phenomena in ionized matter, such as atomic, molecular, radiation-transport, excitation and ionization processes. 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 Magnetic Fusion Energy (MFE), these scientific issues include: (1) chaos, turbulence, and transport; (2) stability, magnetic reconnection, and dynamos (3) wave-particle interaction and plasma heating; and (4) sheaths and boundary layers. 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 major science issues are: (1) high energy density physics that describes intense laser-plasma and beam-plasma interactions, and (2) non-neutral plasmas, as is seen in the formation, transport, and focusing of intense heavy ion beams.

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. There is also a very active program of collaboration with comparable experience abroad aimed at establishing an international database of Tokamak experimental results.

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, affect particle transport in the plasma and the stability of the plasma. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layer physics using a “magnetic divertor” to control 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 in a small volume. 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, plasma heating, stability, and confinement.

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 results have already been achieved 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 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 also continue, on more than a dozen small-scale, alternative concept devices and basic science experiments, focusing on the 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 to several fields of science including space and astrophysics, and turbulent transport, which is of interest to 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 the 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 transport properties similar to a tokamak but should have different stability properties. A national team is working 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. Conceptual designs also use an even more radical approach in the Quasi-Poloridal Stellarator (QPS), which has a different symmetry to achieve an even more compact configuration. Both approaches will 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 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 of 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 meet the challenge of describing complex non-linear plasma systems at the most fundamental level. These descriptions range from analytic theory to highly sophisticated computer simulation codes, both of which are used to analyze data from current experiments, guide future experiments, design future experimental devices, and assess projections of their performance. Analytic theory and computer codes represent a growing knowledge base that, in the end, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and 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 (SciDAC) program. Major scientific challenges exist in many areas of plasma and fusion science that can best be addressed through advances in scientific supercomputing. Projects currently underway are focused on understanding and controlling plasma turbulence, investigating the physics of magnetic reconnection, understanding and controlling magnetohydrodynamic instabilities in magnetically confined plasmas, simulating the propagation and absorption of radio waves in magnetically confined plasmas, and understanding atomic physics in the edge region of 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 addition to their work on domestic experiments, scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad, and conduct comparative studies to enhance understanding of underlying physics. The Fusion Energy Sciences program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. 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 between fusion theory and experiments. Non-perturbing measurements of the dynamic temperatures, densities, and electromagnetic fields in the core of near-burning plasmas 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.

Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
Tokamak Experimental Research	44,960	44,602	48,609	+4,007	+9.0%
Alternative Concept Experimental Research	50,620	50,736	50,913	+177	+0.3%
Theory	27,290	27,146	27,608	+462	+1.7%
General Plasma Science	8,477	8,786	9,060	+274	+3.1%
SBIR/STTR	0	6,390	6,375	-15	-0.2%
Total, Science	131,347	137,660	142,565	+4,905	+3.6%

Detailed Program Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Tokamak Experimental Research	**44,960**	**44,602**	**48,609**
▪ **DIII-D Research**	**22,775**	**21,880**	**22,733**

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 Magnetic Fusion Energy (MFE) fusion topical science areas — energy transport, stability, plasma-wave interactions, and boundary physics, and five thrust areas that integrate across topical areas to achieve fusion goals. In FY 2003, funding for physics research and data analysis will be increased. Research in all topical science and thrust 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 continue. 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; this heating power will be used to further verify the predicted current drive physics. A new DIII-D operating mode exhibits two radial regions of improved heat insulation (transport barriers). The resulting plasmas have very high performance and possible steady state potential. Research efforts will be focused on finding a way to alleviate limitations imposed by the requirement of neutral beam injection in a direction to reduce the plasma current (for shaping the current profile) while maximizing the amount of current generated by the plasma itself. In FY 2003, the experimental operating time is being increased allowing an expanded experimental program on the topical science areas and on investigation of the physics of promising new approaches to Advanced Tokamaks.

▪ **Alcator C-Mod Research**	**7,391**	**7,745**	**8,464**

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 and density burning plasma physics tokamaks. The approach to ignition and sustained burn of a plasma is an important integrating science topic for fusion. In FY 2003, the funding for physics research and data analysis will be significantly increased from 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 are achieved in the plasma when currents are driven by radio waves. It will also continue to 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. Increased operation of the machine will also allow further exploration of the compact high field tokamak regimes and operation scenarios required for achievement of ignition in compact devices. A new lower hybrid current drive system will be in the process of being commissioned. In FY 2003, radio frequency heating power will be increased and better discharge density control will be implemented, creating plasma conditions characterized by low collisionality, close to that required for a future power plant.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **International Collaborations and Education**....................	**7,550**	**8,005**	**10,255**

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. The United States will participate in the International Tokamak Physics Activity (ITPA) with Japan, Europe, and Russia to enhance collaboration on physics issues related to tokamak burning plasmas. In FY 2003, 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 Science issues cited in the Science Subprogram description. Funding for educational activities in FY 2003 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 outreach efforts related to fusion science and technology.

▪ **Experimental Plasma Research (Tokamaks)**....................	**7,244**	**6,972**	**7,157**

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 2003, 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 confined plasmas, including techniques aimed at understanding how barriers to heat loss can be formed in plasmas; (2) methods to measure the production, movement, and loss/retention of the particles that are needed to ignite and sustain a burning plasma; and (3) new approaches that are required to measure plasma parameters in alternate magnetic configurations, which add unique constraints due to magnetic field configuration and strength, and limited lines of sight into the plasma. The requested funding level in FY 2003 supports the highest-rated renewal proposals, 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 in FY 2002.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Alternative Concept Experimental Research	**50,620**	**50,736**	**50,913**
▪ **NSTX Research**	**12,446**	**12,625**	**13,696**

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.

In FY 2003, the funding for physics research and data analysis will be increased. 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 refined. The investigation of the spherical torus plasma properties appropriate for enabling plasma pulse durations up to 1 second using non-inductive current drive is a crucial mission element of the NSTX program. The experience and understanding in current startup and maintenance using Coaxial Helicity Injection, radio-frequency wave, pressure gradient (bootstrap current), and magnetic induction will be combined to create the plasma conditions that minimize the dissipation of the solenoid magnet flux while permitting increased plasma pulse durations. In FY 2003 the program will demonstrate the use of a combination of non-inductive techniques to assist in starting up the plasma and sustaining it for up to 1 second and in development of operational scenarios for subsequent requirements of longer duration and higher performance plasmas. Extensive measurements and analysis of the interactions among these current drive techniques will be carried out over a range of plasma parameters and conditions to establish a basis to begin the development of the plasma conditions that enable the extension of the plasma pulse toward 5 seconds during FY 2004-2006.

In preparation for longer-term objectives, the research activities will concentrate on measuring and analyzing the dispersion of edge heat flux and assessing the impact on plasma facing component requirements under high heating power in NSTX; exploring and characterizing spherical torus plasmas having simultaneously good plasma containment and high plasma-to-magnetic pressure ratio for durations much larger than the energy containment times; and measuring and analyzing the effects of energetic ion driven instabilities on the physics mechanisms that limit the high ratios of plasma-to-applied toroidal field pressure and high energy confinement efficiency in spherical torus plasmas. The spherical torus plasma, as in all high beta plasmas, is uniquely characterized by fast ions of supra-Alfven velocities and with large radius of gyration relative to plasma size that could potentially lead to new plasma behaviors of interest. Comparison with theory will contribute to the scientific understanding of these effects needed to consider future experiments with similar energetic ion properties.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Experimental Plasma Research (Alternatives)**..................	**24,536**	**24,609**	**23,443**

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 (reversed field pinch), and research in support of a novel compact stellarator design.

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 at the University of Wisconsin is the world's first stellarator designed to use a simplified combination of such magnetic fields. Stellarator research at Auburn, ORNL, and PPPL also supports the new proof-of-principle experiment, NCSX, being proposed as part of the facility operation subprogram.

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 an FRC plasma can be compressed to multi-keV temperatures using fast liner compression technology developed by the DOE Defense Programs.

In FY 2003, research efforts on most of these exploratory activities will continue. Research on new concepts will be initiated and old ones discontinued as appropriate through peer review.

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
▪ **Inertial Fusion Energy Experiments**	**13,638**	**13,502**	**13,774**

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 (multiple charged Bismuth, 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. 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 (HCX) at LBNL will be the primary experimental facility for heavy ion beam transport studies. The 500 kV test stand at LLNL 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.

Theory	**27,290**	**27,146**	**27,608**

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 a predictive understanding of advanced tokamak operating modes. These tools are also being extended to innovative or alternate confinement geometries. In alternate concept theory, the emphasis is on understanding the fundamental processes determining equilibrium, stability, and confinement in each concept. 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 2003 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 SciDAC program, is to promote the use of modern computer languages and advanced computing techniques to bring about a qualitative improvement in the development of models of plasma behavior. This will ensure that advanced modeling tools are available to support a set of innovative national experiments and fruitful collaboration on major international facilities. In FY 2003, efforts will be focused on comparison of

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

experimental results with improved turbulence calculations, the inclusion of the plasma's self-generated currents in gross stability simulations, simulation of the propagation and absorption of short wavelength waves in magnetized plasmas, and improved simulations of magnetic reconnection. These additions will improve the fidelity of the simulations and provide an enhanced predictive understanding of fusion plasmas.

General Plasma Science	**8,477**	**8,786**	**9,060**

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 2003, the program will continue to fund proposals that have been peer reviewed. A major joint announcement of opportunity in basic plasma physics will be held in 2003 under the NSF/DOE Partnership. 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. The Office of Fusion Energy Sciences will share the cost of funding plasma physics frontier science centers funded by NSF.

SBIR/STTR	**0**	**6,390**	**6,375**

In FY 2001 $4,994,000 and $300,000 were transferred to the SBIR and STTR programs, respectively. The FY 2002 and FY 2003 amounts are the estimated requirements for the continuation of these programs. Beginning in FY 2002, all FES program SBIR/STTR requirements will be funded in the Science subprogram.

Total, Science	**131,347**	**137,660**	**142,565**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Tokamak Experimental Research	
▪ Funding for DIII-D research is increased about 3.9% to provide additional funding for plasma research and data analysis in support of increased facility operations	+853
▪ Funding for Alcator C-Mod research is increased about 9.3% to provide for additional data analysis and research in support of increased facility operations	+719
▪ Funding is increased to allow for funding a number of modest scale research activities pending the outcome of reviews. This also provides partial funding for the transfer of ORNL personnel and equipment to a new experimental site on the ORNL campus	+2,250
▪ The level of funding for Tokamak Experimental Plasma Research is modestly increased to allow scientific efforts at close to the pace established in FY 2002	+185
Total, Tokamak Experimental Research	+4,007
Alternative Concept Experimental Research	
▪ Funding for NSTX research is increased about 8.5% to provide for additional diagnostics development, data analysis, and research in support of increased operations	+1,071
▪ Funding for compact stellarator research at PPPL and ORNL in this subprogram is reduced (-$2,501,000) as funding to start fabrication of the NCSX project is provided under the Facility Operations subprogram. Funding for other Alternate Concepts research is increased (+$1,335,000) to allow scientific efforts to follow up on FY 2002 results	-1,166
▪ Funding for IFE science is slightly increased to allow research to proceed close to the pace established in FY 2002	+272
Total, Alternative Concept Experimental Research	+177
Theory	
▪ Funding for theory and modeling to support experiments is increased to allow scientific efforts to proceed at close to the pace established in FY 2002.	+462
Total, Theory	+462

	FY 2003 vs. FY 2002 ($000)
General Plasma Science	
▪ The funds available for the NSF/DOE partnership are increased to provide funding opportunities within the NSF/DOE partnership, the plasma physics Junior Faculty Development possible program, and support with NSF of plasma science centers..........	+274
Total, General Plasma Science	+274
SBIR/STTR	
▪ Support for SBIR/STTR is provided at the mandated level...	-15
Total Funding Change, Science...	+4,905

Facility Operations

Mission Supporting Goals and Objectives

The Facility Operations subprogram manages all FES facility operations and construction to the highest standards of overall performance, using merit evaluation and independent peer review. The fusion research facilities will be operated in a safe and environmentally sound manner, with high efficiency relative to the planned number of weeks of operation, with maximum quantity and quality of data collection relative to the installed diagnostic capability, and in a manner responsive to the needs of the scientific users. In addition, construction, fabrication and upgrades of major fusion facilities will be accomplished in accordance with highest standards and with minimum deviation from approved cost and schedule baselines.

This activity provides mainly for the operation, maintenance and enhancement of major fusion research facilities; namely, DIII-D at General Atomics, Alcator C-Mod at MIT, and NSTX at PPPL. These user facilities enable U.S. scientists from universities, laboratories, and industry, as well as visiting foreign scientists, to conduct 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. The Facility Operations subprogram funds: operating and maintenance personnel, electric power, expendable supplies, replacement parts, system modifications and facility enhancements as well as capital equipment funding for upgrading and enhancing the research capability of DIII-D and C-Mod. In FY2003, a significant increase in the operating time for the major fusion research facilities, to a level of 21 weeks for each facility, is proposed. This will provide an excellent scientific return on the capital investment in these facilities and will enable a much broader investigation of key fusion science issues than heretofore possible. Examples of this scientific return are described in the Science Subprogram section.

With the anticipated completion of TFTR D&D in FY 2002, funding from that activity is proposed to be used in FY 2003 to provide additional support for existing experiments, to increase the operating time of the major facilities and to initiate a Major Item of Equipment project. This project, known as the National Compact Stellarator Experiment (NCSX), would be located at PPPL and consists of the design and fabrication of a compact stellarator proof-of-principle class experiment. The Fusion Energy Sciences Advisory Committee has supported the physics basis for NCSX. This fusion confinement concept has the potential to be operated without plasma disruptions, leading to power plant designs that are simpler and more reliable than those based on the current lead concept, the tokamak. The initial total estimated cost (TEC) of NCSX is $69,000,000, with completion scheduled for mid-FY 2007. However, since the conceptual design has not been completed, the cost and schedule estimates are preliminary.

Funding is also included in this subprogram for General Plant Projects (GPP) and General Purpose Equipment (GPE) at PPPL. GPP and GPE funding supports essential facility renovations and other necessary capital alterations and additions to buildings and utility systems.

In summary, the principal objective of the Facility Operations subprogram is to operate the major fusion research 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 facilities while building a culture of operational excellence and complying with all applicable safety and environmental requirements. Funding included for these facilities provides a significant increase in operating time relative to FY 2002.

The table below summarizes the scheduled weeks of operations for DIII-D, C-Mod, and NSTX.

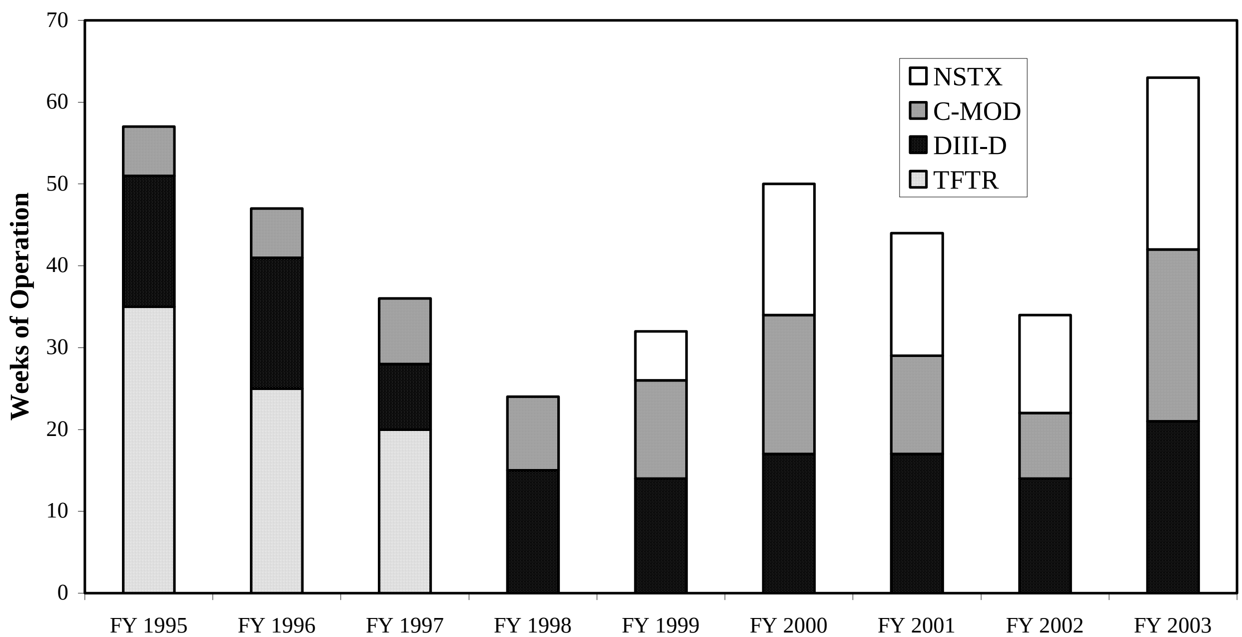
Accomplishments will be reported on specific performance measures involving leadership, excellence, and relevance; quality; and safety and health. The specific measures are for the deviation in weeks of operation of the major facilities to be within 10% of the scheduled weeks and for deviations in cost and schedule for construction, fabrication and upgrade projects to be within 10% of approved baselines. Data on worker injuries will be obtained and reviewed.

Weeks of Fusion Facility Operation

(Weeks of Operations)

	FY 2001	FY 2002	FY 2003
DIII-D	17	14	21
Alcator C-Mod	12	8	21
NSTX	15	12	21

Recent operating history of major fusion experimental facilities



Funding Schedule

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
TFTR	19,625	19,604	0	-19,604	--
DIII-D	29,134	29,037	32,909	+3,872	+13.3%
Alcator C-Mod	10,645	9,835	13,789	+3,954	+40.2%
NSTX	15,089	14,186	19,446	+5,260	+37.1%
NCSX	0	0	11,026	+11,026	--
GPP/GPE/Other	2,509	1,489	1,483	-6	-0.4%
Total, Facility Operations	77,002	74,151	78,653	+4,502	+6.1%

Detailed Program Justification

(dollars in thousands)

	FY 2001	FY 2002	FY 2003
TFTR	**19,625**	**19,604**	**0**

The TFTR Decontamination and Decommissioning (D&D) activity is planned for completion in FY 2002.

DIII-D	**29,134**	**29,037**	**32,909**

Provide significantly increased 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 2003, these funds support 21 weeks of plasma operation.

Alcator C-Mod	**10,645**	**9,835**	**13,789**

Provide significantly increased support for operation, maintenance, major inspection of the electrical generator, and minor machine improvements. In FY 2003, these funds support 21 weeks of plasma operation. Fabrication of a plasma heating and current drive system for Alcator C-Mod will be completed in FY 2003. This enhancement, called lower Hybrid Modification, is a Major Item of Equipment with a TEC of $5,190,000 and a FY 2003 request of $1,019,000.

NSTX	**15,089**	**14, 186**	**19,446**

Provide significantly increased support for operation, maintenance, and improvement of the NSTX facility and installation of planned diagnostic upgrades. In FY 2003, these funds support 21 weeks of plasma operation.

NCSX	**0**	**0**	**11,026**

Initiate a Major Item of Equipment project to design and fabricate a compact stellarator proof-of principle class experiment with a TEC of $69,000,000. The TEC is preliminary because it is based on pre-conceptual design activities. The estimate will be improved as conceptual and preliminary design work is completed. Cost growth of up to 20% may occur before an approved baseline is established.

	FY 2001	FY 2002	FY 2003
	(dollars in thousands)		
General Plant Projects/General Purpose Equipment/Other	**2,509**	**1,489**	**1,483**

These funds provide primarily for general infrastructure repairs and upgrades for the PPPL site based upon quantitative analysis of safety requirements, equipment reliability and research needs.

	FY 2001	FY 2002	FY 2003
Total, Facility Operations	**77,002**	**74,151**	**78,653**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
TFTR	
▪ The TFTR Decontamination and Decommissioning (D&D) activity is planned for completion in FY 2002	-19,604
DIII-D	
▪ Experimental operating time is being increased from 14 weeks to 21 weeks to support high priority experiments and thereby relieve a large backlog of desirable research proposals	+3,872
Alcator C-Mod	
▪ Experimental operating time is being increased from 8 weeks to 21 weeks to support high priority experiments that take advantage of C-Mod's unique high field and wave heating systems	+3,954
NSTX	
▪ Experimental operating time is being increased from 12 weeks to 21 weeks to support important experiments that explore the limits of this unique, innovative confinement concept	+5,260
NCSX	
• Funding is provided to initiate the design and fabrication of the NCSX project at PPPL	+11,026
GPP/GPE/Other	
• Funding held essentially constant	-6
Total Funding Change, Facility Operations	+4,502

Enabling R&D

Mission Supporting Goals and Objectives

The Enabling R&D subprogram develops the cutting edge technologies that enable FES research facilities to achieve their goals and investigates innovations needed to create attractive visions of designs and technologies for fusion energy systems.

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.

Funding Schedule

	(dollars in thousands)				
	FY 2001	FY 2002	FY 2003	$ Change	% Change
Engineering Research	26,979	28,528	28,454	-74	-0.3%
Materials Research	6,629	7,141	7,638	+497	+7.0%
Total, Enabling R&D	33,608	35,669	36,092	+423	+1.2%

Detailed Justification

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003
Engineering Research	**26,979**	**28,528**	**28,454**
▪ **Plasma Technology**	**12,040**	**11,777**	**12,092**

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. By early FY 2003, it is planned to complete testing of a prototype radio frequency antenna for the JET, the world's only plasma experiment using the complete set of fusion fuels, which will enable JET to build a powerful plasma heating device workable under rapidly changing plasma parameters. A design 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 or C-Mod will be completed. By the end of FY 2003, it is planned to complete the basic research that will determine the feasibility of deploying new plasma-facing component technology, which is based on flowing liquid surfaces, that could revolutionize the approach to plasma particle density and edge temperature control in plasma experiments. 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**	**9,691**	**10,318**	**10,906**

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 2003, the required tritium inventory reduction and stabilization at TSTA will be completed and transferred to EM. By early FY 2003, it is planned to begin experiments in the newly constructed Safety and Tritium Applied Research (STAR) Facility at INEEL under a cost-sharing collaboration with Japan to resolve key issues of tritium control and chemistry for coolants proposed to be used in fusion energy systems. Technical assessment will be continued for 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

	(dollars in thousands)		
	FY 2001	FY 2002	FY 2003

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.

▪ **Advanced Design**	**5,248**	**6,433**	**5,456**

Funding for this element will focus on design studies of systems for next-step plasma science experiment options. Systems science studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics and the prospects of possible inertial and advanced magnetic confinement concept fusion energy systems will be conducted in an iterative fashion with the experimental community.

Materials Research..	**6,629**	**7,141**	**7,638**

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 in 1998. Research includes materials and conditions relevant to inertial fusion systems as well as magnetic systems. Investigations will be conducted on the limits of strength and toughness of materials based on dislocation propagation and interactions with crystalline matrix obstacles, and the changes to thermal and electrical conductivity in materials based on electron and photon transport and scattering at the atomic level.

SBIR/STTR..	**0**	**0**	**0**

In FY 2001 $855,000 and $51,000 were transferred to the SBIR and STTR programs, respectively. Beginning in FY 2002, all SBIR/STTR requirements will be funded in the Science subprogram.

Total, Enabling R&D	**33,608**	**35,669**	**36,092**

Explanation of Funding Changes from FY 2002 to FY 2003

	FY 2003 vs. FY 2002 ($000)
Engineering Research	
▪ Funding for plasma technologies is increased to allow scientific efforts to proceed at the pace established in FY 2002.	+315
▪ Funding for TSTA is decreased slightly to $2,953,000 as efforts to clean up the facility prior to turning it over to the Office of Environmental Management for Decontamination and Decommissioning are expected to be coming to completion. Funding for other fusion technologies activities is increased to allow scientific efforts to proceed at the pace established in FY 2002.	+588
▪ Funding is reduced due to the completion of the series of workshops necessary to prepare for the July 2002 community planning activity.	-977
Total, Engineering Research	-74
Materials Research	
▪ Funding for materials research is increased to allow additional peer reviewed scientific efforts to be initiated	+497
Total Funding Change, Enabling R&D	+423

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2001	FY 2002	FY 2003	$ Change	% Change
General Plant Projects	2,094	1,370	995	-375	-27.4%
Capital Equipment	9,123	4,975	15,774	+10,799	+217.1%
Total, Capital Operating Expenses	11,217	6,345	16,769	+10,424	+164.3%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2001	FY 2002	FY 2003 Request at Target	Accept-ance Date
DIII-D Upgrade	27,203	26,360	843	0	0	FY 2001
Alcator C-Mod LH Modification	5,190	1,133	1,833	1,205	1,019	FY 2003
NCSX	69,000[a]	0	0	0	11,026	FY 2007
Total, Major Items of Equipment		27,493	2,676	1,205	12,045	

[a] TEC based on pre-conceptual design activities. The estimates will be improved as conceptual and preliminary design work is completed. Cost growth of up to 20% may occur.