Fusion Energy Sciences

Program Mission

The Fusion Energy Sciences program is a broad-based, fundamental research effort, producing valuable scientific knowledge and technological benefits in the near term with the aim of providing the science base for a fusion energy option in the long term.

This is a time of important progress and discovery in fusion research. By virtue of previous investments in facilities, and more recently, sophisticated diagnostics and modeling capabilities, the Fusion Energy Sciences program is making great progress in understanding the fundamental processes of confining fusion fuels, such as the mechanisms responsible for turbulent losses of particles and energy across the magnetic field lines. In addition, the program is identifying and exploring innovative approaches to fusion power in search of an optimized confinement system with an affordable development path.

The high quality of the research in this program is continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goal

The goal of the Fusion Energy Sciences program is to:

> *"Acquire the knowledge base for an economically and environmentally attractive fusion energy source."*

Although there is not a schedule for developing and deploying fusion energy systems the availability of fusion, as an option for large central station power plants, would be valuable insurance against possible environmental concerns about fossil and nuclear energy. In addition, there may be nearer term non-electric applications of fusion in transmutation of wastes and isotope production.

Program Objectives

Crosscutting and interrelated objectives of the Fusion Energy Sciences program, as developed through stakeholder meetings and endorsed by the Fusion Energy Sciences Advisory Committee, are summarized below.

- *Understand the physics of plasmas, the fourth state of matter*. Plasmas comprise most of the visible universe, both stellar and interstellar, and have many practical applications. Progress in plasma physics has been the prime engine driving progress in fusion research, and conversely, fusion energy has been the dominant motivation for plasma physics research.
- *Identify and explore innovative and cost-effective development paths to fusion energy*. There are several approaches to fusion, from the tokamak, which is the most advanced power plant candidate, to alternative magnetic configurations, or to inertial confinement using particle beams or lasers. The

current fusion program includes research on tokamak improvements and, increasingly, research on other innovative concepts, including drivers for inertial fusion energy.

- *Explore the science and technology of energy producing plasmas, the next frontier in fusion research, as a partner in an international effort*. Understanding the physics of energy-producing (i.e. burning), plasmas and developing the technologies essential for fusion energy are linked goals that can best be achieved through the cooperative efforts of the world community. The long-term benefits to the United States in such a cooperative effort include enhanced progress toward our mission through scientific and technological integration in the much larger world fusion effort as an energy source for a growing world population.

The Fusion Energy Sciences budget is divided into three subprograms; Science, Facility Operations, and Enabling R&D. The Science subprogram includes research funds for plasma science and the development of improved confinement concepts. Funds for building and operating major experimental facilities are in the Facility Operations subprogram. The Enabling R&D subprogram includes funds for establishing the scientific foundation which underlies current advances in fusion technology and provides technological capabilities and innovations needed to advance plasma science and develop the knowledge base for an attractive fusion energy source.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes $96,600,000 to maintain support of the Department's scientific user facilities. This investment will provide significant research time for thousands of scientists in universities, and other Federal laboratories. It will also leverage both Federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. National science investment. The proposed funding will support operations at the Department's three major fusion energy physics facilities: the Doublet III-D at General Atomics, the Alcator C-Mod at the Massachusetts Institute of Technology and the National Spherical Torus Experiment at Princeton Plasma Physics Laboratory.

Performance Measures

The Fusion Energy Sciences program supports the Department's strategic goal of delivering the scientific and technological innovations critical to meeting the Nation's energy challenges. The performance measures of the Fusion Energy Sciences program fall into four areas: (1) excellence of the science, (2) relevance to the DOE mission and national needs, (3) stewardship of research capabilities, and (4) human resource management. The ways in which the Fusion Energy Sciences program measures performance include components such as peer review, specific charges to the Fusion Energy Sciences Advisory Committee (FESAC), and professional recognition of research performers. These have been an integral part of the program for many years. Each major research facility has a Program Advisory Committee (PAC) that provides broadly based community input directly to the facility team. Proposals for new facilities or upgrades to existing facilities at laboratories have both scientific and cost and schedule reviews.

For FY 2000, specific performance measures are:

- The National Spherical Torus Experiment (NSTX) will operate with a National Research Team demonstrating long pulse (greater than 1 second) operation at plasma currents approaching 1 megampere, a factor of 40 increase over the current exploratory level spherical torus experiments.
- Three new innovative concept exploration experiments--the LSX field-reversed configuration, the flow-stabilized Z pinch (both at the University of Washington) and the Pegasus spherical torus at the University of Wisconsin--will be fully operational providing basic scientific understanding of relevant concept phenomena.
- The DIII-D tokamak will test the feasibility of using increased electron cyclotron heating power and improved power exhaust techniques to extend the pulse length of advanced toroidal operating modes, a necessary requirement for future fusion energy sources.
- A decontamination and decommissioning contract at the Princeton Plasma Physics Laboratory (PPPL) will be awarded for the removal of the Tokamak Fusion Test Reactor (TFTR) tokamak and activated components from the experimental test cell.
- The materials research program will be coordinated with design studies through an overall systems approach, and broadened to allow increased modeling and innovative exploratory research on novel materials" as recommended by the FY 1998 FESAC materials review.
- New funding opportunities in basic plasma science and junior plasma physics faculty development programs will be provided through competitive announcements.
- The theory of strong turbulence will be used as a foundation to develop models for using shear in the plasma flow to stabilize the transport of energy and particles in toroidal devices such as tokamaks and stellarators. In addition, a new energy transport code framework, based on modern computing techniques, will be completed and made available for use via the web.

Significant Accomplishments and Program Shifts

Science

- To accommodate continuing governmental financial constraints, the fusion sciences program continues to move toward more innovation and increased understanding of a wider range of confinement concepts, and away from the more costly, large scale devices aimed at providing integrated plasma and technology experiments operating with power plant-scale plasma parameters.
  - Support of the goal to understand the physics of plasmas continues at the increased level of funding for general plasma science to improve the basis for fusion science and research on high-temperature toroidal plasmas in the DIII-D, C-MOD, and NSTX experiments.
  - Support of the goal to explore innovative and more affordable development paths includes increased operation of the new NSTX science facility. Work on concept improvement at the exploratory level in both physics and enabling R&D will continue to receive strong emphasis.
- A major review of magnetic and inertial fusion energy options by the Secretary of Energy Advisory Board has begun in FY 1999 in response to congressional requests.

- The National Academy Review of the Quality of Science in the Fusion Energy Sciences Program will be carried out in FY 1999 as part of a follow-up to the 1996 restructuring of the fusion program.
- A review of leading candidates for the next proof-of-principle steps within the innovative confinement concepts program was carried out, and program recommendations will be made by FESAC in FY 1999.
- In FY 1999 scientists at the University of Wisconsin will begin testing new stellarator symmetry principles which promise to improve understanding of how to optimize this toroidal fusion concept. At the Lawrence Livermore National Laboratory the first experiments on high temperature sustainment of spheromak plasmas will begin. Both of these elements represent initial results from the FY 1996 restructuring of the fusion program to work more on innovative confinement concepts.
- Within the NSF/DOE Partnership in Basic Plasma Science and Engineering begun in FY 1997, an additional set of applications were reviewed in FY 1998, and 13 were selected for funding including two NSF Career awards. Of the successful applicants, 7 were funded directly by OFES and funding was shared for one of the NSF Career awards. The fusion-sponsored development program for junior faculty in plasma physics in FY 1998 resulted in 2 additional awards. Both programs will continue in FY 1999 and planning with other agencies, including NSF, will be carried out for FY 2000 initiatives.
- A peer-reviewed competition for new ideas in measurement techniques for toroidal and burning plasma devices was carried out in early FY 1999 and awards were announced in February 1999.
- The Electron-Impact Ionization Theory, which was developed at the National Institute of Standards and Technology for fusion applications, is beginning to find application in modeling for air pollution control devices and ionization and radiation monitors. Its application to modeling for plasma processing of semiconducting devices by INTEL and other companies, which was reported last year, continues to grow.
- Current drive using new microwave hardware was shown for high magnetic field operation of the Alcator C-Mod facility. These results, along with demonstrated microwave heating at high magnetic field, indicate that advanced toroidal operating modes can be produced and studied in Alcator C-Mod.

Facility Operations

- The National Spherical Torus Experimental (NSTX) project at the Princeton Plasma Physics Laboratory (PPPL) will be completed in FY 1999 and a national research team will be organized. The facility will begin experimental operations by the 3rd quarter of FY 1999 and the NSTX Program Advisory Committee (PAC) will provide guidance to PPPL for initial operations.
- Significant modifications to the divertor and heating systems of the DIII-D facility were completed, providing capabilities required for FY 2000 experiments that will extend the pulse duration of advanced toroidal operating modes. Important experimental results were obtained that show plasma stability control with feedback coils and demonstration of radio frequency current drive that is necessary for long pulse operations.

Enabling R&D

- Support of the goal to explore the science and technology of energy producing plasmas is dramatically reduced by termination in FY 1999 of U.S. participation in the international pursuit of leading edge science in an integrated, large-scale experimental facility (ITER).
- In early FY 1999, the U.S. will close out its participation in ITER design activities.
- In FY 1999, we will work with other ITER Parties to attempt to complete the testing of the ITER superconducting model coil in Japan. This testing program will confirm the design and establish operating margins and will allow us to benefit from the $45,000,000 we have invested in building a major portion of the coil.
- The fusion program will continue its bilateral and multilateral activities on major scientific facilities abroad and maintain observer contact with the ITER project to keep informed of progress by the remaining three ITER parties.
- The program will retain low activation materials research. However, remaining enabling R&D activities supporting energy-producing plasmas will be drastically reduced.
- A series of critical enabling R&D tasks involving radio-frequency heating and current drive components were successfully completed over the past year. Tasks include fabrication of the NSTX antenna and tuning system, and installation of a DIII-D high power microwave system. The results of these auxiliary heating development efforts will have broad applicability to future U.S. fusion experiments.
- AWARDS

  Marshall Rosenbluth, University of California at San Diego, was awarded the **National Medal of Science** in December 1997

  Darin Ernst, Princeton Plasma Physics Laboratory, won the **1998 APS-DPP Award for Outstanding Doctoral Dissertation in Plasma Physics**

  Nine fusion researchers were elected **Fellows of the American Physical Society in 1998**

  Paul Woskov, MIT Plasma Science and Fusion Center, in collaboration with PNNL, won a **1998 R&D 100 Award** for a device that measures smokestack emissions. The award winning work has its roots in fusion diagnostics and plasma physics.

Funding of Contractor Security Clearances

- In FY 1999, the Department divided the responsibility for obtaining and maintaining security clearances. The Office of Security Affairs, which was responsible for funding all Federal and contractor employee clearances, now pays only for clearances of Federal employees, both at headquarters and the field. Program organizations are now responsible for contractor clearances, using program funds. This change in policy enables program managers to make the decisions as to how many and what level clearances are necessary for effective program execution. In this way, it is hoped that any backlog of essential clearances which are impeding program success can be cleared up by those managers most directly involved. The Office of Science is budgeting $115,000 and $96,000 for estimated contractor security clearances in FY 1999 and FY 2000, respectively, within this decision unit.

Funding Profile

(dollars in thousands)

	FY 1998 Current Appropriation	FY 1999 Original Appropriation	FY 1999 Adjustments	FY 1999 Current Appropriation	FY 2000 Request
Fusion Energy Sciences					
Science	95,116	118,982	-664	118,318	125,434
Facility Operations	56,149	61,195	0	61,195	69,380
Enabling R&D	66,025	43,123	0	43,123	27,800
Program Direction	6,900	0	0	0	0
Subtotal, Fusion Energy Sciences	224,190	223,300	-664	222,636	222,614
General Reduction	0	-664	+664	0	0
Use of Prior Year Balances	-791 [a]	-1,136 [b]	0	-1,136 [b]	0
Total, Fusion Energy Sciences	223,399 [c]	221,500	0	221,500	222,614

Public Law Authorization:

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

[a] Share of Energy Supply, Research and Development general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[b] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[c] Excludes $5,157,000 which has been transferred to the SBIR program and $309,000 which has been transferred to the STTR program.

Funding by Site

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	4,143	4,219	4,419	+200	+4.7%
Sandia National Laboratories	5,850	4,115	3,565	-550	-13.4%
Total, Albuquerque Operations Office	9,993	8,334	7,984	-350	-4.2%
Chicago Operations Office					
Argonne National Laboratory	2,835	2,540	2,135	-405	-15.9%
Brookhaven National Laboratory	50	0	0	0	0.0%
Princeton Plasma Physics Laboratory	49,612	50,332	58,979	+8,647	+17.2%
Total, Chicago Operations Office	52,497	52,872	61,114	+8,242	+15.6%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	4,120	1,740	1,000	-740	-42.5%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	3,947	5,334	5,255	-79	-1.5%
Lawrence Livermore National Laboratory	10,518	11,158	10,168	-990	-8.9%
Stanford Linear Accelerator Center	50	50	50	0	0.0%
Total, Oakland Operations Office	14,515	16,542	15,473	-1,069	-6.5%
Oak Ridge Operations Office					
Oak Ridge Institute for Science and Education	1,229	910	800	-110	-12.1%
Oak Ridge National Laboratory	17,870	17,480	15,866	-1,614	-9.2%
Total, Oak Ridge Operations Office	19,099	18,390	16,666	-1,724	-9.4%
Richland Operations Office					
Pacific Northwest National Laboratory	1,415	1,410	1,430	+20	+1.4%
Savannah River Operations					
Savannah River Tech Center	452	219	0	-219	-100.0%
All Other Sites [a]	122,099	123,129	118,947	-4,182	-3.4%
Subtotal, Fusion Energy Sciences	224,190	222,636	222,614	-22	0.0%
Use of Prior Year Balances	-791 [b]	-1,136 [c]	0	+1,136 [c]	+100.0%
Total, Fusion Energy Sciences	223,399	221,500	222,614	+1,114	+0.5%

[a] Funding provided to laboratories, universities, industry, other federal agencies, and other miscellaneous contractors.

[b] Share of Energy Supply, Research and Development general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

[c] Share of Science general reduction for use of prior year balances assigned to this program. The total general reduction is applied at the appropriation level.

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 fusion enabling R&D program activities in areas of modeling, analysis, and experimental research. Argonne has a lead role internationally in analytical models and experiments for liquid metal cooling in fusion devices, including the ALEX facility, that studies the interaction of flowing liquid metals with magnetic fields, and liquid lithium flow loop that studies corrosion in candidate structural alloy materials. Argonne's capabilities in the engineering design of fusion energy systems has contributed to the design of ITER components, including blankets, tritium systems, and plasma-facing components, as well as to analysis supporting ARIES studies of fusion power plant concepts. Argonne also contributes to low-activation materials research with its unique capabilities in vanadium alloy testing in fission reactors and post-irradiation examinations.

Idaho National Engineering and Environmental Laboratory

Idaho National Engineering and Environmental Laboratory (INEEL) is a Multiprogram Laboratory located on 572,000 acres in Idaho Falls, Idaho. Since 1978, INEEL has been the lead laboratory for fusion safety for the Fusion Energy Sciences program. As the lead laboratory, they have helped to develop the fusion safety data base which will demonstrate the environmental and safety characteristics of both nearer term fusion devices and future fusion power plants. They have focused their research on:
(1) understanding the behavior of the sources of radioactive and hazardous materials in a fusion machine,
(2) understanding the energy sources in a fusion machine that could mobilize these materials, and
(3) developing the analytical tools that demonstrate the environmental and safety characteristics of a fusion machine. In FY 2000, fusion efforts at INEEL will be focused solely on safety research associated with existing or planned domestic experimental facilities.

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. One of LBNL's missions is to study and apply the physics of heavy ion beams and to advance related technologies. The U.S. Heavy-Ion Fusion (HIF), centered at LBNL, program has the long-range goal of developing inertial fusion energy (IFE) as an economically and environmentally attractive source of electric power.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. LLNL is host for Defense Programs' National Ignition Facility, which will give the United States the first opportunity in the world to demonstrate inertial fusion ignition and energy gain in the laboratory. This goal will provide the IFE program with crucial results concerning target physics. This fusion energy mission is consistent with the NIF mission statement. Livermore partners with other Laboratories (LBNL, for example, in Heavy Ion Fusion) in fusion energy research. This program also includes collaborations on the DIII-D tokamak at General Atomics, construction of an innovative concept experiment, The Sustained Spheromak Physics Experiment (SSPX) at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D. The SSPX will start experimental operations in FY 1999. Definitive results on the feasibility of sustaining high temperature spheromak plasmas utilizing external electrode current drive are expected by the end of FY 2000.

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 FY 2000 budget will support the creation of computer codes for modeling the stability of plasmas, as well as work in diagnostics, innovative fusion plasma confinement concepts such as Magnetic Target Fusion, and maintenance of the Tritium Systems Test Assembly (TSTA) facility in a standby mode.

Oak Ridge Institute for Science and Education

Oak Ridge Institute for Science and Education (ORISE) is located on a 150 acre site in Oak Ridge, Tennessee. ORISE was established by DOE to undertake national and international programs in education, training, health, and the environment. ORISE and its programs are operated by Oak Ridge Associated Universities (ORAU) through a management and operating contract with DOE. Established in 1946, ORAU is a consortium of 88 colleges and universities. For the Office of Fusion Energy Sciences (OFES), ORISE acts as an independent and unbiased agent to administer the Fusion Energy Sciences Graduate and Postgraduate Fellowship Programs, in conjunction with OFES, the Oak Ridge Operations Office (ORO), participating universities, DOE laboratories, and industries. ORISE also assists in the organization and administrative support for the Fusion Energy Sciences Advisory Committee meetings.

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 plasma experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. ORNL will provide leadership of the Virtual Laboratory for Technology, which integrates all U.S. fusion program enabling R&D activities into a coordinated multi-institutional framework. 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 particles. Research is also done in the area of turbulence and its effect on transport of heat through plasma. 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.

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 teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the National Spherical Torus Experiment (NSTX), which is an innovative toroidal confinement device closely related to the tokamak, and is currently working on the conceptual design of another innovative toroidal concept, the compact stellarator. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks in the U.S. and the large JET (Europe) and JT-60U (Japan) tokamaks abroad. This work 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 175 Ph.D. graduates since its founding in 1951.

Sandia National Laboratory

Sandia National Laboratory is a Multiprogram Laboratory, with a total of 3,700 acres, located in Albuquerque, New Mexico, with other sites in Livermore, California, and Tonapah, Nevada. Sandia's Fusion Energy Sciences program plays a lead role in developing plasma-facing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interfaces of plasmas and fusion device first wall. 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 in use in fusion devices. Materials samples and prototypes are tested in Sandia's Plasma Materials Test Facility, which use high-power electron beams to stimulate 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 fusion experiments in areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing.

Stanford Linear Accelerator Center

Stanford Linear Accelerator Center (SLAC) is a program-dedicated laboratory (High Energy Physics) located on 426 acres in Menlo Park, California. SLAC is operated for the United States Department of Energy by Stanford University. The main interest in fusion at SLAC is the possibility of adapting the accelerator science and technology from elementary particle physics to the production of fusion power from the implosion of inertial fusion targets driven by beams of high energy, heavy ions. A member of the accelerator research department at SLAC has been involved with the heavy ion fusion program since its inception.

All Other Sites

The Fusion Energy Sciences program funds research at 51 colleges/universities located in 25 states. This line also includes funding for DIII-D and related programs at General Atomics and funding of research awaiting distribution pending completion of review results or program office detailed planning.

Science

Mission Supporting Goals and Objectives

The goals of this subprogram are to advance our understanding of plasma science, and to develop innovative approaches for confining a fusion plasma. These goals are accomplished through a modest program in basic plasma science; active research programs in both toroidal innovations and in non-toroidal concepts; focused efforts to resolve outstanding physics issues related to energy producing plasmas; strong theory and modeling programs; and the creation of improved diagnostics that make possible rigorous testing of the scientific principles of fusion.

Plasma science is the study of ionized matter—ranging from neon lights to stars—that make up 99 percent of the visible universe. It contributes not only to fusion research, but also to many national science and technology goals, ranging from astrophysics to industrial processing to national security. One objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma physics. Ongoing programs including a development program for junior faculty in plasma physics and a joint NSF/DOE partnership in plasma physics and engineering contribute to this objective.

Fusion energy research advances through a balanced combination of large-, medium-, and small-scale experiments, theory, and modeling. The largest component of the Science subprogram is the tokamak research activity, which focuses on gaining a predictive understanding of the behavior of plasmas in near reactor-level conditions where the fusion fuel begins to "burn". Tokamak research will be carried out primarily on the DIII-D facility at General Atomics. DIII-D has been a major contributor to the world fusion program over the past decade by developing advanced modes of toroidal operations through the flexibility of its plasma shaping and computer control systems, and by increasing the knowledge base of fusion physics through extensive diagnostics and theoretical and modeling support of experiments. The other major U.S. tokamak experiment, the Alcator C-Mod at the Massachusetts Institute of Technology (MIT), uses high magnetic fields to explore high temperature and density plasmas in a unique, compact, and cost-effective facility. Additional high-leverage tokamak research will be carried out through international collaborations on large, state-of-the-art facilities abroad. Increased collaboration on facilities such as JET (Europe) and JT-60 (Japan) was recommended by the Fusion Energy Science Advisory Committee.

Research on alternative confinement concepts, both magnetic and inertial, is aimed at identifying approaches that may improve the economical and environmental attractiveness of fusion energy sources. This research is carried out at various levels ranging from the concept explorations stage to the proof-of-principle stage. The first proof-of-principle experiment, the new National Spherical Torus Experiment (NSTX) facility at the Princeton Plasma Physics Laboratory (PPPL), will begin its first full year of operation in FY 2000, with a goal of demonstrating improved stability and confinement in a very compact structure over the next several years. Additional proof-of-principle level experiments at PPPL, University of Wisconsin, and Los Alamos National Laboratory have been positively reviewed and are awaiting further consideration by the Fusion Energy Sciences Advisory Committee. Small-scale exploratory experiments are carried out primarily at universities, while proof-of-principle experiments, such as the NSTX will be primarily hosted at national laboratories.

The Inertial Fusion Energy (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 Office of Defense Programs. The IFE program depends on the ICF program for experimental research into the physics of target ignition that will be tested in the National Ignition Facility at LLNL. Efforts in IFE focus on developing the components needed to apply the ICF results to energy systems. These include the most efficient methods for heating and compressing a target pellet to fusion conditions, methods for clearing the target chamber between pulses, and target design.

Theory and modeling are essential to progress in fusion and plasma science because they provide the capability to analyze existing experiments, produce new ideas to improve performance, and provide a scientific assessment of new ideas. An important component of the theory program is the development and use of computational tools to help understand the physical phenomena that govern confinement of high temperature plasmas. Similarly, the development and improvement of diagnostic tools for analyzing plasma behavior continues to provide new insights regarding fusion plasmas.

Performance Measures

- Three new innovative concept exploration experiments--the LSX field-reversed configuration, the flow-stabilized Z pinch (both at the University of Washington) and the Pegasus spherical torus at the University of Wisconsin--will be fully operational providing basic scientific understanding of relevant concept phenomena.
- A new energy transport code framework, based on modern computing techniques, will be completed and made available for use via the web.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Tokamak Experimental Research	46,198	46,831	45,918	-913	-1.9%
Alternative Concept Experimental Research	23,996	38,600	45,150	+6,550	+17.0%
Theory	19,773	22,500	23,000	+500	+2.2%
General Plasma Science	5,149	6,109	6,500	+391	+6.4%
SBIR/STTR	0	4,278	4,866	+588	+13.7%
Total, Science	95,116	118,318	125,434	+7,116	+6.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Tokamak Experimental Research			
■ TFTR physics research was completed in 1998.	5,500	0	0
■ DIII-D at General Atomics (GA) is the major operating tokamak in the United States. DIII-D is a national facility, with about half of its scientific staff coming from U.S. fusion laboratories other than GA, as well as some from several foreign laboratories. In FY 2000 the research activity will focus on use of two new hardware improvements in auxiliary heating and power exhaust systems. This will allow progress in the development of advanced toroidal operations for long pulses which is essential for incorporation of these operating modes into the design of future machines.	21,430	21,905	22,520
■ Alcator C-Mod will also operate as a national facility with an improved set of diagnostics. Research activity will focus on support of the compact, high field approach to ignition and on the physics of the plasma edge and power exhaust.	6,211	7,600	7,800
■ Several unique, innovative tokamak experiments are supported at leading universities. These focus on various topics, including advanced toroidal operating modes and plasma stability and control. This program also develops unique diagnostic probes that provide an understanding of the plasma behavior in fusion research devices, supplying the necessary information for analysis codes and theoretical interpretation. The requested funding level in FY 2000 supports the core diagnostic development research, as well as the work begun as a result of an FY 1999 competitive initiative to develop new diagnostic techniques.	6,557	7,400	7,250

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ International collaboration at the level of $4,200,000 provides the opportunity for joint and coordinated experiments between the U.S. and foreign experiments, thereby increasing the database and the understanding of fusion physics. With the limited operation of major tokamaks in the U.S., international collaboration provides increased opportunity for the U.S. scientists to continue their participation in the advancement of fusion science, especially in the area of burning plasma physics. The scientists from PPPL and ORNL will continue collaborations with JET, Tore Supra, TEXTOR, and ASDEX-UG in Europe and with JT-60U in Japan. The remaining $4,148,000 is required for graduate and postgraduate fellowships in fusion science and technology, general science literacy programs with teachers and students, support for historically black colleges and universities, and similar broad outreach efforts related to fusion science and technology. . . .	6,500	9,926	8,348
Total, Tokamak Experimental Research	46,198	46,831	45,918

Alternative Concept Experimental Research

■ **Experimental Plasma Research (Alternates):** Research on novel magnetic confinement configurations is important both for its intrinsic scientific value and for its potential to discover concepts that would make more attractive fusion power sources. This category has two components. The first component contains twelve diversified exploratory level experiments located primarily in universities. Four of these experiments (Sustained Spheromak Physics Experiment at LLNL; Columbia University/MIT Dipole; Ion Rings at Cornell University; and Ion Trap at LANL) resulted from a FY 1998 innovative concept competition. A second category includes design and experimental work on three novel concepts that have been proposed for full proof-of-principle funding..	14,550	19,000	23,750

■ **NSTX:** The NSTX at PPPL will begin the first full year of research in FY 2000. The research program will be organized as a national collaboration with representatives of other institutions participating in the research activity on an equal basis with researchers from PPPL. Initial objectives will be plasma formation, two methods of controlled startup, plasma heating by radio-frequency waves and diagnostic surveys to define acceptable operational regimes that can be used

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
for more powerful experiments. Advanced diagnostic development specifically for NSTX is also funded by this element.	2,446	9,800	11,300
■ **Inertial Fusion Energy:** Inertial fusion energy research continues with efforts to improve heavy ion accelerator efficiency, chamber wall protection, and design of fusion energy target pellets. Scoping studies for major next step device options will be undertaken, with a goal of providing the inertial fusion energy program the capacity to benefit from physics results on Defense Programs' National Ignition Facility in the latter part of the next decade.	7,000	9,800	10,100
Total, Alternative Concept Experimental Research	23,996	38,600	45,150

Theory

- The theory and modeling program is a broad-based program with researchers located at national laboratories, universities, and industry. A new program emphasis is advanced computing, including the development of new modeling codes and a code library for use by all fusion researchers. Work in tokamak theory ($15,105,000) includes efforts to support existing toroidal experiments and also includes the development of many new theories and modeling tools, since these are usually applied to tokamaks before being applied to alternates. An example of this is work on self organized criticality, which may provide a new approach to understanding confinement. The majority of the work in toroidal theory is aimed at developing a complete physical picture of advanced toroidal operating modes. With the restructuring of the fusion program, there is an increased focus on alternate concepts. In alternate concept theory ($2,707,000), the emphasis will be on understanding the fundamental processes determining equilibrium, stability, and confinement in each alternate. Generic theory ($2,188,000) covers development of basic plasma theory that is applicable not only to fusion research, but also to basic plasma science. It also includes work on atomic theory, which is applicable to all confinement devices.

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
The objective of the advanced computing activity is to improve simulation and modeling capabilities in order to obtain a quantitative understanding of plasma behavior in fusion experiments. This will ensure optimum use of a set of innovative national experiments and fruitful collaboration on major international facilities. In FY 2000, funds ($3,000,000) will be used to develop a modern transport code to simulate energy transport in toroidal magnetic confinement systems. . .	19,773	22,500	23,000
General Plasma Science			
■ The plasma science program focuses on basic plasma science and engineering research, primarily in the university community. Advances in basic plasma physics will support the Fusion Energy Sciences program as well as other important areas of science and technology. Both the Plasma Science Junior Faculty Development Program and collaborative efforts such as the NSF/DOE plasma science and engineering program will continue at FY 1999 levels. The program will also continue to collect and distribute atomic physics data for fusion.	5,149	6,109	6,500
SBIR/STTR			
■ In FY 1998 $3,476,000 and $208,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	4,278	4,866
Total, Science	95,116	118,318	125,434

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Tokamak Experimental Research	
■ Additional funding is provided for increased diagnostics on DIII-D.	+615
■ Additional funding is provided for increased research expenses on Alcator C-Mod..	+200

	FY 2000 vs. FY 1999 ($000)
■ This decrease is primarily associated with the FY 1999 prior year general reduction account going to zero in FY 2000.	-1,578
■ Reduction will decrease support for research at UCLA	-150
Total, Tokamak Experimental Research	-913
Alternative Concept Experimental Research	
■ Support for NSTX research is increased to provide funding for personnel and minor equipment for the first full year of operations that includes research collaborations and preparations of advanced diagnostics.	+1,500
■ Funding for alternate concept experiments is increased to maintain breadth and permit establishment of one or more proof-of-principle experiments..	+4,750
■ This increase will permit continued efforts to improve accelerator efficiency for inertial fusion energy..	+300
Total, Alternative Concept Experimental Research	+6,550
Theory	
■ The advanced computational effort will expand efforts to develop new codes to predict plasma performance.	+500
General Plasma Science	
■ These funds will enhance the NSF/DOE Partnership in Basic Plasma Science and Engineering.	+391
SBIR/STTR	
■ Support for SBIR/STTR is mandated at 2.65 percent. These grants will support plasma science, fusion science, and fusion enabling R&D.	+588
Total Funding Change, Science	+7,116

Facility Operations

Mission Supporting Goals and Objectives

This activity provides for the operation of major experimental facilities that are the essential tools that enable scientists in university, industry, and laboratory based research groups to perform experimental research in fusion research facilities: DIII-D at GA, Alcator C-Mod at MIT, and NSTX at PPPL. These 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. It includes the cost of operating personnel, electric power, expendable supplies, replacement parts and subsystems, and inventories. In the case of PPPL, this funding also supports beginning the final three-year phase of decontamination and decommissioning of the Tokamak Fusion Test Reactor which was shut down in FY 1997; ongoing caretaking for the tritium systems and activated elements is required during this process. General plant projects (GPP) funding for PPPL supports minor facility renovations, other capital alterations and additions, and buildings and utility systems. Capital equipment funding for upgrading the research capability of DIII-D is also included, as are funds for design, modification, and installation of the NSTX neutral beam heating system, and for further enhancements to the facility.

The principal objective of the Facility Operations subprogram is to maximize the quantity and quality of data collected for experiments being conducted at fusion energy science facilities.

The following table summarizes the scheduled weeks of operations for DIII-D and NSTX.

Facility Utilization

(Weeks of Operation)

	FY 1998	FY 1999	FY 2000
DIII-D	15	14	14
Alcator C-Mod	9	12	18
TFTR	8	0 [a]	0 [a]
NSTX	0	6	14

[a] Facility Shutdown.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
TFTR	5,140	3,600	13,600	+10,000	+277.8%
DIII-D	26,370	29,195	29,880	+685	+2.3%
Alcator C-Mod	9,689	9,923	10,100	+177	+1.8%
NSTX	13,850	16,800	15,000	-1,800	-10.7%
General Plant Projects /Other	1,100	1,677	800	-877	-52.3%
Total, Facility Operations	56,149	61,195	69,380	+8,185	+13.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
TFTR			
■ Begin a three-year program ($10,000,000 in FY 2000 out of a planned total of $48,000,000) to complete the decontamination and decommissioning of TFTR. This activity will provide for the removal and disposal of the tokamak and remaining activated components from the test cell and the basement. In addition during the D&D funding ($3,600,000) is necessary to maintain and keep the facility safe during the project.	5,140	3,600	13,600
DIII-D			
■ Provides support for operation, maintenance, and improvement of the DIII-D Electron Cyclotron Heating (ECH) systems and support for other equipment at the GA site. In FY 2000, these funds support plasma operation using hydrogen and deuterium fuel for approximately 14 weeks; plus downtime for significant upgrades to the ECH, divertor systems, and maintenance.	26,370	29,195	29,880
Alcator C-Mod			
■ Provides support for operation, maintenance and minor machine improvements. In FY 2000, these funds support plasma operation using hydrogen and deuterium fuel for approximately 18 weeks; plus down time for machine and diagnostic improvements.	9,689	9,923	10,100

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
NSTX			
■ Provides for continuation of research activity on the NSTX experiment and installation of the first set of planned diagnostic upgrades. This will allow extension of the pulse duration to 1 second and operation at plasma currents approaching 1 megampere, a factor of 40 increases over current exploratory level spherical torus experiments; first investigations of non-inductive current drive, a principal program objective; and measurement of advanced plasma confinement scenarios.	1,770	7,900	12,500
■ **NSTX Project:** Project completed in FY 1999 and facility begins operations.	12,080	5,450	0
■ **NSTX Neutral Beam:** Project for preparation and installation of a previous TFTR neutral beam heating system on NSTX.	0	3,450	2,500
Total, NSTX	13,850	16,800	15,000
General Plant Projects/Other			
■ These funds provide primarily for general infrastructure repairs and upgrades. The major project included in the FY 2000 plan is an upgrade of the fire alarm system throughout the site where NSTX is located.	1,100	1,677	800
Total, Facility Operations	56,149	61,195	69,380

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
TFTR	
■ Funding is provided to initiate TFTR decontamination and decommissioning.	+10,000
DIII-D	
■ Additional funding is for operation of increased number of DIII-D systems (ECH, divertor, etc.).	+685
Alcator C-Mod	
■ Additional funding is provided for increased operation of the Alcator C-Mod.	+177
NSTX	
■ A decrease for the NSTX project at PPPL is due to the completion of fabrication, and a shift to facility operations.	-5,450
■ An increase in NSTX facility operations to support the first full year of operations.	+4,600
■ A decrease in NSTX neutral beam heating system to complete this fabrication effort.	-950
Total, NSTX	-1,800
General Plant Projects/Other	
■ General Plant Projects support at PPPL is increased $100,000 to reflect maintenance requirements; support for other facility operations is terminated.	-877
Total Funding Change, Facility Operations	+8,185

Enabling R&D

Mission Supporting Goals and Objectives

For sustained scientific progress toward ultimate research goals, science-oriented programs that push the frontiers of human knowledge, such as fusion, require intellectual resources, experimental facilities with state-of-the-art technological capabilities, and technology innovations. The Enabling R&D subprogram includes funds for: (1) establishing the scientific foundation that underlies current technological advances in fusion, and (2) providing the technological capabilities and innovations needed to advance fusion science; developing the knowledge base for an attractive fusion energy source. These contribute to two strategic goals for the fusion program. This subprogram is divided into two elements: Engineering Research and Materials Research.

For the Engineering Research element, activities through FY 1998 were heavily oriented toward the ITER Engineering Design Activities (EDA), a four party (European Union, Japan, Russian, U.S.) international effort to demonstrate the scientific and technological feasibility of fusion as an energy source. In July 1998 the other three ITER parties prepared to enter into a 3-year post-EDA extension period that would develop a reduced cost design and provide the basis for an assessment of the technical, financial, and hosting readiness to proceed with ITER construction as an international project. However the DOE was unable to obtain congressional agreement for U.S. participation in the extension. Accordingly, the U.S. effort toward ITER will be closed out in early FY 1999, and the Engineering Research element restructured by being downsized and redirected away from energy-oriented goals.

In restructuring this element in FY 1999, the scope of activities will be broadened to address more fully the diversity of domestic interests in enabling R&D. These interests include a focus on critical needs for enabling technologies for U.S. plasma experiments and for international collaborations that allow the U.S. to access plasma experimental conditions not available domestically. These interests also include the scientific foundations of innovative technology concepts for future plasma experiments. These innovations are needed to exploit the performance gains being sought from physics concept improvement research. Major FY 1998 accomplishments include: completion, as an ITER participant, of the ITER Final Design Report, which is the first comprehensive, fully integrated design of a major fusion power experiment; completion of winding the ITER superconducting magnet model coil, which will be shipped to Japan in early FY 1999 for testing in a Japanese facility during FY 1999; and completion of critical tasks involving radio-frequency heating and plasma current drive components that have broad applicability to the U.S. fusion program.

The Materials Research element continues to focus its scientific research on low-activation materials which have high performance capability and can withstand long-term exposure to the energetic particles and electromagnetic radiation expected from energy-producing plasmas. During FY 1998, this element made major inroads toward mapping of irradiation effects on candidate low-activation alloys, which is needed to set priorities for future research, and underwent a review by FESAC that will continue to influence planning for FY 1999 and beyond.

Funding Schedule

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Engineering Research	58,281	34,991	20,074	-14,917	-42.6%
Materials Research	7,744	7,000	7,000	0	0.0%
SBIR/STTR	0	1,132	726	-406	-35.9%
Total, Enabling R&D	66,025	43,123	27,800	-15,323	-35.5%

Detailed Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Engineering Research			
■ Funding reductions will require a substantial downsizing and redirection of effort on the energy-oriented technology segment of the fusion program. Efforts will be focused on critical needs of domestic plasma experiments and on the scientific foundations of innovative technology concepts for future plasma experiments. Nearer-term experiment support efforts will be oriented toward plasma facing components ($5,600,000) and plasma heating and fueling technologies ($3,700,000). Longer-term efforts will be oriented toward: superconducting magnet research ($1,500,000) and plasma facing and energy extraction component innovations ($1,500,000) needed to fully exploit investments in concept improvement experiments; and toward tritium research ($1,000,000) and safety research ($1,000,000) issues critical to the safety and environmental attractiveness of fusion as an energy source. Advanced design studies will be directed toward identifying attractive pathways toward fusion energy ($2,950,000). In addition, design studies of next-step options ($2,224,000), taking fullest advantage of recent scientific advances, will continue. Management of this diverse collection of fusion technologies will be accomplished through a Virtual Laboratory for Technology ($600,000) whereby improved coordination and communication of plans, progress, and results will be accomplished through the use of modern information technology.	58,281	34,991	20,074

	FY 1998	FY 1999	FY 2000
	(dollars in thousands)		
Materials Research			
■ Materials research remains a key element in developing a safe, reliable, and environmentally attractive fusion energy system. Scientific understanding and the development research and testing of vanadium alloys, silicon carbide composite materials, and advanced ferritic steels for structural service in the high power zones for fusion energy sources will continue. Priorities for this work, including innovative approaches to evaluating materials and improved modeling of materials behavior are guided by the results of a Fusion Energy Sciences Advisory Committee review conducted during 1998.	7,744	7,000	7,000
SBIR/STTR			
■ In FY 1998 $1,681,000 and $101,000 were transferred to the SBIR and STTR programs, respectively. The FY 1999 and FY 2000 amounts are the estimated requirement for the continuation of the SBIR and STTR programs.	0	1,132	726
Total, Enabling R&D	66,025	43,123	27,800

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Engineering Research	
■ Reduction in research on superconducting magnets plasma facing components and plasma fueling (following completion of ITER Superconducting Model Coil)..	-7,322
■ Reduction in research on energy extraction, diagnostics, tritium processing, vacuum vessel welding, remote handling, and safety.	-2,731
■ Reduction in design of next step option experiments being considered within U.S. domestic fusion program.	-1,276
■ Increase in Advanced Design Studies	+500
■ Reduction in information technology research	-948
■ Reduction in ITER closeout costs to zero in FY 2000	-3,140
Total, Engineering Research	-14,917

	FY 2000 vs. FY 1999 ($000)
SBIR/STTR	
■ Reduction due to overall reduction in Engineering Research.	-406
Total Funding Change, Enabling R&D	-15,323

Program Direction

Mission Supporting Goals and Objectives

This subprogram was transferred to the Science Program Direction decision unit in FY 1999 at the direction of Congress. This subprogram provided the Federal staffing resources and associated funding needed to plan, direct, manage, and administer the highly complex scientific and technical research and development program in fusion energy.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Chicago Operations Office					
Salaries and Benefits	910	0	0	0	0.0%
Travel	74	0	0	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	190	0	0	0	0.0%
Total, Chicago Operations Office	1,174	0	0	0	0.0%
Full Time Equivalents	11	0	0	0	0.0%
Oakland Operations Office					
Salaries and Benefits	184	0	0	0	0.0%
Travel	14	0	0	0	0.0%
Support Services	0	0	0	0	0.0%
Other Related Expenses	2	0	0	0	0.0%
Total, Oakland Operations Office	200	0	0	0	0.0%
Full Time Equivalents	2	0	0	0	0.0%
Headquarters					
Salaries and Benefits	4,001	0	0	0	0.0%
Travel	225	0	0	0	0.0%
Support Services	600	0	0	0	0.0%
Other Related Expenses	700	0	0	0	0.0%
Total, Headquarters	5,526	0	0	0	0.0%
Full Time Equivalents	39	0	0	0	0.0%

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Total Fusion Energy Sciences					
Salaries and Benefits	5,095	0	0	0	0.0%
Travel	313	0	0	0	0.0%
Support Services	600	0	0	0	0.0%
Other Related Expenses	892	0	0	0	0.0%
Total, Program Direction	6,900	0	0	0	0.0%
Full Time Equivalents	52	0	0	0	0.0%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Salaries and Benefits			
■ Funded staff managing and supporting the Fusion Energy Sciences program.	5,095	0	0
Travel			
■ Provided on-site contractor and facility oversite and participated in major scientific conferences to maintain state-of-the-art scientific and technical expertise.	313	0	0
Support Services			
■ Provided the level of support services needed to provide for the program's mailroom; security; travel services; information technology, infrastructure; and environment, safety and health support..	600	0	0
Other Related Expenses			
■ Provided funds to cover the minimum level of funds to cover hardware/software acquisitions, infrastructure technology upgrades, training, special emphasis programs and the Working Capital Fund..	892	0	0
Total, Program Direction	6,900	0	0

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
■ This subprogram was transferred to the Science Program Direction decision unit in FY 1999 at the direction of Congress.	N/A

Support Services

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Technical Support Services					
Feasibility of Design Considerations . . .	0	0	0	0	0.0%
Economic and Environmental Analysis .	0	0	0	0	0.0%
Test and Evaluation Studies	0	0	0	0	0.0%
Total, Technical Support Services	0	0	0	0	0.0%
Management Support Services					
Management Studies	0	0	0	0	0.0%
Training and Education	5	0	0	0	0.0%
ADP Support	245	0	0	0	0.0%
Administrative Support Services	350	0	0	0	0.0%
Total, Management Support Services	600	0	0	0	0.0%
Total, Support Services	600	0	0	0	0.0%

Other Related Expenses

	(dollars in thousands)				
	FY 1998	FY 1999	FY 2000	$ Change	% Change
Training	0	0	0	0	0.0%
Working Capital Fund	500	0	0	0	0.0%
Printing and Reproduction	0	0	0	0	0.0%
Rental Space	26	0	0	0	0.0%
Software Procurement/Maintenance Activities/Capital Acquisitions	366	0	0	0	0.0%
Total, Other Related Expenses	892	0	0	0	0.0%

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
General Plant Projects	1,100	700	800	+100	+14.3%
Capital Equipment	15,295	16,645	10,810	-5,835	-35.1%
Total, Capital Operating Expenses	16,395	17,345	11,610	-5,735	-33.1%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp- riations	FY 1998	FY 1999	FY 2000	Accept- ance Date
DIII-D Upgrade	32,400	18,225	1,550	5,440	5,440	FY 2002
NSTX	21,100	3,570	12,080	5,450	0	FY 1999
NSTX - Neutral Beam	5,950	0	0	3,450	2,500	FY 2000
Total, Major Items of Equipment		21,795	13,630	14,340	7,940	