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. The National Energy Policy states that fusion power has the long-range potential to serve as an abundant and clean source of energy and recommends that the Department develop fusion. The next frontier in the quest for fusion power is a sustained, burning (or self-heated) plasma, and the Fusion Energy Sciences Advisory Committee (FESAC) has concluded that the fusion program is technically and scientifically ready to proceed with a burning plasma experiment and has recommended joining the ongoing negotiations to construct the international burning plasma experiment, ITER. The National Research Council of the National Academy of Sciences has endorsed this strategy. Based in part on these recommendations and an assessment by the Office of Science of the cost estimate for the construction of ITER, the President has decided that the U.S. should join the ITER negotiations.

Overview:

Fusion science is a subfield of plasma science that deals primarily with studying the fundamental processes taking place in plasmas where the temperature and density approach the conditions needed to allow the nuclei of two low-mass elements, like hydrogen isotopes, to join together, or fuse. When these nuclei fuse, a large amount of energy is released. Fusion science research is organized around the two leading methods of confining the fusion plasma—magnetic, where strong magnetic fields constrain the charged plasma particles, and inertial, where laser or particle beams compress and heat the plasma in very short pulses.

During 1998-1999, the FESAC conducted a major review of the fusion program that culminated in the report, "Priorities and Balance within the Fusion Energy Sciences Program," dated September 1999. A hallmark of this report is that it presents the first approach to an evenhanded treatment of magnetic fusion science and inertial fusion science. In December 2000, FESAC reviewed a more detailed, independent report, "Report of the Integrated Program Planning Activity for the DOE Fusion Energy Sciences Program," (IPPA) that reaffirmed that the priorities, balance, and strategic vision laid out in the FESAC 1999 report remain valid. Recommendations in the report of the 2001 National Research Council (NRC) Fusion Assessment Committee review of the quality of the science in the program are consistent with the report. Further, the NRC Fusion Assessment also states "*that the quality of science funded by the United States fusion research program in pursuit of a practical source of power from fusion (the fusion energy goal) is easily on a par with the quality in other leading areas of contemporary physical science*."

Based on these recent recommendations and assessments, the programmatic goals for the Magnetic Fusion Energy (MFE) and the Inertial Fusion Energy (IFE) parts are designed to address the scientific and technology issues facing fusion energy development.

For magnetic fusion, the scientific and technology issues include:

- the transport of plasma heat from the core outward to the plasma edge and to the material walls as a result of electromagnetic turbulence in the plasma (chaos, turbulence, and transport),

- the stability of the magnetic configuration and its variation in time as the plasma pressure, density, turbulence level, and population of high energy fusion products change (stability, reconnection, and dynamo),
- the role of the colder plasma at the plasma edge and its interaction with both material walls and the hot plasma core (sheaths and boundary layers),
- the interaction of electrons and ions in the plasma with high-power electromagnetic waves injected into the plasma for plasma heating, current drive and control (wave-particle interaction), and
- the development of reliable and economical superconducting magnets, plasma heating and fueling systems, vacuum chamber, and heat extraction systems and materials that can perform satisfactorily in an environment of fusion plasmas and high energy neutrons.

For inertial fusion, the scientific and technology issues include:

- The high-energy-density physics necessary to understand the plasmas produced by intense laser-plasma and beam-plasma interactions,
- the behavior of non-neutral plasmas (such as beams of heavy ions), and
- the acceleration and transport of high-current beams, the development of a target chamber and associated debris clearing, and the fabrication and accurate injection of low-cost targets.

These issues have been codified into four thrusts that characterize the program activities:

- Burning Plasmas, which will include our efforts in support of ITER;
- Fundamental Understanding, which includes Theory and Modeling, as well as general plasma science;
- Configuration Optimization, which includes experiments on advanced tokamaks, magnetic alternates, and inertial fusion concepts, as well as facility operations and enabling R&D; and
- Materials and Technology, which includes fusion specific materials research and fusion nuclear technology research.

Progress in each and all of these thrust areas, in an integrated fashion, is required for ultimate success in achieving a practical fusion energy source.

In light of the President's decision to join the ITER negotiations, many elements of the current fusion program that are broadly applicable to burning plasmas will now be directed more specifically toward the needs of ITER, which will be the focal point of burning plasma fusion research around the world. These elements represent areas of fusion research in which the U.S. has particular strengths, such as theory, modeling and tokamak experimental physics. Longer range technology activities aimed at an eventual commercial fusion reactor will be curtailed to fund new activities related to participating in the ITER project, and to focus on aspects of the present program that most directly support preparations for building and operating ITER: operations and research for the tokamak experimental program (DIII-D and Alcator C-Mod) relevant to burning plasma physics, and ITER-specific computer simulations. The new and redirected elements of the fusion program, and the associated increases in FY 2004 resources, are detailed in the table below. These are resources that would have been allocated differently in this request had the President decided to not enter the negotiations. The U.S. funding commitment to ITER will increase significantly in the outyears as the project moves to construction and eventually to science operations.

Fusion Program Resource Changes in Preparation for ITER

Elements	FY 2004 Resources
DIII-D Experimental Program	$5,000,000
Alcator C-Mod Experimental Program.........................	2,000,000
Fusion Plasma Theory & Computation........................	3,000,000
ITER Preparations	2,000,000
Total	$12,000,000

How We Work:

The primary role of the Fusion Energy Sciences (FES) program governance is the funding, management, and oversight of the program. FES has established an open process for obtaining scientific input for major decisions, such as planning, funding, evaluating and, where necessary, terminating facilities, projects, and research efforts. There are also mechanisms in place for building fusion community consensus and orchestrating international collaborations that are fully integrated with the domestic program. FES is likewise active in promoting effective outreach to and communication with related scientific and technical communities, industrial and government stakeholders, and the public.

Advisory and Consultative Activities:

The Department of Energy uses a variety of external advisory entities to provide input that is used in making informed decisions on programmatic priorities and allocation of resources. The FESAC is a standing committee that provides independent advice to the Director of the Office of Science on complex scientific and technological issues that arise in the planning, implementation, and management of the fusion energy sciences program. The Committee members are drawn from universities, national laboratories, and private firms involved in fusion research. The Director of the Office of Science charges the Committee to provide advice and recommendations on various issues of concern to the fusion energy sciences program. The Committee conducts its business in public meetings, and submits reports containing its advice and recommendations to the Department.

In December 1998, Secretary Richardson asked the Secretary of Energy Advisory Board (SEAB) to form a Task Force on Fusion Energy to conduct a review of the Department's fusion energy technologies, both magnetic and inertial, and to provide recommendations as to the role of these technologies as part of a national fusion energy research program. The final report, "Realizing the Promise of Fusion Energy," August 9, 1999, stated "The scientific progress on fusion has been remarkable. As a result, it is the Task Force's view that the threshold scientific question – namely, whether a fusion system producing sufficient net energy gain to be attractive as a commercial power source can be sustained and controlled – can and will be solved…it is our view that we should pursue fusion energy aggressively."

In December 2002, the National Research Council recommended to the Department that, "…the United States enter ITER negotiations while the strategy for an expanded U.S. fusion program is defined and evaluated."

A variety of other committees and groups provide input to program planning. Ad hoc activities by fusion researchers, such as the 2002 Snowmass meeting, provide a forum for community debate and formation of consensus. The President's Committee of Advisors on Science and Technology (PCAST) has also examined the fusion program on several occasions. As noted, the National Research Council, whose Plasma Physics Committee serves as a continuing connection to the general plasma physics community, recently carried out an assessment of the Department of Energy's Fusion Energy Sciences' strategy for addressing the physics of burning plasmas. In addition, the extensive international collaborations carried out by U.S. fusion researchers provide informal feedback regarding the U.S. program and its role in the international fusion energy effort. These sources of information and advice are integrated with peer reviews of research proposals and when combined with high-level program reviews and assessments provide the basis for prioritizing program directions and allocations of funding.

Program Advisory Committees (PACs) serve an extremely important role in providing guidance to facility directors in the form of program review and advice regarding allocation of facility run time. These PACs are formed primarily from researchers from outside the host facility, including non-U.S. members. They review proposals for research to be carried out on the facility and assess support requirements, and, in conjunction with host research committees, provide peer recommendations regarding priority assignments of facility time. Because of the extensive involvement of researchers from outside the institutions, PACs are also useful in assisting coordination of overall research programs. Interactions among PACs for major facilities assure that complementary experiments are appropriately scheduled and planned.

Facility Operations Reviews:

FES program managers perform quarterly reviews of the progress in operating the major fusion facilities. In addition, a review of each of these major facilities occurs periodically by peers from the other facilities. Further, quarterly reviews of each major project are conducted by the Associate Director for Fusion Energy Sciences with the Federal project manager in the field and other involved staff from both the Department and the performers.

Program Reviews:

The peer review process is used as the primary mechanism for evaluating proposals, assessing progress and quality of work, and for initiating and terminating facilities, projects, and research programs. This policy applies to all university and industry programs funded through grants, national laboratory programs funded through Field Work Proposals (FWPs), and contracts from other performers. Peer review guidelines for FES derive from best practices of government organizations that fund science and technology research and development, such as those documented in the General Accounting Office report, "Federal Research: Peer Review Practices at Federal Science Agencies Vary" (GAO/RCED-99-99, March 1999), as well as more specifically from relevant peer review practices of other programs in the Office of Science.

Merit review in FES is based on peer evaluation of proposals and performance in a formal process using specific criteria and the review and advice of qualified peers. In addition to the review of the scientific quality of the programs provided by the peer review process, FES also reviews the programs for their balance, relevance, and standing in the broader scientific community.

Universities and most industries submit grant proposals to receive funding from FES for their proposed work. The grant review process is governed by the already established SC Merit Review System. DOE national laboratories submit annual field work proposals for funding of both new and ongoing activities. These are subject to peer review according to procedures that are patterned after those given in 10 CFR Part 605 that govern the SC grant program. For the major facilities that FES funds, these extensive reviews are conducted as part of a contract or cooperative agreement renewal, with nominally five-year renewal dates. External peer reviews of laboratory programs are carried on a periodic basis. Grants are typically reviewed every three years.

Planning and Priority Setting:

The FESAC carries out an invaluable role in the fusion energy program by identifying critical scientific issues and providing advice on medium- and long-term goals to address these issues. Most recently, the

FESAC has restated support for conclusions and recommendations first given in the 1999 report "Priorities and Balance within the Fusion Energy Sciences Program."

A program planning activity carried out by the research community, "Report of the Integrated Program Planning Activity for the DOE Fusion Energy Sciences Program," (IPPA) December 2000, provides goals for magnetic and inertial fusion, and a framework and process necessary for the achievement of these goals. The long-term program goals developed in the IPPA are:

- Advance the fundamental understanding of plasma, the fourth state of matter, and enhance predictive capabilities, through the comparison of well-diagnosed experiments, theory and simulation.
- Resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic plasma confinement configurations.
- Advance understanding and innovation in high-performance plasmas, optimizing for projected power plant requirements; and participate in a burning plasma experiment.
- Develop enabling technologies needed to advance fusion science; pursue innovative technologies and materials to improve the vision for fusion energy; and apply systems analysis to optimize fusion development.
- Advance the fundamental understanding and predictability of high-energy-density plasmas for IFE, leveraging from the Inertial Confinement Fusion (ICF) target physics work sponsored by the National Nuclear Security Agency (NNSA).
- Develop the science and technology of attractive repetition-rated IFE power systems, leveraging from the ICF work sponsored by NNSA.

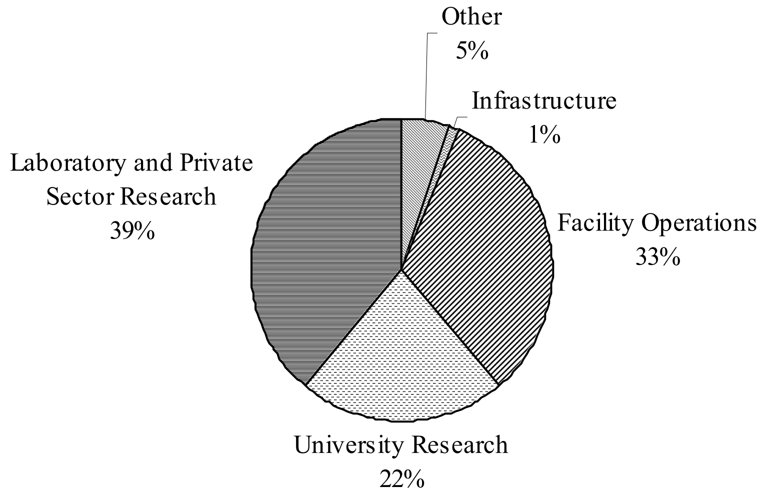
A variety of sources of information and advice, as noted above under the heading "Advisory Activities," are integrated with peer reviews of research proposals and when combined with high-level program reviews and assessments provide the basis for prioritizing program directions and allocations of funding.

How We Spend Our Budget:

The FES budget has three major components: Science, Facility Operations, and Enabling Research and Development. Research efforts are distributed across universities, laboratories, and private sector institutions. In addition to a major research facility at Massachusetts Institute of Technology (MIT), there are several smaller experimental facilities located at universities. There are two other major facilities, located at a national laboratory, and a private sector institution. Enabling Research and Development supports and improves the technical capabilities for ongoing experiments and provides limited long-term development for future fusion power requirements.

The balance of funding levels and priorities underwent overall scrutiny in 1996 by the FESAC when the fusion program focus changed to an increased emphasis on the science underpinnings of fusion research and away from timeline-driven technology development. Subsequent reviews of program quality, relevance, and performance, such as the FESAC review in 1999, "Priorities and Balance Within the Fusion Energy Sciences Program" have made additional adjustments to funding levels for individual programs. As an example, facility operations were planned to be enhanced in FY 2003 relative to FY 2002 and operating time for FY 2004 will remain at the planned FY 2003 level. The research results from these facilities provide a significant addition to the knowledge base required for fusion energy, and therefore it is essential to exploit these facilities to the fullest extent possible. The following chart illustrates the allocation of funding to the major program elements.

Fusion Energy Sciences
Category Breakdown (FY 2004 Request)



Who Does the Research:

The DOE fusion energy sciences program involves over 1,100 researchers and students at more than 70 U.S. academic, federal, and private sector institutions. The program funds research activities at 67 academic and private sector institutions located in 30 states and at 11 DOE and Federal laboratories in 8 states. The three major facilities are operated by the hosting institutions, but are configured with national research teams made up of local scientists and engineers, and researchers from other institutions and universities, as well as foreign collaborators.

University Research:

University researchers continue to be a critically important component of the fusion research program and are responsible for training graduate students. University research is carried out on the full range of scientific and technical topics of importance to fusion energy. University researchers are active participants on the major fusion facilities and one of the major facilities is sited at a university (Alcator C-Mod at MIT). In addition, there are 16 smaller research and technology facilities located at universities, including a basic plasma user science facility at UCLA that is jointly funded by DOE and NSF. There are 5 universities with significant groups of theorists and modelers. About 50 Ph.D. degrees in plasma science and engineering are awarded each year. Over the past three decades, many of these graduates have gone into the industrial sector and brought with them the technical basis for many of the plasma applications found in industry today, including the plasma processing on which today's semiconductor fabrication lines are based.

The university grants program is proposal driven. External scientific peers review proposals submitted in response to announcements of opportunity and funding is competitively awarded according to the guidelines published in 10 CFR Part 605. Support for basic plasma physics is carried out through the NSF/DOE Partnership in Basic Plasma Science and Engineering.

National Laboratory and Private Sector Research:

The Fusion Energy Sciences program supports national laboratory-based fusion research groups at the Princeton Plasma Physics Laboratory, Oak Ridge National Laboratory, Sandia National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Idaho National Engineering and Environmental Laboratory, Argonne National Laboratory, and Los Alamos National Laboratory. In addition, one of the major research facilities is located at and operated by General Atomics in San Diego, California. The laboratory programs are driven by the needs of the Department, and research and development carried out there is tailored to take specific advantage of the facilities and broadly based capabilities found at the laboratories.

Laboratories submit field work proposals for continuation of ongoing or new work. Selected parts of proposals for continuing work are reviewed on a periodic basis, and proposals for new work are peer reviewed. FES program managers review laboratory performance on a yearly basis to examine the quality of their research and to identify needed changes, corrective actions, or redirection of effort.

Program Strategic Performance Goals

SC6-1: Improve 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 and Enabling Technologies subprograms)

Performance Indicator

Eighty percent of all new research projects will be peer reviewed and deemed excellent and relevant, and annually, 30% of all ongoing projects will be subject to peer review with merit evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
	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. (SC6-1)	Conduct feedback control experiments in DIII-D with the new internal control coils to reach plasma operating conditions beyond the limits that can be achieved without the stabilizing effect of a near-by conducting wall. (SC6-1)
	Produce high temperature plasmas with 5 Megawatts of Ion Cyclotron Radio Frequency (ICRF) power for pulse lengths of 0.5 second in Alcator C-Mod. Assess the stability and confinement properties of these plasmas, which would have collisionalities in the same range as that expected for the burning plasma regime. (SC6-1)	Compare energy confinement, H-mode thresholds, and divertor particle dynamics in single-null, double-null, and inner-wall-limited discharges in Alcator C-Mod, establishing limits of divertor power handling for advanced tokamak plasma regimes and requirements for advanced divertors for planned burning plasma tokamaks. (SC6-1)
		Include electron dynamics in turbulent transport simulations and compare the results with experimental results from both U.S. and foreign tokamaks to benchmark the simulation code.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
		(SC6-1)
Use recently upgraded plasma microwave heating system and new sensors on DIII-D to study feedback stabilization of disruptive plasma oscillations. (met goal)		Expand the experiments on stabilization of Neoclassical Tearing Mode instabilities with increased electron cyclotron heating power in DIII-D and compare the results with computational models to benchmark the theories. (SC6-1)
		Complete detailed design of an advanced, high-power, load tolerant, ion cyclotron radio frequency antenna for C-Mod. (SC6-1)
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) (met goal)	Complete testing of the High-Power Prototype advanced ion-cyclotron radio frequency antenna that will be used at the Joint European Torus.	

SC6-2: Resolve outstanding science/technology issues and explore options for more attractive magnetic and inertial fusion energy systems (Science and Enabling R&D subprograms)

Performance Indicator

Eighty percent of all new research projects will be peer reviewed and deemed excellent and relevant, and annually, 30% of all ongoing projects will be subject to peer review with merit evaluation.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Demonstrate innovative techniques for initiating and maintaining current in a spherical torus. (SC6-2) (Goal met)		Assess confinement and stability in NSTX by characterizing high confinement regimes with edge barriers and by obtaining initial results on the avoidance or suppression of plasma pressure limiting modes in high-pressure plasmas. (SC6-2)
		Integrate elements of initial plasma neutralized beam focus and carry out initial experiments in support of heavy ion beam inertial fusion. (SC6-2)
		Carry out full voltage beamlet acceleration and determine beamlet characteristic (multibeamlet source configured in FY 2003) for heavy ion beam inertial fusion. (SC6-2)
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. (goal met)	Complete preliminary experimental and modeling investigations of nano-scale thermodynamic, mechanical, and creep-rupture properties of nanocomposited ferritic steels.	Under a cost-shared collaborative program with Japan for irradiation testing of fusion materials in U.S. fission reactors, complete first phase of testing to evaluate the effects of neutron bombardment on the microstructural

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
		evolution, and property changes of candidate fusion materials.
Complete analysis of JET MARK-II inner divertor performance. (goal met)		

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

Performance Indicator

Average operational downtime of FES facilities will not exceed 10% of total time scheduled, and construction and upgrades of facilities will be within 10% of baseline schedule and cost.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Keep deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of project baselines; successfully complete within cost and in a safe manner all TFTR decontamination and decommissioning activities. (goal met)	Keep deviations in cost and schedule for upgrades and construction of scientific user facilities within 10 percent of project baselines; complete the National Compact Stellarator Experiment (NCSX) Preliminary Design. (SC7-6)	Complete the Final Design of the National Compact Stellarator Experiment and begin fabrication.
Keep deviations in weeks of operation for each major facility within 10 percent of the scheduled weeks. (goal not met)	Keep deviations in weeks of operation for each major facility within 10 percent of the scheduled weeks. (SC7-6)	Keep deviations in weeks of operation for each major facility within 10 percent of the scheduled weeks. (SC7-6)

Program Assessment Rating Tool (PART) Assessment

In the PART review, the OMB gave the FES program a perfect score (100) in the “Purpose” section, and a fairly high score (73) in the “Management” section. These scores are attributed to the use of standard management practices in the Office of Science. In the “Planning” section, the low score (56) is attributed by OMB to the FES program’s lack of long-term and annual performance measures. Nevertheless, the OMB recognizes that the FES program has made significant strides toward developing such measures despite the problems inherent in predicting and then measuring scientific progress.

Specifically, OMB stated that the FES program delivers projects on cost and schedule, and it receives a significant amount of external expert assessments of its research and program management strategies. However, OMB finds that the program budget is not sufficiently aligned with program goals so that the impact of funding changes on performance is readily known and so that basic research elements can be distinguished from applied research elements.

To address these findings, the program will work to reform its performance measures and goals, understanding the difficulties that basic research program face in attempting to predict future scientific progress. The program will also work to further clarify the relationship between the program’s goals and the budget.

Significant Program Shifts

The budget requested for FY 2004 is equal to the FY 2003 Request. The FY 2004 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).

The principal program shifts result from a view that a burning plasma physics experiment is the appropriate next step in the fusion program. Evaluations of domestic technical progress over the past decade have led to an evolution in the program direction to include the burning plasma focus. With the President's decision to join the ITER negotiations to build a burning plasma experimental facility, longer range technology activities will be curtailed to focus on aspects of the present program that most directly support preparations for the realization of the burning plasma device and experiments. In fact, the majority of the existing and proposed program elements already contribute to improving our understanding and future advancement of tokamak science thereby providing a strong base for our future contributions to and ability to benefit from these future experiments.

Whether or not a burning plasma experiment will be realized through the construction and operation of the proposed ITER device will depend on the success of the international negotiations in determining an agreed-upon site for the facility, an agreed-upon financial and procurement arrangement, and satisfactory management and oversight arrangements. In these negotiations, the U.S. will strive for incorporation of its principles of equity, accountability and visibility, which will be an important part of any decision-making process for joining any future construction project. Should the ITER project not proceed to fruition, FESAC has recommended that the U.S. fusion program continue toward a burning plasma experiment, using the FIRE concept which is a modest size burning plasma experiment for which conceptual design studies have been carried out, and seeking partnership from within the international fusion community. Specific burning plasma tasks outlined in this budget proposal are supportive of ITER and would also be supportive of FIRE, as the technical physics issues are similar.

A new program to support fusion science "Centers of Excellence" will be initiated in FY 2004. This new program opportunity responds to recommendations made by the National Research Council in their 2001 assessment of the Fusion Energy Sciences program. This program will enhance the long term development of the human capital that will be needed to carry out a sustained fusion energy program, as well as providing key connections to cross-cutting science efforts at the university level. Proposals will be solicited and peer reviewed to select proposals for funding in FY 2004. It is intended that the role of these centers will be similar to the Science Frontier Centers funded by the National Science Foundation.

AWARDS

- A CalTech student received the 2002 Award for Outstanding Doctoral Dissertation in plasma physics.
- Seven fusion researchers were elected Fellows of the American Physical Society in 2001.
- Four fusion researchers received the 2002 Award for Excellence in Plasma Physics Research from the American Physical Society.
- A young researcher with the IFE program received a Presidential Early Career Award for Scientists and Engineers.

- The TFTR D&D effort at PPPL was honored as 2002 Project of the Year by the Professional Engineers Society of Mercer County (NJ) for use of diamond wire cutting of complex metal vessels.
- A fusion Engineer was honored by the ASME with their Engineering and Technology Management Leadership Award.

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 2002, the FES program supported 365 graduate students and post-doctoral investigators. Of these, 50 students conducted research at the DIII-D tokamak at General Atomics, the Alcator C-Mod tokamak at MIT, or the NSTX at PPPL. A Junior Faculty development program for university plasma physics researchers and the NSF/DOE partnership in basic plasma physics and engineering focus on the academic community and student education.

	FY 2000	FY 2001	FY 2002	FY 2003, est.	FY 2004, est.
# University Grants	177	188	188	185	185
# Permanent PhD's [a]	749	741	731	740	730
# Postdocs	91	99	99	100	100
# Grad Students	246	246	266	270	260
# PhD's awarded	49	49	53	50	50

[a] Permanent PhD's includes faculty, research physicists at universities, and all PhD-level staff at national laboratories.

Scientific Discovery through Advanced Computing (SciDAC)

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all Office of Science mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit tera-scale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, astrophysics and computational chemistry.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes funds 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.

The total number of weeks of operation at all of the major fusion facilities is shown in the following table.	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
Maximum weeks	75	75	75	75	75
Scheduled weeks	54	44	34	63	63
Unscheduled weeks of Downtime	7%	0%	6%	TBD	TBD

In addition to the operation of the major fusion facilities, several Major Item of Equipment projects are supported in the fusion program. Milestones for these projects are shown in the following table.

FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
Completed NSTX Neutral Beam.				
			Complete NCSX preliminary design. Start NCSX project.	Complete final design of NCSX and begin fabrication.
Started C-Mod Lower Hybrid Upgrade Project.			Complete C-Mod Lower Hybrid Upgrade Project.	

Funding Profile

(dollars in thousands)

	FY 2002 Comparable Appropriation	FY 2003 Request	FY 2004 Request	$ Change	% Change
Fusion Energy Sciences					
Science	134,307	142,565	144,670	+2,105	+1.5%
Facility Operations	70,803	78,653	87,726	+9,073	+11.5%
Enabling R&D	35,990	36,092	24,914	-11,178	-31.0%
Subtotal, Fusion Energy Sciences	241,100	257,310	257,310	0	--
Adjustment	0	0	0	0	--
Total, Fusion Energy Sciences	241,100[bc]	257,310	257,310	0	--

Public Law Authorization:
Public Law 95-91, "Department of Energy Organization Act"
Public Law 103-62, "Government Performance and Results Act of 1993"

[b] Excludes $139,000 for the FY 2002 rescission contained in section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.
[c] Excludes $5,888,000 which was transferred to the SBIR program and $353,000 which was transferred to the STTR program.

Funding By Site[a]

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	7,799	7,308	3,765	-3,543	-48.5%
Sandia National Laboratories	3,178	3,213	2,786	-427	-13.3%
Total, Albuquerque Operations Office	10,977	10,521	6,551	-3,970	-37.7%
Chicago Operations Office					
Argonne National Laboratory	1,662	1,522	1,192	-330	-21.7%
Princeton Plasma Physics Laboratory	69,607	63,576	70,563	+6,987	+11.0%
Chicago Operations Office	44,586	49,317	50,140	+823	+1.7%
Total, Chicago Operations Office	115,855	114,415	121,895	+7,480	+6.5%
Idaho Operations Office					
Idaho National Engineering and Environmental Laboratory	2,356	2,392	1,823	-569	-23.8%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	5,952	5,799	5,718	-81	-1.4%
Lawrence Livermore National Laboratory	14,510	14,411	13,408	-1,003	-7.0%
Oakland Operations Office	69,595	73,779	69,926	-3,853	-5.2%
Total, Oakland Operations Office	90,057	93,989	89,052	-4,937	-5.3%
Oak Ridge Operations Office					
Oak Ridge Inst. For Science & Education	347	808	888	+80	+9.9%
Oak Ridge National Laboratory	19,454	19,258	18,693	-565	-2.9%
Oak Ridge Operations Office	0	0	0	0	--
Total, Oak Ridge Operations Office	19,801	20,066	19,581	-485	-2.4%
Richland Operations Office					
Pacific Northwest National Laboratory	1,415	1,556	1,440	-116	-7.5%
Richland Operations Office	0	0	0	0	--
Total, Richland Operations Office	1,415	1,556	1,440	-116	-7.5%

[a] On December 20, 2002, the National Nuclear Security Administration (NNSA) disestablished the Albuquerque, Oakland, and Nevada Operations Offices, renamed existing area offices as site offices, established a new Nevada Site Office, and established a single NNSA Service Center to be located in Albuquerque. Other aspects of the NNSA organizational changes will be phased in and consolidation of the Service Center in Albuquerque will be completed by September 30, 2004. For budget display purposes, DOE is displaying non-NNSA budgets by site in the traditional pre-NNSA organizational format.

	(dollars in thousands)				
	FY 2002	FY 2003	FY 2004	$ Change	% Change
Savannah River Operations Office					
Savannah River Laboratory	50	49	45	-4	-8.2%
Washington Headquarters	589	14,322	16,923	+2,601	+18.2%
Total, Fusion Energy Sciences	241,100[bc]	257,310	257,310	0	--

[b] Excludes $139,000 for the FY 2002 rescission contained in section 1403 of P.L. 107-226, Supplemental Appropriations for further recovery from and response to Terrorist attacks on the United States.
[c] Excludes $5,888,000 which was transferred to the SBIR program and $353,000 which was transferred to the STTR program.

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 magnetic 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. In FY 2003, INEEL will complete a small tritium laboratory (Safety and Tritium Applied Research Facility).

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 accelerator 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 from and completion of the stabilization of the Tritium Systems Test Assembly facility prior to turning the facility over to the Office of Environmental Management for Decontamination and Decommissioning at the end of FY 2003.

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, is a major partner with PPPL on 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 has completed 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 Measures

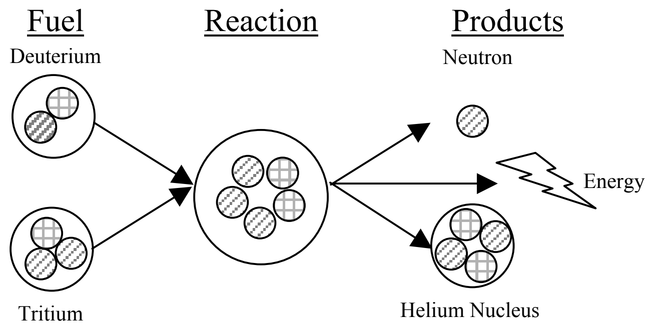
The Science subprogram supports the quest for fusion power by fostering fundamental research in plasma science aimed at a predictive understanding of plasmas in a broad range of plasma confinement configurations. There are two basic approaches to confining a fusion plasma and insulating it from its much colder surroundings—magnetic and inertial confinement. In the former, carefully engineered magnetic fields isolate the plasma from the walls of the surrounding vacuum chamber, while in the latter, a pellet of fusion fuel is compressed and heated so quickly that there is no time for the heat to escape. There has been great progress in plasma science during the past three decades, in both magnetic and inertial confinement, and today the world is at the threshold of a major advance in fusion power development--the study of burning plasmas, in which the self-heating from fusion reactions dominates the plasma behavior.

Plasmas, the fourth state of matter, comprise over 99% of the visible universe and are rich in complex, collective phenomena. During the past decade there has been considerable progress in our fundamental understanding of key individual phenomena in fusion plasmas, such as transport driven by micro-turbulence, and macroscopic equilibrium and stability of magnetically confined plasmas. Over the next five years the Science subprogram will continue to advance the understanding of plasmas through an integrated program of experiments, theory, and simulation as outlined in the ***Integrated Program Planning Activity for the Fusion Energy Sciences Program*** prepared for FES and reviewed by the Fusion Energy Sciences Advisory Committee. This integrated research program will focus on well-defined plasma scientific issues including turbulent transport, macroscopic stability, wave particle interactions, multiphase interfaces, hydrodynamic stability, implosion dynamics, and heavy-ion beam transport and focusing. We expect this research program to yield new methods for sustaining and controlling high temperature, high-density plasmas, which will have a major impact on a burning plasma experiment, such as ITER, and to benefit from ignition experiments on the NNSA-sponsored National Ignition Facility (NIF).

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 Junior Faculty development grants for members of university plasma physics faculties, will continue to contribute to this objective. A new "Centers of Excellence in Fusion Science" program will also foster fundamental understanding and connections to related sciences.

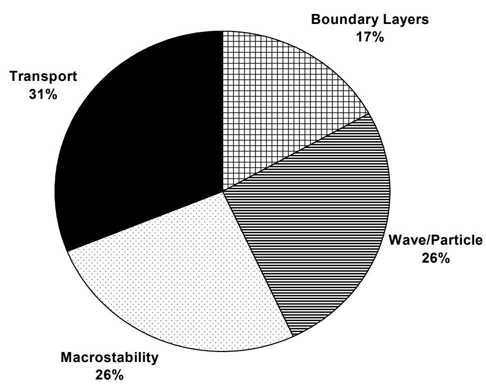
Plasma science includes not only plasma physics but also physical phenomena in a much wider class of ionized matter, in which atomic, molecular, radiation-transport, excitation, and ionization processes are important. These phenomena can play significant roles in partially ionized media and in the interaction 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, industrial processing, and national security.

Fusion science, a major sub-field of plasma science, is focused primarily on describing the fundamental processes taking place in plasmas where the peak temperatures are greater than 100 million degrees Celsius and densities great enough that hydrogenic nuclei collide and 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 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 fields is likely to be required for ultimate success in achieving a practical fusion energy source.



The total funding spent on MFE in FY 2002 is split roughly as shown to address major scientific issues.

For Inertial Fusion Energy (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.

SCIENCE ACCOMPLISHMENTS

Research funded by the Fusion Energy Sciences program in FY 2002 produced major scientific results over a wide range of activities. Selected accomplishments that address scientific issues for fusion and long-term fusion goals include:

- Studies of feedback stabilization of disruptive plasma oscillation were successfully carried out in DIII-D in FY 2002, using the recently acquired electron cyclotron heating (ECH) power. Up to 4.0

MW of ECH power was deposited in selected regions of the plasma, using steerable ECH antennae, to drive additional plasma current. These currents alter the conditions for detrimental plasma oscillations and stabilize them to avoid disruptions. The stabilization of different modes of oscillations has been demonstrated, raising the performance of the plasma and extending its pulse length. (SC6-1 FY 2002 Target)

- NSTX has successfully demonstrated innovative techniques for initiating and maintaining current in a spherical torus. The device initiated plasmas using Coaxial Helicity Injection and maintained high ratios of plasma pressure to applied magnetic pressure for increased durations by raising current drive while reducing induction. A number of these plasmas were operating in the High-Confinement-Mode (H-mode) lasting essentially the flat-top duration of the plasma current. (SC6-1 FY 2002 Target)
- Improved modeling of macroscopic stability has been achieved. Improvements in extended magnetohydrodynamic codes enabled by the Scientific Discovery through Advanced Computing initiative have made it possible to simulate the dynamics of NSTX plasmas that have strong sheared flows.
- There are new results in the area of transport and turbulence in tokamaks. New measurements using high speed cameras on C-Mod, NSTX and DII-D have shown the presence of "blobs" of high density plasma being formed and moving outward from the region of good confinement in all three machines. Movies showing the time evolution of this process have been made. These "blobs" may account for the bigger part of the turbulent transfer across the magnetic field. Together with other direct measurements, this work is now providing some insight into the cause of the density limits observed in tokamaks.
- With the availability of the new, high-performance computer at the National Energy Research Scientific Computing Center, it is now possible to simulate the turbulence in tokamaks approaching the size of the International Thermonuclear Experimental Reactor (ITER). Simulations performed in the past year indicate that the transport caused by the plasma turbulence initially increases with the size of the plasma, but then levels off at a constant value. This is a favorable result for reactor-scale tokamaks like ITER and provides increased confidence that they will achieve their desired fusion energy gain.
- One major concern for tokamaks is that tokamak discharges might prematurely terminate (disrupt) when the plasma pressure or density exceeds their limits, and cause excessive current or heat loads on the tokamak components. On DIII-D, such disruptions have been successfully terminated by injecting high-pressure noble gas into the plasma, thereby, avoiding high-energy runaway electrons, unwanted plasma currents in the vessel, and excessive heat load on divertor target plates.
- Innovative confinement concepts have also shown improvements in stability, turbulence and transport. New results have been achieved in some of these concepts that will provide the basis in the future for further development as fusion power sources. As an example, current profile modification experiments in the Madison Symmetric Torus (MST) at the University of Wisconsin have greatly reduced magnetic fluctuations, increasing the energy confinement time by a factor of 10 above the usual empirical scaling for reversed-field pinches (RFPs).
- Inertial fusion energy is a non-magnetically confined approach to fusion energy in which energy-producing targets are compressed and ignited by external beams. For heavy ion beam drivers, producing, transporting, and focusing the beams are the main technical challenges and are one of the

main IFE program goals. Recent experiments at LBNL have achieved record currents in the high current experiment (HCX) using both electrostatic and magnetic focusing elements. The results from these measurements provide an important database for validating beam transport calculations.

Subprogram Goals

Advance the fundamental understanding of plasma, the fourth state of matter, and enhance predictive capabilities, through the comparison of well-diagnosed experiments, theory and simulation.

Resolve outstanding scientific issues and establish reduced-cost paths to more attractive fusion energy systems by investigating a broad range of innovative magnetic and inertial plasma confinement configurations.

Advance understanding and innovation in high-performance magnetically confined plasmas, optimizing for projected power plant requirements and participate in an international burning plasma experiment.

Advance the fundamental understanding and predictability of high energy density plasmas for IFE, leveraging from the Inertial Confinement Fusion (ICF) target physics work sponsored by the National Nuclear Security Agency (NNSA).

Performance Indicators

(1) Fraction of all new research projects that are peer reviewed and deemed excellent and relevant; target 80%.
(2) Fraction of all ongoing projects subject to peer review with merit evaluation; target 30% per year.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Show that stability in a tokamak can be affected by the interaction of microwaves with electrons in the core of the plasma. Result: achieved on DIII-D.	Maintain high performance in DIII-D by controlling plasma instabilities with microwaves.	Use higher power radio frequency and microwave systems to extend the range of validity for the negative central shear mode of advanced tokamak operation on the DIII-D facility.
	Explore operating regime of the newly discovered "quiescent double barrier" mode on DIII-D.	Develop improved physics understanding of the "quiescent double barrier" mode on DIII-D and evaluate its impact on the operational range of advanced tokamaks.
Apply new diagnostics including high speed cameras to increase understanding of transport at the edge of tokamaks. Result: achieved on C-Mod and NSTX.	Demonstrate the role of self-driven currents in edge instabilities in DIII-D using the new edge current diagnostics.	Carry out studies of transport in the edge of C-MOD plasmas for high densities near density limits.
Using improved magnetohydrodynamic codes developed under SciDAC to analyze NSTX modes with toroidal totation to explain changes in plasma profiles. Result: achieved on NSTX.	Measure and analyze the dispersion of heat flux on plasma facing components under conditions of high heating power in NSTX.	Assess confinement and stability in NSTX by characterizing high confinement regimes with edge barriers and by obtaining initial results on the avoidance or suppression of plasma pressure plasmas.

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Demonstrate enhanced energy confinement times in a reversed-field-pinch by use of current modification. Result: achieved transiently on MST at the University of Wisconsin.	Study the effects of magnetic fluctuations in high temperature plasmas on magnetic reconnection and dynamo.	Continue the study of the magnetic dynamo, which is intrinsic to the reversed-field –pinch and is of interest to several other fields of non-fusion plasma science.
Bring on line 3 new experimental facilities for heavy ion inertial fusion research (high current experiment, source test stand and plasma system for beam focusing) and begin initial operation of each. Result: Each of the facilities was completed and brought into operation.	Conduct beam transport analysis for full current beams in HCX to provide a data base for "end to end" beam simulations.	Evaluate the effects of stray electrons on heavy ion beam instabilities by comparing results from the high current experiment (HCX) with calculations of beam transport through HCX.
	Carry out detailed comparisons of experimental measurements of turbulence in tokamak facilities with calculations made with codes enhanced under SciDAC.	Explore MHD equilibrium and stability in stellarators using linear and nonlinear global stability codes, including free-boundary and finite larmor radius effects. Compare code calculations with experimental results from international stellarators in preparation for the operation of NCSX.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Tokamak Experimental Research	45,479	48,609	46,340	-2,269	-4.7%
Alternative Concept Experimental Research	52,328	50,913	52,169	+1,256	+2.5%
Theory	27,628	27,608	28,508	+900	+3.3%
General Plasma Science	8,872	9,060	11,050	+1,990	+22.0%
SBIR/STTR	0	6,375	6,603	+228	+3.6%
Total, Science	134,307	142,565	144,670	+2,105	+1.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Tokamak Experimental Research	**45,479**	**48,609**	**46,340**

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 facilities abroad aimed at establishing an international database of Tokamak experimental results. In association with the International Tokamak Physics Activity, both DIII-D and Alcator C-Mod will increase their efforts on joint experiments with other major facilities in Europe and Japan in support of ITER-relevant physics issues.

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 and microwave current drive and the interface between the plasma edge and the material walls of the confinement vessel by means of a "magnetic divertor." Achieving high performance regimes for longer pulse duration, approaching the steady state, will require simultaneous advances in all of the scientific issues listed above.

	FY 2002	FY 2003	FY 2004
▪ **DIII-D Research**	**23,747**	**22,733**	**23,329**

The DIII-D tokamak is the largest magnetic fusion facility in the United States. DIII-D provides for considerable experimental flexibility and has extensive diagnostic instrumentation to measure what is happening in a high temperature plasma. It also has unique capabilities to shape the plasma, which, in turn, affects particle transport in the plasma and the stability of the plasma. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layer physics using a "magnetic divertor" to control the 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.)

The DIII-D experimental program contributes to all four key Magnetic Fusion Energy (MFE) fusion topical science areas—energy transport, stability, plasma-wave interactions, and boundary physics, and various thrust areas that integrate across topical areas to support the goal of achieving a burning plasma. The level of effort for most physics research topics in FY 2004 remains essentially flat from FY 2003, however, *there will be an increased effort on joint research topics in support of burning plasma physics, specifically for ITER. The research will elucidate the effects of plasma edge instabilities and high pressure in various plasma confinement regimes, extending the duration of stable plasma operation, and helping build cross-machine data bases using dimensionless parameter ("wind tunnel") techniques among other topics.*

(dollars in thousands)		
FY 2002	FY 2003	FY 2004

The program will also continue the investigation of the scientific basis for optimization of the tokamak approach to fusion energy production. This research includes investigation of different modes of operation of fusion plasmas in the so-called Advanced Tokamak (AT) regime for enhancing the attractiveness of tokamak plasmas for energy production. In particular, the experimental program will aim at accomplishing the following three related research goals in FY 2004: 1) demonstrate the technical benefits of operating AT plasmas with a normalized beta (a measure of plasma pressure) value above the "standard" value, made possible by feedback control of new internal wall stabilization coils installed in FY 2003. The initial experiments in FY 2003 with these coils will set direction of the experiments in FY 2004. 2) Extend the "Negative Central Shear" mode of AT research to higher performance and long pulse plasmas using the 6 MW Ion Cyclotron Range Frequency (ICRF) system, and the 6 MW Electron Cyclotron Heating (ECH) system. The refurbishment and commissioning of the ICRF system, which was built about 4 years ago, will start in FY 2003, and it will be available for these experiments in FY 2004. This system will provide additional electron heating capability and improve the current drive provided by the ECH system. 3) Investigate further the physics of the Quiescent Double Barrier (QDB) AT regime, which was discovered in DIII-D 3 years ago. The QDB regime is attractive for steady-state operation of AT plasmas because of the absence of periodic heat pulses that impinge on divertor target plates. The activities in all these three areas are interrelated, and they will improve the physics basis and demonstration of a long-pulse, high-performance AT for energy production purposes.

	FY 2002	FY 2003	FY 2004
▪ **Alcator C-Mod Research**..	**7,479**	**8,464**	**8,458**

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 high power densities.

By virtue of these characteristics, Alcator C-Mod 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, high density burning plasma physics tokamaks. Burning plasmas can be achieved for short pulses in a low cost tokamak by trading high magnetic field for large size (and cost). Alcator C-Mod has made significant contributions to the world fusion program in the areas of plasma heating, stability, and confinement in high field tokamaks, which are important integrating issues related to ignition and burning of a fusion plasma. In FY 2004 the C-Mod research effort is approximately level with that of FY 2003. However, *resources will be focused on ITER relevant topics such as understanding the physics of the plasma edge in the presence of large heat flows, measuring the effects of and mitigating disruptions in the plasma, controlling the current density profile for better stability, and helping build cross-machine data bases using dimensionless parameter ("wind tunnel") techniques*.

Research will also continue to examine the physics of the plasma edge, power and particle exhaust from the plasma, mechanisms of self-generation of plasma flows, and the characteristics of the Advanced Tokamak modes achieved when currents are driven by radio and microwaves. It will also focus on studying transport in the plasma edge at high densities and in relation to the plasma density limit. A diagnostic neutral beam will further improve visualization of turbulence in the edge and core of high density plasmas, and beam enabled diagnostics will shed light on the plasma physics of temperature and density profile pedestals whose features are now thought to predict future machine

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

behavior. Active MHD spectroscopy is a novel method for sensing the onset of instability and will also be implemented in FY 2004. This diagnostic may well revolutionize the way a plasma discharge is feedback controlled to avoid disruptions. Compact high field tokamak regimes and operation scenarios required for ignition in compact devices will be further explored. The new lower hybrid (microwave) current drive system will be in operation, and experiments will begin using it for control of the current density profile.

- **International Collaborations, Education and Other** **7,158** **10,255** **7,540**

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.

International collaboration will continue on unique tokamaks abroad. However, *the United States will reduce the international program activities in FY 2004 and focus on joint International Tokamak Physics Activity (ITPA) with Japan, Europe, and Russia to enhance collaboration on physics issues related to tokamak burning plasmas.* In FY 2004, the remaining direct collaboration with international 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 the relocation of personnel and facilities to a new location within ORNL has been transferred to the facility operations subprogram. Funding for educational activities in FY 2004 will support research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, and outreach efforts related to fusion science and technology.

- **Experimental Plasma Research (Tokamaks)**......................... **7,095** **7,157** **7,013**

Funding provided in this category, for FY 2004, will continue to support research on innovative tokamak experiments at universities and the development of diagnostic instruments.

The Electric Tokamak (ET) at UCLA will explore several new approaches to toroidal magnetic confinement using radio waves to drive plasma rotation and in order to achieve a very high plasma pressure relative to the applied magnetic field, which in turn will produce a deep magnetic well for good plasma confinement. Complementing the advanced tokamak research on DIII-D and Alcator C-Mod is the exploratory work on two university tokamaks. This has the prospect of leading to more efficient use of magnetized volume and steady-state plasma stability, with associated attractiveness in eventual fusion power applications. The goal of the High Beta Tokamak (HBT) at Columbia University is to demonstrate the feasibility of stabilizing instabilities in a high pressure tokamak plasma using a combination of a close-fitting conducting wall, plasma rotation, and active

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

feedback. This work is closely coordinated with the DIII-D program, and promising results have already been achieved on DIII-D.

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 energy 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 2004 supports research that will enhance our understanding of critical plasma phenomena and the means of affecting these phenomena to improve energy and particle confinement in tokamaks and innovative confinement machines. *The funding will also support development of diagnostic systems related to the processes associated with burning plasmas, on U.S. and foreign facilities.* Currently supported programs were the highest ranked proposals submitted to a competitive peer review in FY 2002.

	FY 2002	FY 2003	FY 2004
Alternative Concept Experimental Research	**52,328**	**50,913**	**52,169**

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 operating in FY 2000. Like DIII-D and Alcator C-Mod, NSTX is also operated as a national scientific user facility.

	FY 2002	FY 2003	FY 2004
▪ **NSTX Research**	**12,780**	**13,696**	**15,951**

NSTX is one of the world's two largest embodiments of the spherical torus confinement concept. 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. Plasmas in spherical torii 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 torii 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. An associated issue for spherical torus configurations is the challenge of driving plasma current via radio-frequency waves or biased electrodes. Such current drive techniques are essential to achieving sustained operation of a spherical torus.

The spherical torus plasma, as in all high beta plasmas, is uniquely characterized by high velocity fast ions and with a large radius of gyration relative to plasma size that could potentially lead to new plasma behaviors of interest. In FY 2004, increased funding will allow enhanced participations by national team members in several areas. Comparison of experimental results with theory will

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

contribute to the scientific understanding of these effects needed to consider future experiments with similar energetic ion properties. Several new diagnostics that will become operational will be used on NSTX. Using these new diagnostics, assessment of long wavelength turbulence in the plasma core in a range of operating scenarios will also be undertaken. Additionally, measurement of current profile modifications from the applications of RF techniques, neutral beam injection, and the bootstrap effect will be pursued with measurement techniques suitable for low magnetic field devices. Finally, new measurement techniques using beams of energetic atoms and lasers will be employed to assess changes in the profile of the plasma current induced by radio-frequency waves, injected energetic neutral particles, and changes in the plasma pressure profile to determine how best to sustain large currents in spherical torii.

- **Experimental Plasma Research (Alternatives)** **25,955** **23,443** **22,721**

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 both the NCSX and QPS novel compact stellarator designs.

The goals of this work are to: a) find new innovative confinement schemes that have advantages when compared to the tokamak; b) find new innovative ways of increasing the plasma performance of advanced confinement schemes like the tokamak, stellarator, or reversed field pinch; and c) find innovative ways to study in an isolated manner key issues of plasma behavior, such as reconnection or turbulence. All these efforts are to be done on small, low cost experimental devices.

The Innovative Confinement Concept (ICC) development program is a broad-based activity with researchers located at national laboratories, universities, and industry. Because of the small size of the experiments and the use of the latest technologies, these small-scale experiments provide excellent places to train students and post-docs, and develop the next generation of fusion scientists who will need to explore the next frontier of fusion research, burning plasma.

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.

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

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. Another design, the Quasi-Poloidal Stellarator (QPS), using an even more radical approach, is being pursued at ORNL. This design is based on a different symmetry to achieve an even more compact configuration. Both approaches will strengthen U.S. involvement in the much larger world stellarator program.

The magnetized target fusion program (funded by the FES program) at LANL and the Air Force Research Laboratory will study the possibility that a field reversed configuration plasma can be compressed to multi-keV temperatures using fast liner compression technology developed by NNSA's Defense Programs.

The key to success in this program is to be continually generating new innovative ideas. In order to foster a vigorous breeding ground for these kinds of ideas, each year approximately 1/3 of the concepts will be competitively peer reviewed. This review will be used to weed out the concepts that have not been able to follow through with their initial innovative ideas, and to find new innovative ideas that can be pursued in small experiments. The review will affect the innovative confinement concepts program in FY 2004. It is anticipated that there will be some changes in the program.

	FY 2002	FY 2003	FY 2004
▪ **Inertial Fusion Energy Experiments**......................................	**13,593**	**13,774**	**13,497**

An entirely different set of science explorations is being carried out in the area of inertial fusion. 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. In assessments of IFE carried out by several committees and study groups in the past, heavy ions were recommended as the optimum driver for inertial fusion energy, with lasers as possible alternatives. Based on these assessments, heavy ions define the focus for the FES program. However, there have been recent advances in energy producing target design and high average power laser technology. In the NNSA inertial confinement program, there is a dual use program for high average power lasers that has inertial fusion energy relevance. Within the FES program, there are some elements that support innovation in IFE (fast ignitor science, for example) with relevance to laser driven IFE and there are commonalities in technology areas in target chambers and target technologies that are coordinated between FES and NNSA. 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.

The inertial fusion energy program is focused 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.

Heavy ion accelerators continue to be the leading IFE driver candidate. The physics of intense heavy ion beams (multiply charged Bismuth, for example) and other non-neutral plasmas are 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.

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. In FY 2004, the High Current Experiment (HCX) will do experiments to simulate ion bunch control with electrostatic and magnetic focusing elements. The dynamics of stray electrons will be studied, and results used to compare with beam simulation calculations. The neutralized focus experiments using the facility jointly developed by PPPL and LBNL will be completed. New ion beamlet acceleration tests will be completed to obtain beamlet characteristics. Physics experiments carried out on NNSA-funded facilities including (in the future) the National Ignition Facility (NIF) will provide high energy density physics data to be used in the design of targets for IFE experiments. Experiments on 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	**27,628**	**27,608**	**28,508**

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 facilities, 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 controlled.

The theory and modeling program is a broad-based program with researchers located at national laboratories, universities, and industry. Institutional diversity is a strength of the program, since theorists at different types of institutions play different roles in the program. Theorists in larger groups, which are mainly at national laboratories and industry, generally support major experiments, work on large problems requiring a team effort, or tackle complex issues requiring a multidisciplinary teams while those at universities generally support smaller, innovative experiments or work on more fundamental problems in plasma physics.

The theory program is composed of four elements—tokamak theory, alternate concept theory, generic theory, and advanced computation. The main thrust of the work in tokamak theory is aimed at

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

developing a predictive understanding of advanced tokamak operating modes and burning plasmas, both of which are important to ITER. 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.

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.

In FY 2004 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 the preparations for a burning plasma experiment, a set of innovative national experiments, and fruitful collaboration on major international facilities. Through the middle of FY 2004, computational efforts will be focused on comparison of experimental results with turbulence calculations, that include kinetic electrons, the inclusion of the plasma's self-generated currents, and flows 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 the basis for developing a more comprehensive predictive understanding of fusion plasmas, which will be of great value in planning for a burning plasma experimental program in ITER. *In addition, the FES program will initiate a new "Centers of Excellence in Fusion Science" program in FY 2004. This action responds to a recommendation from the NRC assessment report. It is anticipated that no more than 2 centers will be funded.* Continuation of this effort in the future could lead to a more comprehensive capability that would pave the way to improved utilization of ITER and enhanced scientific understanding from ITER.

General Plasma Science...	**8,872**	**9,060**	**11,050**

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

	(dollars in thousands)	
FY 2002	FY 2003	FY 2004

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 2004, the program will continue to fund proposals that have been peer reviewed. *In addition, Fusion Energy Sciences will initiate a new "Centers of Excellence in Fusion Science" program in FY 2004. This action responds to a recommendation from the NRC assessment report. It is anticipated that no more than 2 centers will be funded.* 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 continue to share the cost of funding plasma physics frontier science centers funded by NSF.

	FY 2002	FY 2003	FY 2004
SBIR/STTR	**0**	**6,375**	**6,603**

The FY 2002, FY 2003 and FY 2004 amounts are the estimated requirements for the continuation of these programs.

	FY 2002	FY 2003	FY 2004
Total, Science	**134,307**	**142,565**	**144,670**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Tokamak Experimental Research	
▪ Funding for DIII-D research in the Science subprogram has increased marginally to cover research preparations and data analysis needs.	+596
▪ A slight decrease in funding for the Alcator C-Mod.	-6
▪ Funding for support of studies using International Facilities is reduced and redirected to higher priority FES activities.	-1,194
▪ Funding for the relocation of personnel and facilities to a new location at ORNL has been transferred to the Facilities Operations subprogram.	-1,521
▪ Funding for Experimental Plasma Research (Tokamaks) has been marginally reduced to cover higher priority activities.	-144
Total, Tokamak Experimental Research	-2,269
Alternative Concept Experimental Research	
▪ Funding for NSTX research is increased to provide for additional data analysis and research in support of operations	+2,255
▪ Funding for Experimental Plasma Research is reduced and redirected to higher priority FES activities.	-722
▪ Funding for IFE is reduced and redirected to higher priority FES activities. The rate of progress in ion source development will be slowed.	-277
Total, Alternative Concept Experimental Research	+1,256

	FY 2004 vs. FY 2003 ($000)
Theory	
▪ Funding is increased for studies of innovative concepts and burning plasma physics.	+900
General Plasma Science	
▪ Funding is increased for initiation of "Centers of Excellence in Fusion Science", with 1-2 new centers.	+1,990
SBIR/STTR	
▪ Support for SBIR/STTR is provided at the mandated level.	+228
Total Funding Change, Science	**+2,105**

Facility Operations

Mission Supporting Goals and Measures

The Facility Operations subprogram manages the operation of the major fusion research facilities and the fabrication of new projects to the highest standards of overall performance, using merit evaluation and independent peer review. The 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, fabrication of new projects 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 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 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 provides funds for operating and maintenance personnel, electric power, expendable supplies, replacement parts, system modifications and facility enhancements. In FY 2004, funding is requested to operate the major fusion facilities at a level of 84% of full utilization.

Funding is also provided for the continuation of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment project at PPPL. In FY 2004, the project will be in its second year, following the FY 2003 request for project start, and FY 2004 funding will support the final design activities and initial procurements of hardware.

Funding is also provided for ITER transitional activities, in which U.S. scientists and engineers will be involved in various technical activities that support both ITER negotiations for a construction project as well as preparations for eventual project construction.

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. Funding is also provided for the move of ORNL personnel and facilities to a new location at ORNL.

FACILITY OPERATIONS ACCOMPLISHMENTS

In FY 2002, 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 completed the majority of the installation of a new system of Resistive Wall Mode stabilization coils to provide for increased control of the fusion plasma in real-time. Also, 5 Electron Cyclotron Heating power systems were operated simultaneously into the DIII-D plasma, and this will enable higher performance plasma operation in the future.

- Upgrades to improve the performance capability of NSTX were completed successfully. A real-time digital control system was added to provide precision control of the coil systems and enable improved control of the fusion plasma. The vacuum vessel bakeout temperature was upgraded to 350 degrees, thereby providing for the creation of cleaner plasma in a shorter time than for the current system. The Coaxial Helical Injection system for injecting fuel particles was installed on NSTX, and initial operation to form a plasma was successful.
- In accordance with previous advice from technical experts to periodically inspect the Alcator C-Mod coil system, MIT personnel disassembled the device, performed the inspection, and confirmed coil system integrity. The device was re-assembled and returned to full operation. The C-Mod Lower Hybrid heating system remains on track for completion in FY 2003. A new diagnostic neutral beam was added to improve plasma characterization.
- The TFTR decontamination and decommissioning (D&D) activities at PPPL were completed successfully within cost and schedule.

Subprogram Goals

Operate major fusion facilities for specified number of weeks.

For facility upgrades and new projects accomplish cost and schedule targets**.**

Performance Indicator

Average operational downtime of FES facilities will not exceed 10% of total time scheduled and construction and upgrades of facilities will be within 10% of baseline schedule.

Annual Performance Results and Targets

FY 2002 Results		FY 2003 Request Targets		FY 2004 Targets	
Operate DIII-D	12 weeks vs. 14 weeks planned	Operate DIII-D	21 weeks	Operate DIII-D	21 weeks
Operate Alcator C-Mod	8 weeks	Operate Alcator C-Mod	21 weeks	Operate Alcator C-Mod	21 weeks
Operate NSTX	12 weeks	Operate NSTX	21 weeks	Operate NSTX	21 weeks
For TFTR, completed the project on cost and on schedule.					
		For NCSX, complete Preliminary Design.		For NCSX, complete the Final Design and begin hardware procurement.	
		For Alcator C-Mod, complete Lower Hybrid project.			

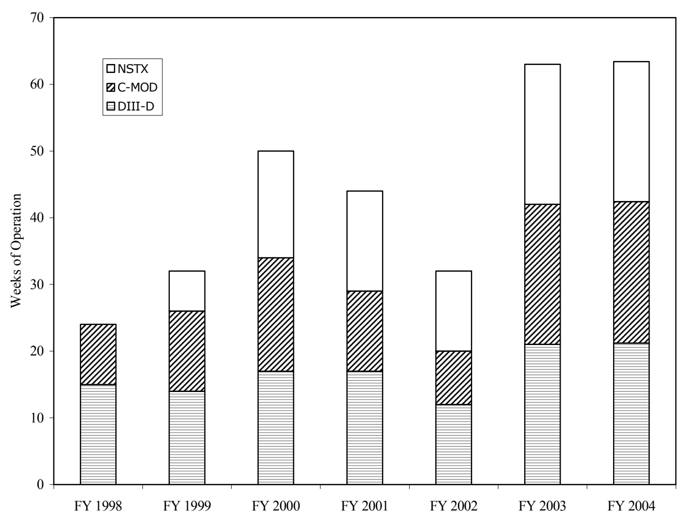
The table below summarizes the longer-term history of operation of the major fusion facilities.

Weeks of Fusion Facility Operation

(Weeks of Operations)

	FY 2002 Actual	FY 2003 Request	FY 2004
DIII-D	12	21	21
Alcator C-Mod	8	21	21
NSTX	12	21	21
Total	32	63	63

Recent operating history of major fusion experimental facilities



Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
TFTR	15,794	0	0	0	--
DIII-D	27,184	32,909	33,336	+427	+1.3%
Alcator C-Mod	10,095	13,789	14,249	+460	+3.3%
NSTX	15,241	19,446	19,237	-209	-1.1%
NCSX	0	11,026	15,921	+4,895	+44.4%
ITER	0	0	1,990	+1,990	--
GPP/GPE/Other	2,489	1,483	2,993	+1,510	+101.8%
Total, Facility Operations	70,803	78,653	87,726	+9,073	+11.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
TFTR	**15,794**	**0**	**0**

The TFTR Decontamination and Decommissioning (D&D) activity was completed in FY 2002.

DIII-D	**27,184**	**32,909**	**33,336**

Provide support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. The improvements include replacement of two microwave heating tubes. In FY 2004, these funds support 21 weeks of single shift plasma operation during which time essential scientific research will be performed as described in the science subprogram.

Alcator C-Mod	**10,095**	**13,789**	**14,249**

Provide support for operation, maintenance, and minor machine improvements. The improvements include additional diagnostics and preparations for heating system additions. In FY 2004, these funds support 21 weeks of single shift plasma operation during which time essential scientific research will be performed as described in the science subprogram.

NSTX	**15,241**	**19,446**	**19,237**

Provide support for operation, maintenance, and improvement of the NSTX facility and installation of planned diagnostic upgrades. In FY 2004, these funds support 21 weeks of single shift plasma operation. The FY 2004 budget will continue to support preventive maintenance and purchase of critical spare parts to minimize down time and improve facility reliability. In addition, new hardware will be installed to optimize research output. This includes an improved resonant field control system, a prototype microwave scattering system to measure high-k fluctuations, an imaging diagnostic for edge helium emission, and an array of absolutely calibrated x-ray detectors for Lyman-alpha emission from the divertor.

NCSX	**0**	**11,026**	**15,921**

Funding in the amount of $15,921,000 is requested for the continuation of the National Compact Stellarator Experiment (NCSX) Major Item of Equipment, which was initiated in FY 2003 and consists of the design and fabrication of a compact stellarator proof-of-principle class experiment. These funds will allow completion of the final design of most systems and the procurement of long lead-time items. 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 NCSX design will allow experiments that compare confinement and stability in tokamak and stellarator configurations. The preliminary total estimated cost (TEC) of NCSX is $73,500,000, with completion scheduled for FY 2007. When the preliminary design is completed at the end of FY 2003, the cost and schedule baseline will be established.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
ITER	**0**	**0**	**1,990**

Funding in the amount of $1,990,000 is provided to initiate ITER transitional activities such as licensing, project management, preparation of final specifications and system integration. U.S. personnel will participate in these activities in preparation for eventual project construction.

General Plant Projects/General Purpose Equipment/Other	**2,489**	**1,483**	**2,993**

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. Funds also provide for the move of ORNL personnel and facilities to a new location at ORNL.

Total, Facility Operations	**70,803**	**78,653**	**87,726**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
DIII-D	
▪ Funding is approximately the same. The number of weeks of operation, 21, is unchanged from the FY 2003 request and the supporting activities such as maintenance, enhancement and repair are also unchanged.	+427
Alcator C-Mod	
▪ Funding is approximately the same. The number of weeks of operation, 21, is unchanged from the FY 2003 request and the supporting activities such as maintenance, enhancement and repair are also unchanged.	+460
NSTX	
▪ Funding is approximately the same. The number of weeks of operation, 21, is unchanged from the FY 2003 request. However, there is a modest reduction in facility enhancements in FY 2004 relative to FY 2003..	-209
NCSX	
▪ Funding is increased consistent with project needs to design and procure hardware for the NCSX project at PPPL. The level of design activity on key components, such as the magnets and vacuum vessel, will increase in order to keep the projection of schedule	+4,895
ITER	
▪ Funding is increased due to the start of this new activity which provides for preparatory ITER activities…	+1,990

	FY 2004 vs. FY 2003 ($000)
GPP/GPE/Other	
▪ Funding is increased to provide necessary improvements in the PPPL infrastructure and to move ORNL fusion personnel and facilities to a new location at ORNL.	+1,510
Total Funding Change, Facility Operations	**+9,073**

Enabling R&D

Mission Supporting Goals and Measures

The Enabling R&D subprogram develops the cutting edge technologies that enable both U.S. and international fusion research facilities to achieve their goals.

The Engineering Research element addresses the breadth and diversity of domestic interests in enabling R&D for magnetic fusion systems as well as international collaborations that support the mission and objectives of the FES program. The activities in this element focus on critical technology needs for enabling both current and future U.S. plasma experiments to achieve their research goals and full performance potential in a safe manner, with emphasis on plasma heating, fueling, and surface protection technologies. While much of the effort is focused on current devices, a significant amount of the research is specifically focused on future burning plasma experiments. The R&D effort on these technologies involves evolutionary development advances in present day capabilities that will make it possible to enter new plasma experiment regimes, such as burning plasmas. These nearer-term technology advancements also enable international technology collaborations that allow the United States to access plasma experimental conditions not available domestically. This element includes investigation of scientific issues for innovative technology concepts that could make revolutionary changes in the way that plasma experiments are conducted, such as liquid surface approaches to control of plasma particle density and temperature, microwave generators with tunable frequencies and steerable launchers for fine control over plasma heating and current drive, magnet technology which could improve confinement. This element also includes safety research which allows us to conduct both current and future experiments in an environmentally sound and safe manner.

Another activity is conceptual 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. In the past, longer term basic research on future magnetic and inertial fusion energy chamber concepts were conducted in this element, however, those programs are now being terminated and the funding for this category will be used for an orderly closeout of all activities.

The Materials Research element focuses on the key science issues of materials for practical and environmentally attractive uses in fusion research and future facilities. This element continues to strengthen its modeling and theory activities, which makes it more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded by BES, as well as more capable of contributing to broader materials research in niche areas of materials science. Through a variety of cost-shared international collaborations, this element conducts irradiation testing of candidate fusion materials in the simulated fusion environments of fission reactors to provide data for validating and guiding the development of models for the effects of neutron bombardment on the microstructural evolution, damage accumulation, and property changes of fusion materials. This collaborative work supports both near-term fusion devices, such as a burning plasma experiment, as well as other future fusion experimental facilities. In addition, such activities support the long-term goal of developing experimentally validated predictive and analytical tools that can lead the way to nano-scale design of advanced fusion materials with superior performance and lifetime.

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.

In FY 2002, a series of retrospective peer reviews by independent experts was completed of the scientific and technical quality, progress, and relevance of each element of the Enabling R&D subprogram. Summary reports of reviewer panel members' findings and recommendations, along with community action plans to address the most significant findings and recommendations, can be viewed on the Virtual Laboratory for Technology website at http://vlt.ucsd.edu/peer.html. Although most elements of this subprogram were determined to rank highly in most aspects of quality, progress, and relevance, steps have been taken to make improvements in all areas of concern to the reviewers.

ENABLING R&D ACCOMPLISHMENTS

A number of technological advances were made in FY 2002. Examples include:

- Scientists at Sandia National Laboratory achieved record levels of performance in proposed high heat flux components for future burning plasma experiments. The ability to reliably remove high levels of surface heat deposited by burning plasmas, while not deteriorating rapidly or contaminating the plasma with impurities, is a major technology issue for the plasma facing components. The levels of surface heat flux expected on some plasma facing components can reach as high as those observed in rocket nozzles. In testing done on water-cooled tungsten-copper mockups of proposed high heat flux components, the mockups sustained some of the highest levels of heat flux expected in burning plasma experiments for thousands of heating cycles without damage. This testing demonstrated the viability of this concept, with future research aimed at extending performance limits and testing tolerances to off-normal events.
- Scientists at Princeton Plasma Physics Laboratory, University of California San Diego, and Sandia National Laboratory continued to observe encouraging results in 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 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 Laboratory, University of California Los Angeles, University of California Santa Barbara, Princeton University, and Lawrence Livermore National Laboratory continued to make significant progress in developing models for micro-structural 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 Oak Ridge National Laboratory and Princeton Plasma Physics Laboratory completed the design and fabrication of the prototype of a high power radio frequency antenna that will enable increased levels of plasma heating. The prototype, which is to be tested in FY 2003, will validate the

design, performance, and fabrication techniques of antennae to be built for use in the Joint European Torus plasma experiment. These antennae will provide the world's most powerful radio frequency plasma heating capability, and will permit investigation into advanced modes of fusion-relevant plasma performance.

Subprogram Goals

Develop the cutting edge technologies that enable FES research facilities to achieve their scientific goals and allow the U.S. to enter into international collaborations that enable access to plasma experiment conditions not available domestically.

Advance the science base for innovative materials to establish the technical feasibility of fusion energy and to enable fusion to reach its full potential as an environmentally and economically attractive energy source.

Performance Indicator

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

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Targets	FY 2004 Targets
Complete design and fabrication of at least one cutting edge technology that enables a FES research facility to achieve its scientific goals and/or allows the U.S. to enter into an international collaboration enabling access to plasma experiment conditions not available domestically. (goal met)	Initiate installation and begin testing of at least one cutting edge enabling technology.	Complete testing of at least one cutting edge enabling technology.
Complete preliminary investigation of at least one innovative technology that can create a more attractive vision of fusion energy systems. (goal met)	Design and install a liquid lithium limiter on CDX-U for testing as an advanced particle control/high heat flux handling system.	Complete closeout activities of all work on MFE and IFE chamber technologies.
Establish preliminary science base for at least one innovative low activation, high performance structural material that can validate the technical feasibility of fusion energy and enable fusion to reach its full potential as an attractive energy source. (goal met)	Complete initial experimental and modeling investigations of at least one innovative low activation, high performance structural material.	Identify elemental composition and fabrication methods through nanoscience methods to improve the performance and lifetime of at least one low activation structural material system.

Funding Schedule

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
Engineering Research	28,814	28,454	17,314	-11,140	-39.2%
Materials Research....................................	7,176	7,638	7,600	-38	-0.5%
Total, Enabling R&D..................................	35,990	36,092	24,914	-11,178	-31.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Engineering Research	**28,814**	**28,454**	**17,314**
▪ **Plasma Technology**	**12,023**	**12,092**	**13,986**

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 ITER.* Nearer-term experiment support efforts will be oriented toward plasma facing components and plasma heating and fueling technologies. Building on the testing in FY 2003 of a prototype radio frequency antenna—that will enable JET to build a powerful plasma heating device workable under rapidly changing plasma parameters—the detailed design of a similar high performance antenna will be completed for C-Mod in FY 2004. Based on the experimental research and design assessment in FY 2003 for a first-generation liquid metal system that allows lithium to interact directly with the plasma in a controlled way, the preliminary design of a lithium module for future deployment in NSTX will be initiated in FY 2004. This new plasma-facing component technology has the potential to revolutionize the approach to plasma particle density and edge temperature control in plasma experiments. Development and testing will continue for an advanced 1.5 million watt microwave generator that will efficiently heat plasmas to high temperatures, with 60% efficiency to be demonstrated in tests planned for FY 2004. Following completion in FY 2003 of the Safety and Tritium Applied Research (STAR) Facility at INEEL, material science experiments will be fully underway at STAR under a cost-sharing collaboration with Japan to resolve key issues of tritium behavior in different materials proposed to be used in fusion systems. *Additional funding will be provided to allow the STAR facility to undertake safety research for both current devices and* for ITER. Funds will be provided to continue superconducting magnet research, and innovative technology research in the area of plasma-surface interaction sciences that will enable fusion experimental facilities to achieve their major scientific research goals and full performance potential.

	FY 2002	FY 2003	FY 2004
▪ **Fusion Technology**	**10,563**	**10,906**	**1,338**

Fusion Technology efforts such as liquid metal analysis and experiments, which were focused on basic research on future MFE and IFE chamber concepts, are being terminated to provide resources for higher priority and nearer term activities. Funding for this category will be used for an orderly closeout of all activities. With the completion in FY 2003 of the tritium inventory reduction and stabilization at TSTA, TSTA transfer to EM will have been completed by the start of FY 2004.

	FY 2002	FY 2003	FY 2004
▪ **Advanced Design**	**6,228**	**5,456**	**1,990**

Funding for this element will focus on design studies of systems for next-step plasma science experiment options. The FIRE design effort will be completed in FY 2003. Systems science studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics and the prospects of possible advanced magnetic confinement concepts will be conducted in an iterative fashion with the experimental community.

	(dollars in thousands)		
	FY 2002	FY 2003	FY 2004
Materials Research	**7,176**	**7,638**	**7,600**

Materials Research remains a key element of establishing the scientific foundations for safe and environmentally attractive uses of fusion. Through a wide variety of modeling and experiment activities aimed at the science of materials behavior in fusion environments, research on candidate materials for the structural elements of fusion chambers will continue. Priorities for this work are based on the innovative approaches to evaluating materials and improved modeling of materials behavior that were adopted as a result of recommendations from the FESAC review completed in 1998. Investigations of experimentally-validated models that can predict and quantify embrittlement produced by fusion environments of body centered cubic metals, the crystal structure of the most promising structural materials for fusion chambers, is expected to lead in FY 2004 to a Master Curve model that is based on successful approaches taken in other material science research programs. Also during FY 2004, the first phase of a cost-shared collaborative program with Japan for irradiation testing of fusion materials in a U.S. fission reactor (HFIR) will be completed, providing key data to evaluate the effects of neutron bombardment on the microstructural evolution, damage accumulation, and property changes of fusion materials that could be used in next step devices. In addition, results will be available on testing of nanocomposited ferritic steels with alloy compositions and fabrication techniques designed through nanoscience methods to operate at high temperatures without significant deformation by creep mechanisms.

Total, Enabling R&D	**35,990**	**36,092**	**24,914**

Explanation of Funding Changes

	FY 2004 vs. FY 2003 ($000)
Engineering Research	
▪ Plasma Technology funding is increased due to the move of the safety and tritium research program to this category.	+1,894
▪ Funding for TSTA is terminated following completion in FY 2003 of work to clean up the facility prior to turning it over to the Office of Environmental Management for Decontamination and Decommissioning. Funding for other fusion technologies activities is decreased to meet higher priority budget needs in facility operations in preparation for participation in ITER.	-9,568
▪ Advanced Design funding is reduced in order to meet higher priority budget needs in facility operations in preparation for participation in ITER.	-3,466
Total, Engineering Research	-11,140
Materials Research	
▪ Funding is reduced due to completion of a task on irradiation testing in the HFIR reactor in FY 2003.	-38
Total Funding Change, Enabling R&D	**-11,178**

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	$ Change	% Change
General Plant Projects	2,149	995	1,415	+420	+42.2%
Capital Equipment	7,411	15,774	20,089	+4,315	+27.4%
Total, Capital Operating Expenses	9,560	16,769	21,504	+4,735	+28.2%

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2002	FY 2003	FY 2004	Accept-ance Date
DIII-D Upgrade	27,225	27,203	22	0	0	FY 2001
Alcator C-Mod LH Modification	5,200	2,966	1,505	1,019[a]	0	FY 2003
NCSX	73,500[b]	0	0	11,026	15,921	FY 2007
Total, Major Items of Equipment		30,169	1,527	12,045	15,921	

[a] During FY 2003 execution, this funding will be reduced to $729,000 to accommodate funding acceleration in FY 2002 and to retain the TEC of $5,200,000. The $1,019,000 presently in this column is the FY 2003 President's Request funding amount.

[b] The preliminary TEC has increased from $69,000,000 to $73,500,000 based on the recently completed conceptual design activities, which demonstrated that more contingency funds are needed for fabricating the highest risk components. The estimates will be improved as the preliminary design activities are completed in FY 2003 at which time the cost baseline will be set.