Fusion Energy Sciences

Funding Profile by Subprogram

	(dollars in thousands)		
	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Fusion Energy Sciences			
Science	148,642	154,213	159,529
Facility Operations	104,210	121,555	237,004
Enabling R&D	27,831	43,182	31,317
Total, Fusion Energy Sciences	280,683[a]	318,950	427,850

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The Fusion Energy Sciences (FES) program is 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.

Benefits

Total world energy consumption has increased by more than 50% during the past 25 years, and given the rapid pace of world economic growth, this trend is expected to continue. With decreasing fossil fuel resources and increasing awareness that the use of fossil fuels is harming the environment, finding new sources of energy to meet our future energy needs is one of the greatest scientific challenges of the 21st century. Fusion, which is one of the few fundamentally new sources of energy under development by the Department of Energy, has the potential to provide a significant fraction of the world's energy needs by the end of this century.

The fusion process is conceptually simple but very difficult to achieve in practice. Fusion occurs when deuterium and tritium, two isotopes of hydrogen, combine or fuse to form a single helium nucleus. During this fusion process, some of the mass of the deuterium and tritium nuclei is converted into a large amount of energy. Fusion is difficult to achieve on earth because the deuterium and tritium must be confined and heated to a temperature greater than 100 million degrees Celsius, at which point the deuterium and tritium exist in the plasma state. Plasmas are very different from ordinary gases and are subject to a wide variety of collective instabilities that are only partially understood at the present time. Understanding and learning to control these instabilities is a major scientific challenge to achieving practical fusion power.

The ultimate goal of fusion research is an attractive, long-term source of energy. The fusion fuels, deuterium and tritium, are plentiful and may be obtained from sources as common and abundant as sea water and lithium from the earth's crust. Successful development of fusion power would greatly reduce

[a] Total is reduced by $2,906,000 for a rescission in accordance with P.L. 109–148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006; $6,215,000, which was transferred to the SBIR program; and $746,000, which was transferred to the STTR program.

concerns over imported oil, rising gasoline prices, smokestack pollution, global warming, and other problems associated with our dependence on oil and other fossil fuels and would help to meet the energy needs of all mankind for centuries.

U.S. participation in the international ITER Project, a Presidential initiative, is a bold next step in fusion research. ITER is designed to produce, control, and sustain a burning plasma, a plasma whose high temperature is maintained by the alpha particles produced by fusion reactions in the plasma. The European Union, China, India, Japan, Korea, Russia, and the U.S. signed a 35-year agreement to construct, operate, and decommission the ITER facility on November 21, 2006. Research on ITER is expected to provide sufficient information on the complex science of burning plasmas to make a definitive assessment of the scientific feasibility of fusion power.

A science-based portfolio approach is the most effective approach to ensuring the success of ITER and continuing the scientific discovery needed to achieve commercial fusion power. While the knowledge base is now in hand to build ITER, a strong core research program consisting of experiments on existing facilities, comprehensive theory and simulation, and technology development is needed to make the exciting discoveries that will identify successful operating regimes for ITER and develop the skilled workforce needed to carry out research on ITER. A portfolio approach also advances our knowledge of plasma physics and associated technologies, thereby yielding near term benefits in a broad range of scientific disciplines, such as plasma processing of semiconductor chips for computers and other electronic devices, advanced video displays, innovative materials coatings, space propulsion, neutron sources that can enable detection of explosives of highly enriched uranium for homeland security, and efficient destruction of chemical wastes.

Strategic and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, environmental, and management aspects of the DOE mission) plus 16 Strategic Goals that tie to the Strategic Themes. The FES program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation
Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

The FES program has one GPRA Unit Program goal which contributes to Strategic Goal 3.1 and 3.2 in the "goal cascade":

GPRA Unit Program Goal 3.1/2.49.00: Bring the Power of the Stars to Earth—Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels our Sun.

Contribution to Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

The FES program contributes to these Strategic Goals by managing a program of fundamental research into the nature of fusion plasmas and the means for confining plasma to yield energy. This program includes: (1) exploring basic issues in plasma science; (2) developing the scientific basis and computational tools to predict the behavior of magnetically confined plasmas; (3) using the advances in tokamak research to enable the initiation of the burning plasma physics phase of the FES program; (4) exploring innovative confinement options that offer the potential to increase the scientific understanding and to improve the confinement of plasmas in various configurations; (5) investigation of non-neutral plasmas and high energy density physics; and (6) developing the cutting edge technologies that enable fusion facilities to achieve their scientific goals.

These activities require operation of a set of unique and diversified experimental facilities, including smaller-scale devices at universities involving individual Principal Investigators, larger national facilities that require extensive collaboration among domestic institutions, and an even larger, more costly experiment that requires international collaborative efforts to share the costs and gather the scientific and engineering talents needed to undertake such an experiment. These facilities provide scientists with the means to test and extend theoretical understanding and computer models—leading ultimately to an improved predictive capability for fusion science.

The following indicators establish specific long term (10 year) goals in scientific advancement to which the FES program is committed and against which progress can be measured.

- **Predictive Capability for Burning Plasmas:** Progress toward developing a predictive capability for key aspects of burning plasmas using advances in theory and simulation benchmarked against a comprehensive experimental database of stability, transport, wave-particle interaction, and edge effects.
- **Configuration Optimization:** Progress toward demonstrating enhanced fundamental understanding of magnetic confinement and improved basis for future burning plasma experiments through research on magnetic confinement configuration optimization.
- **High Energy Density Plasma Physics:** Progress toward developing the fundamental understanding and predictability of high energy density plasma physics.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.49.00, Bring the Power of the Stars to Earth			
Fusion Energy Sciences	280,683	318,950	427,850

Annual Performance Results and Targets

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
GPRA Unit Program Goal 3.1/2.49.00 (Bring the Power of the Stars to Earth)					
Science[a]					
N/A	N/A	Conduct experiments on the major fusion facilities (DIII-D, Alcator C-Mod and NSTX) leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2005, FES measured plasma behavior in Alcator C-Mod with high-Z antenna guards and input power greater than 3.5 MW.[b] [Met Goal]	Conduct experiments on the major fusion facilities (DIII-D, Alcator C-Mod, and NSTX) leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2006, FES injected 2 MW of neutral power in the counter direction on DIII-D and began physics experiments. [Met Goal]	Conduct experiments on major fusion facilities leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2007, FES will measure and identify magnetic modes on NSTX that are driven by energetic ions traveling faster than the speed of magnetic perturbations (Alfvén speed); such modes are expected in burning plasmas such as ITER.	Conduct experiments on major fusion facilities leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2008, FES will evaluate the generation of plasma rotation and momentum transport, and assess the impact of plasma rotation on stability and confinement. Alcator C-Mod will investigate rotation without external momentum input, NSTX will examine very high rotation speeds, and DIII-D will vary rotation speeds with neutral beams. The results achieved at the major facilities will provide important new data for estimating the magnitude of and assessing the impact of rotation on ITER plasmas.

[a] The performance metrics for Science are not PART measures.

[b] This target addresses issues related to first wall choices and the trade-offs between low-Z and high-Z materials. This choice can affect many important aspects of tokamak operation, including: impurity content and radiation losses from the plasma; hydrogen isotope content in the plasma and retention in the walls; and disruption hardiness of device components. All of these issues are significant when considering choices for next step devices to study burning plasma physics, especially ITER. Definitive experimental results have been compared to model predictions, and are documented in a *Target Completion Report* submitted in September 2005.

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
N/A	N/A	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2005, FES simulated nonlinear plasma edge phenomena using extended MHD codes with a resolution of 20 toroidal modes. [Met Goal]	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2006, FES simulated nonlinear plasma edge phenomena using extended MHD codes with a resolution of 40 toroidal modes. [Met Goal]	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2007, improve the simulation resolution of linear stability properties of Toroidal Alfvén Eigenmodes driven by energetic particles and neutral beams in ITER by increasing the number of toroidal modes used to 15.	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2008, improve the simulation resolution of ITER-relevant modeling of lower hybrid current drive experiments on Alcator C-Mod by increasing the number of poloidal modes used to 2,000 and the number of radial elements used to 1,000 using the leadership class computers at ORNL.
Facility Operations					
Kept deviations in weeks of operation for DIII-D and Alcator C-Mod within 10% of the approved plan. NSTX did not meet the target because of a coil joint failure. [Goal partially met.]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.[Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%. [Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%. [Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.
Kept deviations in cost and schedule for upgrades and construction of scientific user facilities within 10% of approved baselines. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%.	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%.

Status of ITER Activities

The FES program is pushing the boundaries in large scale international scientific collaboration. With the support of a Presidential Initiative, FES is actively leading the U.S. effort to provide components as in-kind contributions, personnel, cash, and contingency in support of ITER—an international project to build and operate the first fusion science facility capable of producing a sustained burning plasma. The mission for ITER is to demonstrate the scientific and technological feasibility of fusion energy. The site selection for the international ITER Project, Cadarache, France, in the European Union, was a major six-party decision on June 28, 2005, at a Ministerial-level meeting in Moscow, Russia.

- **International Negotiations Leading to the Seven Parties Signing Ceremony, November 2006:**

  International negotiations on ITER resulted in the completion of major milestones for the international ITER Project, including: (a) designation of the Director General, a Japanese candidate, chosen to lead the ITER organization, (b) designation of the Principal Deputy Director General, a European Union candidate, chosen to serve as project manager, (c) India joining ITER as a full non-host party, (d) finalization of the procurement allocations to all parties, and (e) completion of the text of the ITER Agreement. Following these milestones, the seven ITER parties of China, the European Union, India, Japan, Korea, Russia, and the United States initialed the Agreement on May 24, 2006, in Brussels to signify that the text was final.

  From the point of initialing until the signing ceremony, held on November 21, 2006 in Paris, France, it was the responsibility of each party delegation to present the final initialed text to their respective governments for further approval. For the U.S., the Agreement and supporting documentation was submitted to Congress in accordance with the Energy Policy Act of 2005, Section 972 (c) for a 120-day review period. The signing of the Agreement confirmed the multilateral commitment for ITER and will be followed by ratification or formal acceptance of the Agreement and entry into force.

- **Management for the International ITER Organization:**

  Significant progress has been made in terms of personnel assigned to the ITER Organization and plans for the establishment of the overall management structure. In May 2006, prior to the parties initialing the Agreement, the Director General Nominee (Director General) and the Principal Deputy Director General Nominee (Principal Deputy Director General) distributed the provisional management structure for the ITER Organization. As expected, the Director General will provide overall leadership of the ITER Organization. The Principal Deputy Director General will support the Director General on all matters related to management of the ITER Organization, especially those matters dealing with construction, supervision of project execution, and managing discussions with the seven parties regarding their deliverables. The U.S. is particularly pleased to note that the Principal Deputy Director General, a European Union candidate, was a member of the senior management team of the Spallation Neutron Source located at Oak Ridge National Laboratory.

  During a meeting among the seven parties in July 2006, the Director General of the ITER organization announced the selection of the Deputy Director General appointments. These key management positions cover the following areas: (a) Environment, Safety & Health (ES&H) including Quality Assurance and Licensing; (b) Administration; (c) Fusion Science and Technology; (d) Tokamak; (e) Central Engineering and Plan Support; and (f) ITER Control, Data Access and Communications Systems (CODAC), Heating Systems and Diagnostics. Most of the Deputy Directors General are now on site. Other key aspects of the ITER Organization structure include: the ITER Council, which will serve an oversight function and will be comprised of members from each party to oversee the Director General, and the functions of the ITER Organization Management

Advisory Committee, Scientific and Technology Advisory Committee, Senior Scientific and Legal Advisors, and the Project Office.

- **Levels of Participation in the International Project:**

  As a result of the international negotiations, a revised allocation of hardware deliverables from each party, including India, was agreed upon. Collectively, the ITER parties are able to accomplish the originally planned ITER construction scope of work and, in addition, provide a contingency or "Central Reserve" for the shared activities at the ITER site, such as design, system integration, provision of infrastructure, and installation of hardware. The provision of a Central Reserve for the ITER Organization, which resulted when India joined, is consistent with sound project management principles. Such contingency resources are to be accessed at the request of the Director General and with subsequent approval by the ITER Council. The amount of funding required by each party remains the same. For each of the 6 non-hosts, including the United States, what was previously a $^{1}/_{10}$ (10%) share of a total that excluded contingency for the site activities, now becomes a $^{1}/_{11}$ share (about 9.1%) of the ITER hardware, personnel, and cash plus contingency for the site activities. The corresponding host share is $^{5}/_{11}$ (45.4%).

- **Next Major Steps for the Seven ITER Parties:**

  The steps following the Ministerial-level signing of the Agreement held on November 21, 2006, include ratification or formal acceptance of the Agreement by mid-2007 and entry into force and formal establishment of the ITER Organization by late 2007.

- **U.S. Contributions to ITER:**

  The U.S. Contributions to ITER Major Item of Equipment (MIE) project is managed by the U.S. ITER Project Office (USIPO) located at the Oak Ridge National Laboratory (ORNL) with current partnering laboratories Princeton Plasma Physics Laboratory (PPPL) and Savannah River National Laboratory (SRNL). In May 2006, the Project Manager relocated from PPPL to ORNL. The USIPO staff includes the Project Manager, Deputy Project Manager, Project Controls Manager, Project Engineering Manager, Procurement Manager, Business Manager, Environmental, Safety and Health (ES&H) and Quality Assurance (QA) Manager, Chief Scientist, Chief Technologist, and Managers for the work breakdown structure elements of magnet systems, first wall and shield systems, port limiters, tokamak cooling water systems, vacuum pumping and fueling systems, ion cyclotron heating system, electron cyclotron heating system, tritium plant exhaust processing system, electric power systems, and diagnostics.

  In FY 2005 and FY 2006, and in accordance with DOE Order 413.3A, the FES program and the USIPO have been preparing for Critical Decision 1 (CD-1), Approve Alternative Selection and Cost Range, in late FY 2007–early FY 2008 and Critical Decision 2b (CD-2b), Approve Performance Baseline, in late FY 2008. In order to accommodate the necessary U.S. long-lead procurements in FY 2008, CD-2a/3a will be performed in conjunction with CD-1. It is important that the schedule for the Critical Decision milestones is consistent with the international ITER Project schedule, and that the schedule benefits from activities of the International ITER Project such as the initial design review to be conducted by the Director General and Principal Deputy Director General beginning in early 2007. The schedule for Critical Decision 2b is dependent on the ability of the international ITER Organization to finalize the design and schedule for the ITER Project—both of which affect the establishment of the performance baseline of the U.S. Contributions to ITER project.

  The Total Project Cost (TPC) for the U.S. Contributions to ITER MIE project remains unchanged and is described in more detail in later sections of the FES budget. Funding in FY 2008 provides for

$149,500,000 for Total Estimated Cost (TEC) activities and $10,500,000 for Other Project Costs (OPC) activities. The funding profile maintains the TPC of $1,122,000,000, but does include shifts in OPC and TEC funding.

In accordance with the Energy Policy Act of 2005, Section 972(c)(5)(C), the Department has submitted to Congress the following reports: (1) A ‘Plan for U.S. Scientific Participation in ITER’; (2) A report describing the management structure of the ITER and estimate of the cost of U.S. participation; and (3) A report describing how U.S. participation in ITER will be funded without a funding reduction in other SC programs. The Department’s FY 2008 budget request provides for increases across the Office of Science (SC) and supports the ITER request of $160,000,000 almost entirely from new funds in the FES budget request.

In support of ITER and the U.S. Contributions to ITER MIE project, FES is placing increased emphasis on its national burning plasma program—a critical underpinning of the fusion science in ITER. FES plans to enhance burning plasma research efforts across the U.S. domestic fusion program by:

- Providing ITER R&D support both in physics and technology and exploring new modes of improved or extended ITER performance;
- Developing safe and environmentally attractive technologies necessary for ITER;
- Exploring fusion simulation efforts that examine the complex behavior of burning plasmas in tokamaks, which will impact the planning and conduct of experimental operations in ITER;
- Conducting experiments on our national science facilities with diagnostics and plasma control that can be extrapolated to ITER; and
- Integrating all that is learned into a forward-looking approach to future fusion applications.

During the ITER negotiations, the U.S. domestic program has continued to support the domestic technical preparations for the ITER project and has begun to plan for the operation of ITER. These activities are being promoted and coordinated through the U.S. Burning Plasma Organization (USBPO) established in 2005 for this purpose. FES appointed the Director of USBPO in May 2005 to lead this effort.

The Energy Policy Act requires development of a plan by DOE for the participation of U.S. scientists in ITER that includes a U.S. research agenda, methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power, and a description of how work at the ITER will relate to other elements of the U.S. fusion program. The Act requires that this plan be developed in consultation with the Fusion Energy Sciences Advisory Committee (FESAC), and reviewed by the National Academy of Sciences.

In FY 2006, DOE initiated steps to develop a plan for the participation of U.S. scientists in ITER. FES asked the USBPO to coordinate and facilitate a coherent burning plasma related work program and ITER supporting research. The USBPO organized a national workshop at ORNL on December 7–9, 2005, to review the developments in the U.S. program on burning plasma related topics since the Snowmass 2002 study that formulated the technical basis for the U.S. to join ITER. The USBPO produced a ‘Plan for U.S. Scientific Participation in ITER’ with technical details in May 2006. As called for, the Plan was presented to FESAC for consultation. FESAC reviewed and agreed with the Plan in early June 2006. The Plan was forwarded to Congress on August 11, 2006, for a 60-day review, as required by the Energy Policy Act of 2005 Section 972(c)(4)(A)(i-iii), and it was concurrently submitted to the National Academy of Sciences for review.

Means and Strategies

The science and the technology of fusion have progressed to the point that the European Union, China, India, Japan, Korea, Russia, and the United States, seven parties representing over half of the world's population, have agreed to build ITER to explore the physics of a sustained burning plasma. In light of this action, many elements of the fusion program that are broadly applicable to burning plasmas are now being directed more specifically toward the needs of ITER. These elements represent areas of fusion research in which the United States has particular strengths relative to the rest of the world, such as theory, modeling, advanced tokamak physics, and fusion technology. Longer range technology activities have already been redirected to support preparations for ITER and associated experiments.

Scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad and conduct comparative studies to supplement the scientific understanding obtained from domestic facilities. 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 United States is collaborating with Korea and China on the design of diagnostics and control systems for their long-pulse, superconducting, advanced tokamaks (KSTAR and EAST). The strengthened relationships resulting from these international collaborations can foster scientific advancement and provide a valuable link with the 80% of the world's fusion research that is conducted outside the United States. The United States is an active participant in the International Tokamak Physics Activity (ITPA), which facilitates identification of high priority research for burning plasmas in general, and for ITER specifically, through workshops and assigned tasks. ITPA further identifies coordinated experiments on the international tokamak programs and coordinates implementation of these experiments through the International Energy Agency Implementing Agreements on tokamaks. In FY 2005, the United States established a community-based Burning Plasma Organization to stimulate and coordinate ITER-related research within the U.S. fusion program.

All research projects undergo regular peer review and merit evaluation based on SC-wide procedures and Federal regulations pertaining to extramural grant programs under 10 Code of Federal Regulations (CFR) 605. A similar and modified process is also followed for research proposals submitted by the laboratory programs and national collaborative facilities. All new projects are selected by peer review and merit evaluation. FES formally peer reviews the FES scientific facilities to assess the scientific output, collaborator satisfaction, the overall cost-effectiveness of each facility's operations, and the ability to deliver the most advanced scientific capability to the fusion community. Major facilities are reviewed by an independent peer review process on a five-year basis as part of the grant renewal process, or an analogous process for national laboratories. The three national fusion facilities (DIII-D at General Atomics, Alcator C-Mod at the Massachusetts Institute of Technology (MIT), and NSTX at PPPL) had such peer reviews in the April-June 2003 time frame. Checkpoint reviews after three years provide interim assessments of program quality. These checkpoint reviews for the three facilities were held in September 2006. Program Advisory Committees for the major facilities provide annual feedback on the quality of research performed at the facility; the reliability and availability of the facility; user access policies and procedures; collaborator satisfaction; facility staffing levels; research and development (R&D) activities to advance the facility; management of the facility; and long-range goals of the facility.

Facility upgrades and construction projects have a goal to stay within 10 percent, on average, of cost and schedule baselines for upgrades and fabrication of scientific facilities. In FES, fabrication of major research facilities has generally been on time and within budget. Major collaborative facilities have a goal to operate more than 90 percent, on average, of total planned annual operating time. FES's operation of major scientific facilities has ensured that a growing number of U.S. scientists have reliable access to those important facilities.

External factors that affect the level of performance include:

- changing mission needs as described by the DOE and SC mission statements and strategic plans;
- scientific opportunities as determined, in part, by proposal pressure and scientific workshops;
- results of external program reviews and international benchmarking activities of entire fields or sub fields, such as those performed by the National Academy of Sciences (NAS);
- unanticipated failures in critical components of scientific facilities that cannot be mitigated in a timely manner; and
- strategic and programmatic decisions made by non-SC funded domestic research activities and by major international research centers.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to verify and validate performance. Monthly, quarterly, semiannual, and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART) Assessment

The Department has implemented a tool, the PART Assessment, to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. FES has incorporated feedback from OMB and has taken or will take the necessary steps to continue to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the FES program a score of 82% overall which corresponds to a rating of "Moderately Effective." The assessment found that FES has developed a limited number of adequate performance measures which are continued for FY 2008. These measures have been incorporated into this budget request, FES grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of Management and Operating (M&O) contractors. To explain these complex scientific measures better, the Office of Science has developed a website (http://www.sc.doe.gov/measures/) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the Fusion Energy Sciences Advisory Committee (FESAC) and also available on the website, will guide reviews, every three years by FESAC, of progress toward achieving the long-term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB has provided FES with three recommendations to further improve performance:

- Develop strategic and implementation plans in response to multiple Congressional requirements.
- Implement the recommendations of expert review panels, especially two major National Academy of Sciences studies, as appropriate.
- Re-engage the advisory committee in a study of how the program could best evolve over the coming decade, including taking into account new and upgraded international facilities.

In response to previous OMB recommendations FES has:

- In accordance with the Energy Policy Act of 2005, prepared several reports which have been submitted to Congress in FY 2006: (1) A 'Plan for U.S. Scientific Participation in ITER'; (2) A report describing the management structure of the ITER and estimate of the cost of U.S. participation; and (3) A report describing how U.S. participation in ITER will be funded without a funding reduction in other SC programs.
- Formally charged the FESAC to assess progress toward the long term goals of the FES program.
- Tasked FESAC to prepare a report that identified and prioritized scientific issues and respective campaign strategies. The final report was completed in April 2005, and formed the basis of the September 2005 FES strategic plan.
- Established a Committee of Visitors (COV) process to provide outside expert validation of the program's merit-based review processes for impact on quality, relevance, and performance. The COV reports are available on the web at http://www.ofes.fusion.doe.gov/more_html/fesac.

During the past three years, COV committees have examined all elements of the FES program in the following order: (1) theory and computation, (2) innovative confinement concepts, high energy density physics, and general plasma science, and (3) tokamak research and enabling R&D. The three COV reports and the FES response to these reports are available at:
http://www.ofes.fusion.doe.gov/more_html/fesac/committeeofvisitors.pdf,
http://www.ofes.fusion.doe.gov/more_html/fesac/covlettertohazeltine.pdf,
http://www.ofes.fusion.doe.gov/more_html/fesac/cov_final.pdf, and
http://www.ofes.fusion.doe.gov/more_html/fesac/ofesresponseto2ndcov.pdf.

In general, these COVs have concluded that the FES-supported research programs are of high quality and that the biggest concern has been flat budgets for these programs. Further, the COVs have found that FES program managers are serious, conscientious, and dedicated, and are doing a good job managing their individual program elements.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov web site. Information concerning FES PART assessments and current follow up actions can be found by searching on "fusion energy sciences" at http://ExpectMore.gov.

Overview

Fusion science is a subfield of plasma science that deals primarily with the study of fundamental processes taking place in plasmas, or ionized gases, when the temperature and density approach the levels needed to allow the nuclei of two low-mass elements, e.g., hydrogen isotopes deuterium and tritium, to join together, or fuse. There are two leading methods of confining the fusion plasma—magnetic confinement, in which strong magnetic fields contain the charged plasma particles, and inertial confinement, in which laser or particle beams or x-rays (drivers) compress and heat the plasma (target) during very short pulses. Most of the world's fusion energy research effort, the United States included, is focused on the magnetic confinement approach. However, the National Nuclear Security Administration (NNSA) supports a robust program in inertial fusion for stockpile stewardship. By leveraging this large NNSA investment in facilities, FES can support a small research effort to study energy-relevant high energy density physics.

The FES program activities are designed to address the scientific and technology issues facing magnetic fusion and high energy density physics. The FESAC Priorities Panel has identified six scientific campaigns, or topical areas, to organize these scientific and technical issues in magnetic fusion and high energy density physics research. Four of these topical areas are in magnetic fusion: Macroscopic Plasma Physics, Multi-scale Transport Physics, Plasma-boundary Interfaces, and Waves and Energetic Particles. One topical area covers High Energy Density Physics, closely related to inertial fusion, and one topical area covers Fusion Engineering Science applicable to critical technologies important to practical fusion energy systems. The panel has identified 15 fundamental scientific questions, one to three for each topical area, in order to guide the key scientific research to be carried out in fusion energy science over the next ten years.

The six topical issues or scientific campaigns have been codified into three thrusts that characterize the program activities:

- Burning Plasmas, that will include our efforts in support of ITER;
- Fundamental Understanding, that includes high performance plasma experiments, theory and modeling, as well as general plasma science;
- Configuration Optimization, that includes innovative experiments on advanced tokamaks, and alternate concepts;

Progress in all of these thrust areas, in an integrated fashion, is required to achieve ultimate success.

How We Work

The primary FES role is the management of resources and technical 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 mutually beneficial 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 SC Director on complex scientific and technological issues that arise in the planning, implementation, and management of the FES program. The Committee members are drawn from universities, national laboratories, and private firms involved in fusion research or related fields. The SC Director charges the Committee to provide advice and recommendations on various issues of concern to the FES program. The Committee conducts its business in public meetings, and submits reports with advice and recommendations to the Department.

A variety of other committees and groups provide input to program planning. For example, the National Research Council’s Plasma Science 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 effort. These high-level program reviews and peer reviews of research proposals provide a sound basis for developing program plans and priorities and allocating 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 comprised primarily of 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 host 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, thereby avoiding unnecessary duplication.

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 with 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 SC programs.

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 proposals 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. Grants typically extend for a three- to five-year period. The grants review process is governed by the already established SC Merit Review System. DOE national laboratories submit annual FWPs for funding of both new and ongoing activities. These are subject to peer review according to procedures patterned after those in 10 CFR Part 605, which governs 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 nominal five-year renewal dates. External peer reviews of laboratory programs are carried out on a periodic basis.

Another review mechanism, described previously in the PART Assessment section, involves charging FESAC to establish a Committee of Visitors (COV) to review program management practices of selected elements of the FES program each year, such that the entire program is reviewed every three to four years. In May 2006, the third COV completed its review of the research portfolio and peer review process for the FES Tokamak Research and Enabling R&D programs. This committee agreed with the recommendations of earlier COVs, and concluded that there was much evidence that the FES program managers have already implemented many of the recommendations of earlier COVs and were working to make further improvements in programs and processes. However, the committee noted that further work was needed to make the content of the review folders complete and consistent across the programs. The committee also developed the following new recommendations:

- statistics on the award process would be helpful
- the review sheet used for program renewals should explicitly include a review of progress
- some form of the proposal score should be communicated to the Principal Investigator (PI) in addition to reviewer comments
- the reviewer pool size should be increased
- the Junior Faculty Award program should be eligible to those outside of basic plasma science

These recommendations are being implemented for proposals requesting funds in FY 2007 and beyond.

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 Director in the field and other involved staff from both the Department and the performers.

MIE/Project Management

FES will continue to comply with the Department's project management regulations and will continue to utilize the oversight functions of the Department and the U.S. ITER Project Office at Oak Ridge National Laboratory in order to ensure that the U.S. investment in ITER is optimized and protected. This will be accomplished through compliance with DOE Order 413.3A, regular SC Office of Project Assessment "Lehman" Reviews, International ITER Reviews, and the overall coordination and management activities among FES, the U.S. ITER Project Office, and the ITER Organization.

As was done for the National Compact Stellarator Experiment, another FES Major Item of Equipment project, the U.S. ITER Project Office will develop a performance baseline, and FES will track these performance baselines on a regular basis. The target for ITER is the same as for other projects: cost-weighted mean percent variance from established cost and schedule baselines kept to less than 10%.

Now that the ITER Agreement has been signed and the ITER Organization is operating under provisional application (until entry into force in 2007), the Interim ITER Council will be providing such management controls and safeguards, as described in the ITER Agreement Article 6—Council. The U.S. and the other ITER parties have representation on the Council. In addition, Article 17—Financial Audit and Article 18—Management Assessment provide provisions for management controls and safeguards. For instance, Article 18 states that "Every two years, the Council shall appoint a Management Assessor who shall assess the management of the activities of the ITER Organization. The scope of the assessment shall be decided by the Council." In the event that a Party should fail to deliver a key component or system, the Common Understanding on Project Resource Management and Article 26—Withdrawal outlines the steps to be followed.

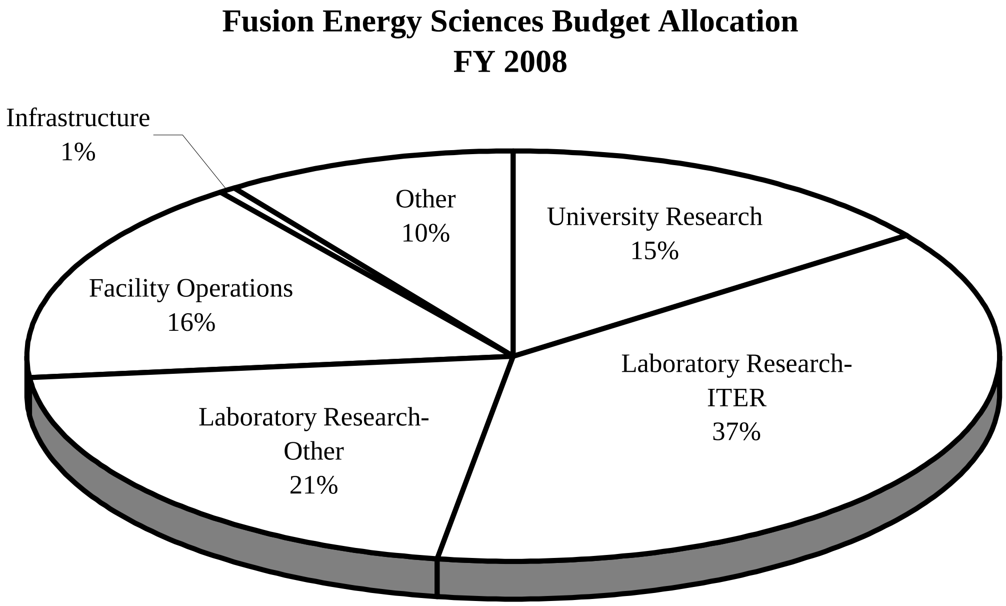
Planning and Priority Setting

The FESAC carries out an invaluable role in the fusion program by identifying critical scientific issues and providing advice on intermediate and long-term goals to address these issues. As described above, FESAC has recently assisted the Department and the fusion community in establishing priorities for the fusion program, including strategies to integrate U.S. activities in ITER into the overall U.S. domestic fusion program.

A variety of sources of information and advice, as noted above, are integrated with peer reviews of research proposals. These, 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 components: Science, Facility Operations, and Enabling R&D. Research efforts are distributed across universities, laboratories, and private sector institutions. There are three major facilities located at: a national laboratory (Princeton Plasma Physics Laboratory [PPPL]); a private sector institution (General Atomics [GA]); and a university (MIT). In addition, there are several smaller experimental facilities located at other universities and labs. Technology supports and improves the technical capabilities for ongoing experiments and provides limited long-term development for future fusion power requirements.



Research

The DOE Fusion Energy Sciences program funds research activities involving over 1,100 researchers and students at 65 academic and private sector institutions located in 30 states and at 11 DOE and Federal laboratories in eight 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. 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 science user facility at the University of California, Los Angeles (UCLA) that is jointly funded by DOE and the National Science Foundation (NSF). There are 5 universities with significant groups of theorists and modelers. About 40 Ph.D. degrees in fusion-related plasma science and engineering are awarded each year. Over the past three decades, many of these graduates have gone into the industrial sector and taken 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 peer reviewed proposals submitted in response to announcements of opportunity and available funding are competitively awarded according to the guidelines published in 10 CFR Part 605. Support for basic plasma physics is carried out mostly through the NSF/DOE Partnership in Basic Plasma Science and Engineering.

In addition, the FES Junior Faculty program supports tenure track university faculty on a competitive basis; research in fusion and plasma science is included in this program.

- **National Laboratory and Private Sector Research**

  FES 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 Laboratory, Argonne National Laboratory, Pacific Northwest 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.

Significant Program Shifts

The FY 2008 request is $427,850,000, 34.1% over the FY 2007 request. The FY 2008 request continues the redirection of the fusion program to prepare for and participate in the ITER project. The most significant increase from FY 2007 to FY 2008 is $100,000,000 for ITER. The increase of $8,900,000 for the remainder of the program generally supports activities at the same level of effort as FY 2007.

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- **International Accomplishments:**

  Multilateral ITER negotiations continued in FY 2006. Significant advances during the negotiations included the selection of Cadarache, France as the host site for ITER, designation and approval of the Director General and Principal Deputy Director General, approval and invitation for India to join the ITER negotiations as a full non-host participant, agreement on the final allocations of “in-kind” hardware among the parties, and establishment of a Central Reserve for the international ITER Organization. As signified on May 24, 2006, by the initialing of the ITER Agreement by the seven parties, the comprehensive process to finalize the draft ITER Agreement and supporting documentation was completed. The steps following the Ministerial-level signing of the Agreement held on November 21, 2006, include ratification or formal acceptance of the Agreement by mid-2007 and entry into force and formal establishment of the ITER Organization by late 2007.

- **U.S. ITER Project Accomplishments:**

  The U.S. ITER Project Office (USIPO), serving as the U.S. domestic agency for the ITER Project, is responsible for the management of the U.S. contributions of hardware, personnel, cash, and contingency. Since the establishment of the Project Office in July 2004, the following accomplishments have been made:

  - preliminary cost and schedule ranges have been prepared, reviewed by SC, and revised to reflect resolution of uncertainties associated with the ITER Project;

- the Deputy Secretary of Energy approved Critical Decision 0, Approve Mission Need, for ITER as called for in DOE Order 413.3A;
- project management documentation required by DOE Order 413.3A is being prepared for the U.S. Contributions to ITER MIE project; and
- appointments of key management positions within the USIPO are now complete.

In FY 2006, and in accordance with DOE Order 413.3A, the FES program and the USIPO have been preparing for Critical Decision 1 (CD-1), Approve Alternative Selection and Cost Range, in late FY 2007–early FY 2008 and Critical Decision 2b (CD-2b), Approve Performance Baseline, in late FY 2008. In order to accommodate the necessary U.S. long-lead procurements in FY 2008, CD-2a/3a will be performed in conjunction with CD-1. It is important that the schedule for the Critical Decision milestones is consistent with the international ITER Project schedule, and that the schedule benefits from activities of the International ITER Project such as the initial design review to be conducted by the Director General and Principal Deputy Director General beginning in early 2007. The schedule for Critical Decision 2b is dependent on the ability of the international ITER Organization to finalize the design and schedule for the ITER Project—both of which affect the establishment of the performance baseline of the U.S. Contributions to ITER MIE project.

The overall Total Project Cost of $1,122,000,000 for the U.S. Contributions to ITER project is maintained.

In FY 2008, funding for the U.S. Contributions to ITER Major Item of Equipment (MIE) project is identified as Total Estimated Cost (TEC) in the Facility Operations subprogram and Other Project Costs (OPC) in the Enabling R&D subprogram. The TEC funding provides for the U.S. “in-kind” equipment contributions, U.S. personnel to work at the ITER site, cash for the U.S. share of common expenses such as infrastructure, hardware assembly and installation, and contingency for the ITER Organization. The OPC funding is provided for R&D in support of equipment—mainly magnets, first wall/shield modules, tritium processing, fueling and pumping, heating systems, and diagnostics, which would be provided by the U.S. to ITER. The results of this R&D are applicable to ITER and other burning plasma experiments. In addition, there is related support, not part of the OPC, for both the ITER physics basis and the preparations for science and technology research to be conducted using ITER. This support comes from a broad spectrum of science and technology activities within the FES program such as experimental research from existing facilities, as well as the fusion plasma theory and computation activities, and is not part of the MIE project.

The annual Total Project Cost (TPC) profile for FY 2006 through FY 2014 is provided below. The profile and TPC could change further in the future if increases in escalation and/or fluctuations in the currency exchange rates occur. The profile is preliminary until the Director General and the ITER Organization have achieved a standard mode of operation, and the baseline scope, cost, and schedule for the MIE project (CD-2b) are established.

U.S. Contributions to ITER MIE Project Annual Profile[a]

(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Costs	Total Project Cost
2006	15,866	3,449	19,315
2007	37,000	23,000	60,000
2008	149,500	10,500	160,000
2009	208,500	6,000	214,500
2010	208,500	821	209,321
2011	181,964	—	181,964
2012	130,000	—	130,000
2013	116,900	—	116,900
2014	30,000	—	30,000
Total	1,078,230	43,770	1,122,000

Estimated TEC, OPC, and TPC

The table below reflects the results of the fall 2005 negotiations; i.e., India joined as an equal, non-host partner, cost sharing among the seven parties and the revised allocation of hardware contributions were finalized, and additional contingency was incorporated into the estimate. The shift in OPC and TEC funding, namely an increase in the TEC and decrease in the OPC, was made to be more consistent with DOE Order 413.3A principles and because less R&D is needed in the outyears. The OPC provides for R&D activities in support of the design; contingency is not provided for R&D. The Total Project Cost (TPC) remains $1,122,000,000. The TPC is based on project completion in 2014. The international ITER Organization recently announced a schedule indicating a first plasma in 2016. The international and domestic project schedule will be more firm at CD-2b, and the estimate remains preliminary until the baseline is established at CD-2b.

[a] Mission Need (CD-0) was approved in July 2005 with a preliminary TPC of $1.122 billion (the OMB cap). The funding profile is also preliminary and incorporates key results of the December 2005 negotiations. During FY 2007 and early FY 2008, U.S. reviews are scheduled to validate the cost and schedule estimates for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2007 and FY 2008 will also validate the international cost and schedule which can have an affect on the U.S. Contributions to ITER project. The baseline TPC, including the funding profile, will be established at CD-2b planned for late FY 2008. The FY 2008 Budget Request is for engineering design and long-lead procurements only. Engineering design may include limited fabrication and testing of design concepts.

	(dollars in thousands)	
	Current Estimate	Previous Estimate
U.S. Contributions to ITER Project		
Total Estimated Cost		
a. Procurement of U.S. in-kind equipment (non-host contribution to ITER)	487,140	573,800
b. Design of US in-kind equipment	58,800	—
c. Installation of U.S. in-kind equipment	69,350	71,900
d. Operation of U.S. ITER Project Office including management, QA, procurement, etc.	112,280	123,600
e. Assignment of U.S. scientists and engineers to ITER Org (non-host contribution to ITER)	22,090	87,300
f. Contribution of funds for support personnel at ITER Org (non-host contribution to ITER)	72,640	36,200
Subtotal	822,300	892,900
Contingency for Items a thru d above[a]	194,680	—
International ITER Organization Reserve[b]	61,250	—
Total Contingency (Current 31%, Previous 16%)	255,930	145,200
Total Estimated Cost (TEC)	1,078,230	1,038,000
Other Project Costs		
Other Project Costs – R&D for above tasks	43,770	68,000
Other Project Costs Contingency (Current 0%, Previous 24%)[c]	—	16,000
Total Other Project Costs (OPC)	43,770	84,000
Total Project Cost (TPC)	1,122,000	1,122,000

Related Annual Funding Requirements

The current estimate in the table below incorporates the results of the fall 2005 negotiations; i.e., agreement was reached on cost sharing during operations, deactivation and decommissioning. Specifically, it considers the procedure for converting currencies into Euros and the 20-year period of annual contributions to the decommissioning fund in conjunction with ITER operations.

[a] Contingency is provided for fabrication, design and installation of U.S. in-kind equipment.
[b] If contingency is needed for personnel and/or cash, such contingency would be covered by the U.S. contribution to the Central Reserve.
[c] Contingency is not provided for OPC activities.

	(dollars in thousands)	
	Current Estimate	Previous Estimate
FY 2015–FY 2034[a]		
U.S. share of annual facility operating costs including commissioning, maintenance, repair, utilities, power, fuel, improvements, and annual contribution to decommissioning fund for the period 2015 to 2034. Estimate is in year 2015 dollars.	56,900	55,700
FY 2035–FY 2039		
U.S. share of the annual cost of deactivation of ITER facility for the period 2035–2039. Estimate is in year 2037 dollars.	18,200	17,700

The Total Project Cost for the U.S. Contributions to ITER MIE project is $1,122,000,000, consisting of TEC funding for the fabrication of the equipment including contingency, provision of personnel, the U.S. share of cash for common project expenses at the ITER site, and contingency for the ITER Organization, and the OPC funding for R&D activities supporting the TEC-funded procurements. This MIE is augmented by the technical output from a significant portion of the FES research program. The U.S. is a major participant in the International Tokamak Physics Activity (ITPA), which delineates high-priority physics needs for ITER and assists their implementation through collaborative experiments among the major international tokamaks, and analysis and interpretation of experiments for extrapolation to ITER. Virtually the entire FES program provides related contributions to such ITER-relevant research, not part of the TEC, OPC, and TPC, and prepares the U.S. for effective participation in ITER when it starts operations.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all SC program offices with the goal of achieving breakthrough scientific advances through computer simulation that are impossible using theoretical or laboratory studies alone. By exploiting the exponential advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-disciplinary collaboration among scientists, computer scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. The SciDAC 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, and astrophysics.

During the past year, multidisciplinary teams of computational plasma physicists, applied mathematicians, and computer scientists continued work on three fundamental SciDAC research projects in the areas of macroscopic stability, electromagnetic wave-plasma interaction, and simulation of turbulent transport of energy and particles. During the preceding three years, these teams achieved significant advances in the simulation of mode conversion of radio frequency waves in tokamak plasmas, modeling of edge instabilities with realistic plasma parameters, and understanding turbulent transport as a function of plasma size in tokamaks. In early FY 2006, the FES program and the Advanced Scientific Computing Research (ASCR) program completed a competitive peer review process and funded two fusion simulation prototype centers—one on integrated simulation of tokamak edge plasmas, and one on integrated simulation of wave-plasma interaction and macroscopic stability.

[a] FY 2015 is the estimated date for start of operations based on the current international ITER schedule. This is one year later than was stated in the FY 2007 Budget request.

Scientific Facilities Utilization

The FES request includes funds to operate and use major fusion physics collaborative science facilities. The Department's three major fusion 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 (NSTX) at the Princeton Plasma Physics Laboratory.

The funding requested will provide research time for about 500 scientists in universities, federally sponsored laboratories, and industry, and will leverage both federally and internationally sponsored research, consistent with a strategy for enhancing the U.S. national science investment.

The total number of hours of operation at all of the major fusion facilities is shown in the following table.

	FY 2006	FY 2007	FY 2008
Optimal hours[a]	2,800	2,800	2,800
Planned hours	1,168	1,440	1,560
Achieved Hours	1,472[b]	N/A	N/A
Hours operated as percent of planned hours	126%	N/A	N/A

In addition to the operation of the major fusion facilities, the National Compact Stellarator Experiment (NCSX) MIE project at PPPL is supported. Milestones for this project are shown in the following table.

FY 2006	FY 2007	FY 2008
Complete fabrication of a vacuum vessel subassembly and two modular coils.	Complete winding of one half of the modular coils.	Complete winding of all of the modular coils.

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 masters and doctoral degrees, 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 2006, the FES program supported 461 graduate students and post-doctoral investigators. Of these, approximately 65 students conducted research at DIII-D, Alcator C-Mod, and NSTX. 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.

[a] This consists of 40 hours per week for DIII-D and NSTX and 32 hours per week for C-Mod.
[b] A refund of prior year tax payments allowed DIII-D to schedule 200 hours over the total supported by the FY 2006 appropriation. Excluding this additional operating time the percentage would be 109%.

Data on the workforce for the FES program are shown in the table below. The numbers for Permanent PhD's, Postdoctoral Associates, and Graduate Students include personnel at universities, national laboratories, and industry.

	FY 2006	FY 2007 estimate	FY 2008 estimate
# University Grants	236	211	260
# Permanent PhD's	707	718	775
# Postdoctoral Associates	110	112	120
# Graduate Students	351	356	385
# PhD's awarded	33	33	36

External Independent Reviews

The costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $100,000,000 within SC are funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to these projects funded within SC. Beginning in FY 2007, the EIR business line will be financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

Joint Program in High Energy Density Laboratory Plasmas

The National Nuclear Security Administration (NNSA) and SC are establishing[a] a joint program in High Energy Density Laboratory Plasmas (HEDLP), a major sub-area within the discipline of high energy density physics (HEDP). The joint program will establish appropriate HEDLP peer review infrastructure, including solicitations, user groups, and user facility policies, in order to effectively steward HEDLP within DOE while maintaining the interdisciplinary nature of this area of science. HEDLP joint program stewardship supports the Department's programmatic goals in inertial confinement fusion science, including exploring energy-related topics, research into extreme states of matter, and stockpile stewardship. Other agencies may join the program in the future as dictated by agency needs and priorities. Funding for the program is shown below.

	(dollars in thousands)		
	FY 2006[b]	FY 2007	FY 2008
Fusion Energy Sciences	15,470	11,949	12,281
NNSA-Office of Defense Programs	12,086	10,000	12,356
Total, High Energy Density Laboratory Plasma Joint Program	27,556	21,949	24,637

The joint program in HEDLP will provide for FES participation in and coordination with the NNSA's Stewardship Science Academic Alliance Program (SSAA) and the National Laser User Facility Program. The joint program will minimize research duplication, increase HEDLP research at NNSA facilities, and provide for a SC-style competitive and peer reviewed grant process. Further details on the FES contributions to the joint program are contained in the FES Alternative Concept High Energy

[a] Establishment of the HEDLP joint program is expected by spring of 2007.
[b] Prior year funds for HEDLP-related activities are included for reference.

Density Physics budget narrative. Similarly, further details on the NNSA contributions to the joint program can be found in the NNSA's budget narrative on Inertial Confinement Fusion (ICF) and High Yield and Focused Stockpile Research campaigns, which include individual investigator (grants) and research centers activities (cooperative agreements) in HEDP funded under the NNSA Stewardship Science Academic Alliances Program (SSAA), and also NNSA user programs such as the National Laser User Facility Program.

In FY 2008, the joint program will issue a combined solicitation for FES university activities and existing NNSA research centers that supports academic research in this area. Separate companion solicitations for the national laboratories will be considered by FES from time to time. The joint program will be assessed frequently to determine its success in advancing HEDLP.

Science

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Science			
Tokamak Experimental Research	45,701	45,838	49,258
Alternative Concept Experimental Research	59,594	56,302	56,711
Theory	24,947	23,900	24,552
SciDAC	4,220	6,970	7,160
General Plasma Science	14,180	13,941	14,655
SBIR/STTR	—	7,262	7,193
Total, Science	148,642	154,213	159,529

Description

The Science subprogram promotes 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, funded by the FES program, 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 mass of the resultant plasma to escape during the time when significant fusion reactions occur. The target physics and major experiments in inertial fusion are funded by NNSA. The scientific feasibility of inertial fusion is underpinned by the pertinent subfields of high energy density physics. The Science subprogram supports exploratory research to combine the favorable features of, and the knowledge gained from, magnetic confinement and/or high energy density physics, both for steady-state and pulsed approaches, in new, innovative fusion concepts. There has been great progress in plasma science during the past three decades, in both magnetic confinement and high energy density physics, and today the world is at the threshold of a major advance in fusion energy development—the study of burning plasmas, in which the self-heating from fusion reactions dominates the plasma behavior. Such a burning plasma will be demonstrated in ITER for the first time. The magnetic fusion program is being organized to emphasize investigation of key physics issues for burning plasmas, in preparation for the ITER experiments.

Benefits

The Science subprogram provides the fundamental understanding of plasma science needed to address and resolve critical scientific issues related to fusion burning plasmas. This work is carried out on major fusion facilities, in small experiments, and supported by extensive theoretical and computational research. The Science subprogram also explores and develops diagnostic techniques and innovative concepts that optimize and improve our approach to creating fusion burning plasmas, thereby seeking to minimize the programmatic risks and costs in the development of a fusion energy source. Finally, this subprogram provides training for graduate students and postdoctoral associates, thus developing the national workforce needed to advance plasma and fusion science.

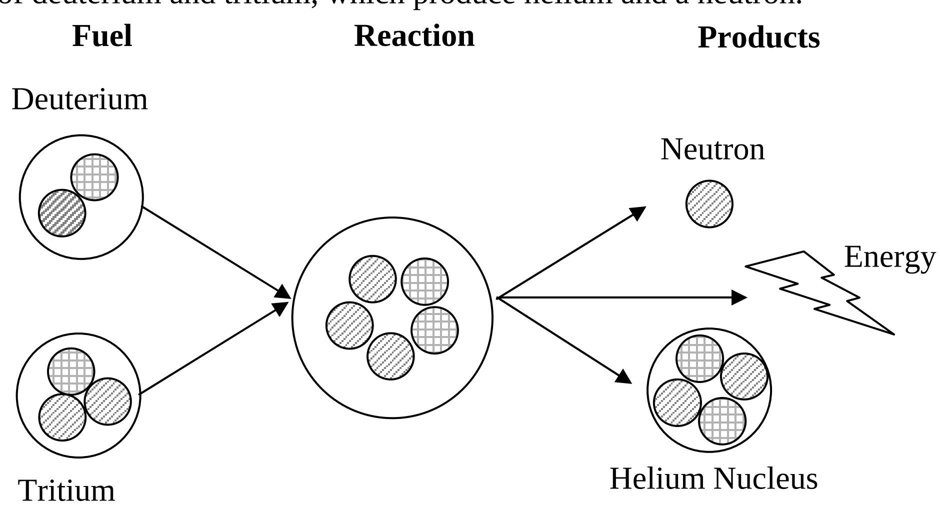
Supporting Information

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 ten years the Science subprogram will continue to advance our understanding of plasmas through an integrated program of experiments, theory, and simulation as outlined in the Integrated Program Planning Activity for the FES Program prepared for FES and reviewed by the FESAC. This integrated research program focuses on well-defined plasma scientific issues including turbulence, transport, macroscopic stability, wave particle interactions, multiphase interfaces, hydrodynamic stability, implosion dynamics, fast ignition, 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. This integrated research program also will benefit from ignition experiments performed at 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, a NSF/DOE partnership in plasma physics and engineering, and the Junior Faculty development grants for members of university plasma physics faculties, will continue to contribute to this objective. The ongoing Fusion Science Centers 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, radioactive 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 industrial processing, national security, space propulsion, and astrophysics.

Fusion science, a major sub-field of plasma science, is focused primarily on describing the fundamental processes taking place in plasmas, or ionized gases, in which peak temperatures are greater than 100 million degrees Celsius, and densities are high enough that light nuclei collide and fuse together, releasing energy and producing heavier nuclei. The reaction most readily achieved in laboratory plasmas is the fusion of deuterium and tritium, which produce helium 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, self-organization, 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 source.

For High Energy Density Physics, the major fusion science issues are: (1) high energy density physics that describes intense laser-plasma and beam-plasma interactions; (2) implosion dynamics and stability; (3) target physics and the science of target fabrication; and (4) non-neutral plasmas, as is seen in the formation, transport, and focusing of intense heavy ion beams.

FY 2006 Science Accomplishments

- **Rotational Stabilization of Instabilities on DIII-D**

  In the quest to stably confine high-pressure plasmas for fusion power, it has long been known that rapid spinning of the plasma due to neutral beam injection stabilizes resistive wall modes, instabilities in the outer region of the plasma. Unfortunately, such rapid rotation will not occur in fusion power plants, where the plasma will be self-heated by the alpha particles produced by the fusion reactions. However, recent research on the DIII-D national fusion facility now indicates that the rotation speed needed to stabilize these modes is lower than previously thought. This research has important implications for ITER, since ITER is expected to have low plasma rotation speed. This favorable result was made possible by the reorientation of one of the neutral beam injectors on DIII-D during a year-long shutdown for maintenance and upgrades.

- **Microwaves Drive a Million Amperes of Plasma Current in Alcator C-Mod**

  Replacing the current driven by the transformer in tokamaks is essential for continuous operation, and an important issue confronting the development of tokamaks into practical fusion power plants. Using current driven by radio-frequency (RF) waves in Alcator C-Mod, nearly 100% of up to 1 million Amperes of current originally driven by the transformer has been replaced using 800 to 900 kilowatts (kW) of RF power, for pulse lengths approaching one current profile rearrangement time. The results are in line with theoretical and numerical predictions, and imply that with increased RF power and pulse length, at higher densities and temperatures, plasmas in Alcator C-Mod could be entirely sustained without the aid of a transformer under conditions approaching those required for near steady-state operation in ITER.

- **High-Resolution Nonlinear Simulations of Edge Localized Modes**

  Predicting the behavior and optimizing the confinement in a tokamak burning plasma device such as ITER requires improved simulations of the entire plasma region, particularly the plasma edge. The steep gradients present at the edge give rise to a class of quasi-periodic nonlinear oscillations known as Edge Localized Modes or ELMs. The simulation of the nonlinear physics of these events is very challenging due to the fine-scale structures that develop and influence the ELM frequency and magnitude. This year, the large nonlinear extended MHD codes being developed in the U.S.—NIMROD and M3D—have been able to substantially increase the realism of their simulations by increasing the resolution of their models, allowing the inclusion and study of physical processes previously neglected—most notably sheared plasma rotation. These high resolution simulations, including sheared plasma flow, help to illuminate the important plasma properties that determine different ELM behavior. This knowledge is key to begin developing control techniques to modify ELM behavior, leading to higher performance in ITER.

- **Ion Heating in the Madison Symmetric Torus**

In the Madison Symmetric Torus (MST), a large reversed field pinch experiment at the University of Wisconsin-Madison, plasmas have recently been produced in which ions, as well as electrons, attain temperatures of about 10 million degrees. The ions are heated by a sudden magnetic reconnection event, during which more than 10 megawatts (MW) of power is transferred from the magnetic field to the ions. The event can now be timed such that it occurs immediately before the period of improved confinement, which retains the added ion heat. In conventional methods of heating plasmas in magnetic fusion, electrons are first heated by microwave sources. The electrons then transferred the energy to the ions by collisions. Losses occur in the process and limit the efficiency of such heating techniques. MST scientists are studying the field reconnection phenomenon as a potential technique for efficient heating of the ions directly without having to go through the cycle of heating the electrons.

- **Novel Method for Generating Plasma Current in the National Spherical Torus Experiment**

  Coaxial Helicity Injection (CHI) has previously been used to generate toroidal currents in small fusion experiments, such as the Helicity Injected Tokamak (HIT-II) at the University of Washington. Recent results from the National Spherical Torus Experiment (NSTX) demonstrate that this technique for generating toroidal current in a plasma works well in larger facilities too. CHI was used to generate a plasma current of 160,000 Amperes, a world record for non-inductive closed-flux current generation. This result is important for future spherical torus fusion experiments, since there will be little room for a solenoid primary winding in such experiments.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Tokamak Experimental Research	**45,701**	**45,838**	**49,258**

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 coordinated programs on the two major U.S. tokamak facilities, DIII-D at General Atomics and Alcator C-Mod at MIT. Both DIII-D and Alcator C-Mod are operated as national collaborative science 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 (ITPA), both DIII-D and Alcator C-Mod continue to increase their efforts on joint experiments with other major facilities in Europe and Japan in support of ITER-relevant physics issues.

In FY 2008, U.S. tokamak research will continue to focus on supporting ITER. DIII-D will have the opportunity to further exploit new experimental flexibilities acquired through hardware improvements completed in FY 2005 and FY 2006. C-Mod will pursue a program with high magnetic field and high power densities incident on ITER-candidate materials, while utilizing recent hardware upgrades to improve control of various plasma parameters. In international collaborations, the scope of joint ITPA experiments will be enhanced to accommodate new experiments in support of ITER. These activities will enhance the understanding of key ITER physics issues, including plasma stability control,

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

disruption mitigation, wave-particle interaction, energy and particle transport, and development of improved plasma discharges for burning plasma studies on ITER.

There will also be some preparatory work for enhanced collaboration on new superconducting tokamaks in Korea and China to investigate steady state physics and technology 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. They do this by controlling the distribution of current in the plasma with electromagnetic wave current drive. The interface between the plasma edge and the material walls of the confinement vessel is managed 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 2006	FY 2007	FY 2008
▪ **DIII-D Research**	**24,274**	**24,300**	**25,264**

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 the properties of high temperature plasma. It also has unique capabilities to shape the plasma and provide feedback control of error fields that, in turn, affect particle transport in the plasma and the stability of the plasma. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layer physics using a “magnetic divertor” to control 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 primary goal of the DIII-D program is to advance the understanding of the science of fusion plasmas in all four key Magnetic Fusion Energy (MFE) fusion topical science areas of energy transport, stability, plasma-wave interactions, and boundary physics, and to explore various crosscutting issues that integrate across topical areas to enable the success of ITER and achieve a burning plasma. In the past few years, the investigation of ITER relevant discharge scenarios, including the development of advanced scenarios, has gained emphasis in the DIII-D experimental program.

In FY 2008, the DIII-D program will continue to exploit the new experimental flexibility acquired in the past two years. DIII-D experiments will focus on providing solutions to key ITER issues and developing the control tools and the science basis for high performance, steady state tokamak operation. High priority will be given to building a firm physics basis for key ITER design decisions in the areas of resistive wall mode stabilization in low rotation plasmas, neoclassical tearing mode stabilization utilizing modulated electron cyclotron current drive, the suppression of edge localized modes with resonant magnetic perturbations, and disruption detection and mitigation techniques. The DIII-D program will also be able to accommodate a reasonable number of ITPA joint experiments with the international community.

	FY 2006	FY 2007	FY 2008
▪ **Alcator C-Mod Research**	**8,490**	**8,890**	**9,133**

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 the only tokamak in the world operating at and above the ITER design magnetic field and plasma densities, and it produces the highest pressure tokamak plasma in the world, approaching pressures expected in ITER. It is also

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

unique in the use of all-metal 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 ITER. The facility has made significant contributions to the world fusion program in the areas of plasma heating, stability, and confinement in high field tokamaks, all of which are important integrating issues for burning plasmas.

In FY 2008, C-Mod will conduct a strong research program primarily in support of ITER. Experiments will test the performance of the tungsten divertor tiles, an ITER-candidate material, under near-ITER-level incident power densities. ITER quasi-steady-state operating scenarios using lower hybrid and ion cyclotron radio frequency waves will be developed. A newly installed cryopump will greatly improve plasma density control, enabling access and investigation into new advanced tokamak regimes. Plasma rotation in the absence of significant momentum injection, also very important to ITER stability, will be further explored.

Other ITER-relevant topics that the C-Mod team will focus on in FY 2008 include plasma surface interaction with all-metal walls, measuring the effects of and mitigating disruptions in the plasma, understanding the physics of the plasma edge in the presence of large heat flows, controlling the current density profile for better stability, and helping to build international cross-machine databases using dimensionless parameter techniques. C-Mod will participate in many joint experiments organized by the ITPA involving all seven ITER parties.

▪ **International**	**4,951**	**5,064**	**5,202**

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 FES program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. This allows U.S. scientists to have access to the unique capabilities of facilities that exist abroad. These include the world's highest performance tokamaks (JET in England and JT-60U 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 Korea on KSTAR on the design of plasma diagnostics, control systems, and with China for physics operations on the new long-pulse, superconducting, advanced tokamak EAST. The U.S. collaboration on EAST was instrumental in EAST achieving its first plasma on September 26, 2006. These collaborations provide a valuable link with the 80% of the world's fusion research that is supported and conducted outside the U.S.

The increase in FY 2008 from the FY 2007 level will allow continued U.S. participation in high priority research activities in support of ITER. These include joint ITPA experiments on the large tokamaks JET and JT-60U, some joint experiments on medium sized tokamaks such as TEXTOR and ASDEX-UG in Germany, and other joint ITER-relevant experiments in the areas of plasma wall interactions, plasma instabilities, and first wall design considerations for ITER. In addition, the level of U.S. participation in steady-state physics and technology issues in Tore Supra, KSTAR, and EAST will be maintained. These activities will prepare U.S. scientists for participation in burning plasma experiments on ITER.

▪ **Diagnostics**	**3,763**	**3,854**	**3,959**

Support of the development of unique measurement capabilities (diagnostic instruments) will continue. Diagnostic instruments serve two important functions: (1) to provide a link between theory/computation and experiments for an understanding of the complex behavior of the plasma in fusion research devices; and (2) to provide sensory tools for feedback control of plasma properties in order to enhance device operation. In FY 2008, research will include the development of diagnostics for fundamental plasma parameter measurements, state-of-the-art measurement techniques, and R&D for ITER-relevant diagnostic systems. Diagnostic systems will be installed and operated on current experiments in the United States and on non-U.S. fusion devices through collaborative programs.

The key areas of diagnostic development research will be those identified in the FESAC Report "Scientific Challenges, Opportunities and Priorities for the U.S. Fusion Energy Sciences Program," April 2005: macroscopic plasma physics, multi-scale transport physics, plasma boundary interfaces, waves and energetic particles, and burning plasma physics.

A competitive peer review of the diagnostics development program will be conducted in FY 2007 for funding that begins in FY 2008.

	FY 2006	FY 2007	FY 2008
▪ **Other**	**4,223**	**3,730**	**5,700**

Funding in this category supports educational activities such as research at historically black colleges and universities (HBCUs), graduate and postgraduate fellowships in fusion science and technology, and summer internships for undergraduates. In addition, there is funding for outreach efforts related to fusion science and enabling R&D and operational costs for the U.S. Burning Plasma Organization and FESAC.

	FY 2006	FY 2007	FY 2008
Alternative Concept Experimental Research	**59,594**	**56,302**	**56,711**

This program element broadens the fusion program by exploring the science of confinement optimization in the extended fusion parameter space, with plasma densities spanning twelve orders of magnitude, seeking physics pathways to improve confinement, stability and reactor configurations. Through this scientific diversity, the program element adds strength and robustness to the overall fusion program, by lowering the overall programmatic risks in the quest for practical fusion power in the long term, for which economics and environmental factors are important. At present, three alternate concepts are being pursued at the larger-scale, proof-of-principle level. A number of concepts are being pursued at a concept-exploration level with smaller-scale experiments, as well as research in establishing a knowledge base for high energy density plasmas. The smaller scale experiments and the cutting-edge research have proven to be effective in attracting students and strongly contribute to fusion workforce development and the intellectual base of the fusion program. The research has also resulted in new ideas for the larger toroidal devices (i.e. ITER support). The diversity combined with the excellence of research make the U.S. program the world leader in innovative concepts.

	FY 2006	FY 2007	FY 2008
▪ **National Spherical Torus Experiment (NSTX) Research**	**15,539**	**16,696**	**16,106**

NSTX is one of the world's two largest spherical torus confinement experiments; the MegaAmp spherical tokamak in England is the other. Spherical tori have a unique, nearly spherical plasma shape that complements the doughnut shaped tokamak and provides a test bed for the theory of toroidal magnetic confinement as the spherical limit is approached. Theory predicts that plasmas in a spherical torus will be stable even when high ratios of plasma-to-magnetic pressure and large self-driven current fractions exist simultaneously, provided there is a nearby conducting wall bounding the plasma. If these predictions are verified in detail, it would indicate that a spherical torus uses applied magnetic fields more efficiently than most other magnetic confinement systems and could, therefore, be expected to lead to a more cost-effective fusion power system. An associated issue for spherical torus configurations is the challenge of starting and maintaining the 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, like all high beta plasmas, is characterized by high temperature, fast ions with a large radius of gyration relative to plasma size that could potentially lead to new plasma behaviors of interest. In FY 2008, NSTX research will focus on topics that are important to ITER, as well as to the development of the spherical torus concept. Research on turbulence and transport will focus on measurements of poloidal rotation at low aspect ratio to validate theoretical work. Macroscopic stability studies will concentrate on the use of feedback stabilization and strong shaping to control pressure-limiting modes. Specific experimental campaigns will contribute to assessing the onset conditions and impact of an instability called a "tearing mode," characterizing the effectiveness of feedback control of resistive wall modes, and investigating the effect of active feedback control of unstable modes on longer pulse, high performance plasmas. Boundary physics studies will emphasize studying the behavior of the edge/divertor plasma at low collisionality at ITER-level heat fluxes. Finally, integrated scenario investigations will center on non-inductive current ramp-up and sustainment of high performance plasmas.

	FY 2006	FY 2007	FY 2008
▪ **Experimental Plasma Research**	**21,389**	**19,990**	**20,638**

This element undertakes cutting-edge research to explore innovative, improved pathways to plasma confinement to produce practical fusion energy. The emphasis is on developing the fundamental understanding of the plasma science that underpins innovative fusion concepts. This element is a broad-based research activity, conducted in about 25 experiments and theory-support projects, involving approximately 30 principal investigators and co-principal investigators in 11 universities, 4 national laboratories and industry. Because of the small size of the experiments and the use of sophisticated technologies, the research provides excellent educational opportunities for students and postdoctoral associates, and helps to develop the next generation of fusion scientists. In order to foster a vigorous breeding ground for research, each project is competitively peer reviewed on a regular basis of three to five years, so that a portfolio of projects with high performance is maintained. This is an area of magnetic fusion research where the United States has a commanding lead over the rest of the world. Because of its innovative and cutting-edge nature, this research element incubates and engenders the future of our quest for fusion energy. It has strong appeal to young and talented undergraduates who desire to make a major impact on the quest for fusion energy, attracting them to graduate studies in fusion.

Research opportunities exist for exploiting the physics and engineering advantages offered by plasma self-organization, geometric variations, higher densities, higher magnetic fields, plasma rotation, shear-flow stabilization, electric fields, and pulsed modes of operation. The Plasma Science and Innovation Center at the University of Washington was established in FY 2005 to provide computational support to the program. Since the inception of the Innovative Confinement Concepts (ICC) program in the restructured fusion program in 1998, a number of small, concept-exploration-level experiments have been constructed, including experiments on spheromaks; field reversed configurations; magnetized target fusion; a levitated dipole; centrifugally confined magnetic mirrors; flow-stabilized z-pinch; and electrostatic confinement. Most of these experiments have entered the second, definitive cycle in the data collection process. The near-term goal of the program is twofold:

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

(1) to generate sufficient experimental data for elucidating the physics principles on which these concepts work in a definitive manner, and (2) to develop computer models for these concepts with a sufficient degree of physics fidelity. The achievement of these two objectives will either allow assessments of the path forward in the further advancements of these concepts or the termination of further development of a particular concept. The requested FY 2008 funding is required to sustain progress of the program towards these goals.

	FY 2006	FY 2007	FY 2008
▪ **High Energy Density Physics**	**15,470**	**11,949**	**12,281**

The combination of high plasma density and high plasma temperature needed for inertial fusion produces plasmas with very high energy densities. Energy densities in excess of 100 billion joules per cubic meter are of interest to inertial fusion, and their study is an emerging field of physics called High Energy Density Physics (HEDP). Plasmas at these energy densities are characterized by having pressures exceeding a million atmospheres. In the laboratory, these high energy density conditions are produced typically through the use of high power lasers, ion beams, or convergence of high density plasma jets.

HEDP is an emerging field of science. Understanding the behavior of matter at high energy densities is identified by the National Academy of Sciences as one of the eleven scientific challenges for the 21st Century. The National Ignition Facility (NIF) is slated to become fully operational in FY 2009–FY 2010, with the first ignition experiment to be initiated around FY 2010. The focus of the FES program is to explore innovative approaches to HEDP and to position the research community to take advantage of the availability of NIF to pursue energy-relevant HEDP, maintaining our world leadership in this field. The research described below is planned in response to the 2007 report of the Interagency Task Force on High Energy Density Physics and in support of the joint program in High Energy Density Laboratory Plasma (HEDLP) between FES and the NNSA ICF program.

The requested funding in FY 2008 is required to sustain research in fast ignition, high Mach number plasma jets and the study of dense plasmas in ultrahigh magnetic fields. These are exciting new fields of HEDP that are attracting worldwide scientific attention. Research will continue on the relativistic physics of thermal transport in fast ignition. The development of the cryogenic targets for fast ignition will be postponed or slowed down. Modest efforts to explore experimental techniques to produce high Mach number, high density plasma jets in the laboratory, create plasmas in high magnetic fields, and study their application to HEDP are being pursued. Research on plasma jet development is expected to be poised to begin studying the merging of plasma jets to form high energy density plasmas. The research leverages and collaborates with NNSA's program efforts in non-defense areas of HEDP and makes use of NNSA's facilities at the University of Rochester, LLNL, and LANL. Collaboration will be extended to other Federal agencies as well, wherever appropriate, through an interagency process that is in progress.

The requested funding will also allow research to continue in heavy ion beam science. The research will develop the knowledge base on the highly successful technique of neutralized drift compression (NDCX-I) using a longitudinal velocity profile demonstrated during FY 2005 and FY 2006. This knowledge base will allow the development of the second generation of the neutralized drift compression experiment that would lay the technical basis for potentially developing an ion-driven HEDP facility for the study of warm dense matter. The requested funding will also allow research on electron cloud dynamics in the High Current Beam Transport Experiment (HCX).

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **Madison Symmetrical Torus**	**6,445**	**6,970**	**6,970**

The goal of the Madison Symmetrical Torus (MST), at the University of Wisconsin-Madison, is to obtain a fundamental understanding of the physics of reversed field pinches (RFPs), particularly magnetic fluctuations and their macroscopic consequences, and to use this understanding to develop the RFP fusion configuration. The RFP is geometrically similar to a tokamak, but with a much weaker magnetic field that reverses direction near the edge of the plasma. Research in the RFP's self-organization properties has astrophysical applications and may lead to a more cost-effective fusion system. The plasma dynamics that limit the energy confinement, the ratio of plasma pressure to magnetic field pressure, and the sustainment of the plasma current in a RFP are being investigated in this experiment. MST is one of the four leading RFP experiments in the world, and is unique in that it pioneered the reduction of magnetic fluctuations by current density profile control. In recent years, this approach has led to a ten-fold increase in energy confinement time.

In FY 2008, MST plans to test electron Bernstein wave injection and complete construction of a lower hybrid wave antenna system that will more than double FY 2006 power levels. The research team will also complete construction of a fast Thomson scattering diagnostic system, continue construction of a programmable power supply to dramatically improve plasma control, and determine whether to pursue full current sustainment by oscillating field current drive. As an important thrust of its overall research program, MST will continue to explore the feasibility of a pulsed power plant scenario, which may prove to have significant advantages over a steady-state fusion power plant.

▪ **National Compact Stellarator Experiment Research**	**751**	**697**	**716**

This funding supports the research portion of the program to be executed with the National Compact Stellarator Experiment (NCSX) at PPPL, which involves participation and a leadership role within the National Compact Stellarator Program (NCSP). PPPL, ORNL, and LLNL are the participants in NCSX research that keep abreast of physics developments in domestic and international stellarator research, factoring those developments into planning of the NCSX experimental program, as well as preparation of long-lead-time physics analysis tools for NCSX application. These tools have a dual use: setting physics requirements for hardware upgrades and interpreting data from future NCSX experiments. Some long-lead hardware upgrades will be designed, such as plasma control, first wall, and diagnostic systems. The NCSX team will: (1) finalize preparations for the start of experimental operations in FY 2009, including requesting initial collaboration proposals; (2) prepare for experiments to elucidate key configuration characteristics by e-beam mapping, including the study of the effects of field perturbations such as coil leads and feeds, and fabrication errors; and (3) set requirements for key diagnostic and facility upgrades.

Theory	**24,947**	**23,900**	**24,552**

The Theory program provides the conceptual scientific underpinning for the FES program by supporting three of its thrust areas: burning plasmas, fundamental understanding and configuration optimization. Theory efforts meet the challenge of describing the complex multiphysics, multiscale, non-linear plasma systems at the most fundamental level and, in doing so, generate world-class science. These descriptions—ranging from analytic theory to highly sophisticated computer simulation codes—are used to interpret results from current experiments, plan new experiments in existing facilities, design future experimental facilities, and assess projections of their performance. The program focuses on both

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

tokamaks and alternate concepts. Work on tokamaks is aimed at developing a predictive understanding of advanced tokamak operating modes and burning plasmas—both of which are important to ITER—while the emphasis on alternate concepts is on understanding the fundamental processes determining equilibrium, stability, and confinement for each concept. The theory program also provides the basic physics needed in the FES program large-scale simulation efforts that are part of the Scientific Discovery through Advanced Computing (SciDAC) portfolio and, together with SciDAC, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and controlled.

The Theory program is a broad-based program with researchers located at six national and federal laboratories, over thirty universities, and several private companies. Institutional diversity is one of the strengths of the program, since theorists at different types of institutions play different but complementary roles in the program. Theorists in larger groups, located mainly at national laboratories and private industry, generally support major experiments, work on large problems requiring a team effort, or tackle complex issues requiring multidisciplinary teams. Those at universities tend to support smaller, innovative experiments or work on more fundamental problems in plasma physics while training the next generation of fusion plasma scientists.

SciDAC	**4,220**	**6,970**	**7,160**

Major scientific challenges exist in many areas of plasma and fusion science that can best be addressed through advances in scientific supercomputing. Current projects are focused on the topics of microturbulence simulation, extended magnetohydrodynamics modeling, and simulation of electromagnetic wave-plasma interaction, which will provide a fundamental understanding of plasma science issues important to a burning plasma and lay the groundwork for a possible future fusion simulation project. New projects will continue to involve collaborations among physicists, applied mathematicians and computer scientists, advancing both the fusion energy science and computational modeling fields. In FY 2006, the FES program and the Advanced Scientific Computing Research program initiated two fusion simulation prototype centers to prepare for a possible fusion simulation project in the future, following a competitive peer review process. One center is focused on integrated simulation of the edge plasma in a tokamak, and the other is concerned with the control of large-scale instabilities with electromagnetic waves.

In FY 2008, these prototype centers, along with the three continuing SciDAC projects, will emphasize development of new computing techniques and will make use of rapid developments in computer hardware to attack complex problems involving a large range of scales in time and space, including plasma turbulence and transport, large scale instabilities and stability limits, boundary layer/edge plasma physics, and wave-plasma interaction. These problems were beyond the capability of the fastest computers in the past, but it is now becoming possible to make progress on problems that once seemed intractable. The objective of the FES 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 and fruitful collaboration on major international facilities.

General Plasma Science	**14,180**	**13,941**	**14,655**

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 that make

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

contributions in many basic and applied physics areas. Principal investigators at universities, laboratories and private industry carry out the research. A critically important element is the education of plasma physicists. Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Fusion Science Centers, and the Plasma Physics Junior Faculty Development Program. The program will continue to fund proposals that have been peer reviewed. Funding will also continue for the Fusion Science Center program that was started in FY 2004 with approximately $2,390,000 each year in FY 2006 and FY 2007. These Centers perform fusion plasma science research in areas of such wide scope and complexity that it would not be feasible for individual investigators or small groups to make progress, and they strengthen the connection between the fusion research community and the broader scientific community. Basic plasma physics user facilities will be supported at both universities and laboratories, sharing costs with NSF where appropriate. FES will provide $1,666,000 toward operations and in-house research at the Basic Plasma Science Facility in FY 2008. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases. The FES program will continue to share with NSF the cost of funding the multi-institutional plasma physics frontier science center started in FY 2003.

SBIR/STTR	**—**	**7,262**	**7,193**

In FY 2006, $6,215,000 and $746,000 was transferred to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. The FY 2007 and FY 2008 amounts are the estimated requirements for the continuation of these programs.

Total, Science	**148,642**	**154,213**	**159,529**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Tokamak Experimental Research	
▪ **DIII-D Research**	
This increase will allow the DIII-D national research team to conduct research relevant to burning plasma issues and topics of interest to the ITER project in addition to maintaining the broad scientific scope of the program.	+964
▪ **Alcator C-Mod Research**	
The increase will maintain the C-Mod research team at current staffing levels.	+243
▪ **International**	
The increase will maintain and enhance the collaborative effort on international tokamaks, allowing U.S. scientists to participate in ongoing tokamak experiments in the European Union and Japan.	+138
▪ **Diagnostics**	
The increase will maintain the level of effort for developing new base-program and ITER-relevant diagnostics.	+105

	FY 2008 vs. FY 2007 ($000)
▪ **Other**	
The increase will restore funding to pre-FY 2007 levels for Historically Black Colleges and Universities, education outreach activities, and operation of the U.S. Burning Plasma Organization.	+1,970
Total, Tokamak Experimental Research	**+3,420**
Alternate Concept Experimental Research	
▪ **National Spherical Torus Experiment Research**	
The net decrease is the result of transferring $750,000 of equipment funds for diagnostic upgrades from the research budget to the facility operations budget. An increase of $160,000 will maintain the NSTX research team at current staffing levels.	-590
▪ **Experimental Plasma Research**	
The increase provides for the same level of effort and focus as FY 2007.	+648
▪ **High Energy Density Physics**	
The increase provides for the same level of effort and focus as FY 2007.	+332
▪ **National Compact Stellarator Experiment Research**	
The increase provides for the same level of effort and focus as FY 2007.	+19
Total, Alternative Concept Experimental Research	**+409**
Theory	
The increase provides for the same level of effort and focus as FY 2007.	+652
SciDAC	
The increase will support the same level of effort as FY 2007.	+190
General Plasma Science	
The increase will support high-quality grants funded under the NSF/DOE Partnership in Basic Plasma Science and Engineering, additional funding for a Junior Faculty grant, and additional research on the Basic Plasma Science Facility at UCLA.	+714
SBIR/STTR	
Support for SBIR/STTR is provided at the mandated level.	-69
Total Funding Change, Science	**+5,316**

Facility Operations

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Facility Operations			
DIII-D	30,780	32,362	34,405
Alcator C-Mod	13,032	13,941	14,322
NSTX	18,681	18,422	19,972
NCSX (MIE)	17,019	15,900	15,900
GPP/GPE/Other	3,538	3,930	2,905
ITER Preparations	5,294	—	—
U.S. Contributions to ITER (MIE TEC)	15,866	37,000	149,500
Total, Facility Operations	104,210	121,555	237,004

Description

The mission of the Facility Operations subprogram is to manage 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 collaborators. In addition, fabrication of new projects and upgrades of major fusion facilities will be accomplished in accordance with the highest standards and with minimum deviation from approved cost and schedule baselines.

Benefits

The Facility Operations subprogram operates the major facilities needed to carry out the scientific research program in a safe and reliable manner. This subprogram ensures that the facilities meet their annual targets for operating weeks and that they have state of the art, flexible systems for heating, fueling, and plasma control required to optimize plasma performance for the experimental programs. Further, this subprogram fabricates and installs the diagnostics that maximize the scientific productivity of the experiments. Finally, this subprogram provides for the fabrication of new facilities such as NCSX, and for participation in the international collaboration on ITER through the U.S. Contributions to ITER MIE project. The ITER MIE TEC funds are budgeted in this subprogram, while the OPC funds are budgeted in the Enabling R&D subprogram.

Supporting Information

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 collaborative 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.

Funding is provided for the continuation of the NCSX MIE project at PPPL. In FY 2008, the project will be in its sixth year and PPPL will continue the fabrication of the major components and assembly of the entire device.

The FY 2008 Request provides for the third year of funding for the U.S. Contributions to ITER MIE project. If there is a reduction in FY 2007 funding, following the reduction in FY 2006, the funding profile will be revised and the TPC will be affected. The FY 2008 TEC funding of $149,500,000 in the Facilities Operations subprogram provides for direct costs for the MIE including U.S. hardware contributions; U.S. personnel assigned to the international ITER Organization; cash for common needs such as infrastructure, hardware assembly, and installation of ITER components; and contingency for the international ITER Organization. The MIE project is being managed by the U.S. ITER Project Office located at ORNL in accordance with DOE Order 413.3A, Program and Project Management for the Acquisition of Capital Assets.

Funding is also included in this subprogram for general plant projects (GPP) and general purpose equipment (GPE) at PPPL. The 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 final year of the five-year effort to support the move of ORNL fusion personnel and facilities to a new location at ORNL.

FY 2006 Facility Operations Accomplishments

In FY 2006, 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:

- A lithium evaporator was installed on NSTX in March 2006 to test the effectiveness of the lithium coating on particle recycling and impurity control. The first experimental test of partially coated plasma facing components using the lithium evaporator was conducted in April – May 2006, and about 1300 mg of lithium have been evaporated to date. Initial experiments with lithium resulted in a large reduction of oxygen impurities in the subsequent plasma discharges.
- PPPL completed winding 4 of the 18 NCSX modular coil winding forms (MCWFs) and fabrication of the 3 vacuum vessel sectors. The MCWFs are steel structures that support the modular coil windings and position them with high accuracy. The vacuum vessel is a highly shaped structure with stringent requirements on vacuum quality and magnetic permeability.
- In FY 2006, Alcator C-Mod’s lower hybrid antenna structure was modified, re-installed, and used reliably for the facility’s first successful current drive studies. Important diagnostic advances include an imaging hard x-ray camera measuring detailed profiles of the fast electrons driven by the lower hybrid system, multiple spectroscopy views implemented for detailed ion temperature and plasma rotation measurements, and upgrades to the motional stark effect detector system which have greatly improved the signal-to-noise for current profile measurement.
- In FY 2006, DIII-D completed a year-long shutdown period during which an extensive number of facility modifications and enhancements were performed. Collectively called the Long Torus Opening Activities (LTOA), the set of improvements that were successfully completed included:
  - rotation of one of four heating neutral beam lines to inject opposite the other three beam lines (including all the support system modifications);

- installation of a new water cooled lower divertor shelf structure in a collaboration with the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP);
- initiation of the procurement of three long-pulse microwave sources (gyrotrons) to replace existing short-pulse gyrotrons;
- additions and modifications to the microwave system infrastructure to support the long-pulse tubes and the testing of a new depressed collector gyrotron; and
- approximately 40 diagnostic modifications and improvements (most involving university or laboratory collaborators) that required or made full use of the extended torus opening.

These modifications will greatly enhance the experimental flexibility of DIII-D, maintaining its status as one of the world's leading fusion research facilities.

The table below summarizes the operation of the major fusion facilities.

Weeks of Fusion Facility Operation

(weeks of operations)

	FY 2006 Results	FY 2007 Request	FY 2008 Request
DIII-D	12[a]	12	15
Alcator C-Mod	16	15	15
NSTX	12	12	12
Total	40	39	42

Detailed Justification

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
DIII-D	**30,780**	**32,362**	**34,405**

Support is provided for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. The DIII-D experimental flexibility was greatly increased by the completion of several hardware improvements in FY 2005 and FY 2006. These included acquisition of three long-pulse (10 second) gyrotrons for high power heating and current drive, addition of particle pumping in the lower divertor, rotation of one of the neutral beam lines in order to control plasma rotation, upgrades to one of the fast wave heating systems, and improvements to the cooling tower, power systems, and field coil connections in order for high performance plasmas to be operated for long pulses. In FY 2008, 15 weeks of single shift plasma operation will be conducted, during which time essential scientific research will be performed as described in the science subprogram. Funding will be provided for completion of a facility power infrastructure upgrade to support maximum utilization of the existing auxiliary heating systems, and for modifications to the coil connections to allow long pulse operations.

[a] A refund of prior year tax payments allowed DIII-D to schedule 5 weeks over the total supported by the FY 2006 appropriation.

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		
Alcator C-Mod	**13,032**	**13,941**	**14,322**

Support is provided for operation, maintenance, minor upgrades, and improvement of the Alcator C-Mod facility and its auxiliary systems, including a new 4-strap ion cyclotron radio frequency (ICRF) antenna, a second lower hybrid wave launcher enabling compound spectra to be investigated, a new data acquisition system, and a non-thermal electron cyclotron emission diagnostic. In FY 2008, C-Mod will be operated for 15 weeks, and a few minor facility upgrades will enable additional ITER-relevant experiments in the future.

National Spherical Torus Experiment	**18,681**	**18,422**	**19,972**

Support is provided for operation, maintenance and a few diagnostics upgrades, including the full poloidal charge exchange recombination spectroscopy system, a fast-ion D-alpha camera, divertor diagnostics, and installation of next-step fluctuation diagnostics. Funding of $750,000 for diagnostic upgrades is transferred from research to facility operations in FY 2008. In FY 2008, there is funding for 12 weeks of operation and a few minor facility upgrades that will enable long pulse, high beta experiments in the future.

National Compact Stellarator Experiment	**17,019**	**15,900**	**15,900**

Funding is requested in FY 2008 for the continuation of the NCSX MIE project consistent with the baseline approved in July 2005. This project was initiated in FY 2003 and consists of the design and fabrication of a compact stellarator proof-of-principle class experiment. PPPL will continue the fabrication of the major components and assembly of the entire device. 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.

General Plant Projects/General Purpose Equipment/Other	**3,538**	**3,930**	**2,905**

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 final year of the move of ORNL fusion personnel and facilities to a new location at ORNL.

ITER Preparations	**5,294**	**—**	**—**

Preparations funding for ITER ended in FY 2006 as the U.S. Contributions to ITER MIE project began. Funding was provided to continue the ITER transitional activities such as safety, licensing, project management, preparation of specifications and system integration. U.S. personnel participated in these activities in preparation for U.S. participation in the international ITER project.

U.S. Contributions to ITER	**15,866**	**37,000**	**149,500**

The U.S. Contributions to ITER MIE project provides hardware, personnel, cash for common expenses, and contingency to the international ITER Organization.

ITER has been designed to provide major advances in all of the key areas of magnetically confined plasma science. ITER's size and magnetic field will provide for study of plasma stability and transport in regimes unexplored by any existing fusion research facility worldwide. Owing to the intense plasma

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

heating by fusion products, it will also access previously unexplored regimes of energetic particle physics. Because of the very strong heat and particle fluxes emerging from ITER plasmas, it will extend regimes of plasma-boundary interaction well beyond previous experience. The new regimes of plasma physics that can be explored for long duration, and the interactions among the anticipated phenomena, are characterized together as the new regime of "burning plasma physics."

The ITER design is based on scientific knowledge and extrapolations derived from the operation of the world's tokamaks over the past decades and on the technical know-how flowing from the fusion technology research and development programs around the world. The ITER design has been internationally validated by wide-ranging physics and engineering work, including detailed physics and computational analyses, specific experiments in existing fusion research facilities and dedicated technology developments and tests performed from 1992 to the present.

The ITER device is a long-pulse tokamak with elongated plasma shape and single null poloidal divertor. The nominal inductive operation produces a deuterium-tritium fusion power of 500 MW for a burn duration of 400 to 3000 seconds, with the injection of 50 MW of auxiliary power. This provides a power gain of up to a factor of 10.

Safety and environmental characteristics of ITER reflect a consensus among the parties on safety principles and design criteria for minimizing the consequences of ITER operation on the public, operators, and the environment. This consensus is supported by results of analysis on all postulated events and their consequences.

DOE will comply with all U.S. environmental and safety requirements applicable to the ITER work that will be conducted in the U.S. Compliance with the National Environmental Policy Act for the U.S. effort is consistent with the standard DOE process in support of long-lead procurement for the manufacture of the components.

DOE's commitment to the ITER Organization is a $^{1}/_{11}$th share (about 9.1%) of the international ITER project costs, which is consistent with the other non-host participants. In addition to scientists and engineers assigned to the ITER Organization, the U.S. has provided one senior management staff member to the ITER Organization, specifically Deputy Director General for Tokamak Systems. All U.S. personnel assigned to the project will comply with the environmental and safety requirements of the host country and with the applicable U.S. legal requirements.

As a result of the extensive collaborative efforts during the ITER Engineering Design Activities (EDA) from 1992 to 1998, and its extension from 1999 to 2001, a mature ITER design exists including completed R&D prototypes of critical ITER components.

The MIE funding provides for procurement of hardware, personnel assigned to the project abroad, U.S. share of cash for ITER project common needs (ITER Organization infrastructure, hardware assembly and installation, and testing of U.S. supplied hardware), contingency, and operation of the U.S. ITER Project Office. The Project Office is responsible for management of U.S. Contributions to ITER including management, quality assurance, procurement, and technical oversight of procurements.

DOE requires the U.S. ITER Project Office to assume a broad leadership role in the integration of ITER-related project activities throughout the U.S. Fusion Energy Sciences Program and, as appropriate, internationally. For managing the direct procurements with industry, the Project Office has assembled experts from throughout the fusion program for technical follow-up and execution of the procurements.

The final allocation of equipment to be supplied by the United States, as revised with the inclusion of India, is indicated below.

- Niobium Tin (Nb_3Sn) Superconducting Strand – Niobium, tin and copper filaments formed into long strands. The U.S. will provide 8% of the total needed for the Toroidal Field Magnets.
- Superconducting Cable – multi-stage cable including strand and insulation. The U.S. will provide 8% of the total needed for the Toroidal Field Magnets.
- Central Solenoid – the U.S. has the lead role for this contribution consisting of six modules plus one spare module; and is responsible for module testing oversight and assembly oversight at the ITER site.
- Blanket Modules – a contribution consisting of 36 (of 360) modules around the tokamak vessel (plus 4 spares), 40 cm thick (including plasma facing components and shield).
- Vacuum Pumping Components – a U.S. contribution consisting of components required to create and maintain the vacuum inside the tokamak vessel.
- Tokamak Exhaust Processing System – a U.S. contribution to include recovery of hydrogen isotopes from impurities such as water and methane, delivery of purified, mixed hydrogen isotopes to the Isotope Separation System, and disposal of non-tritium species.
- Heating and Current-Drive Components for Ion Cyclotron Heating frequencies – the U.S. contribution consists of transmission lines.
- Heating and Current-Drive Components for Electron Cyclotron Heating frequencies – the U.S. contribution consists of transmission lines.
- Fueling Injector – provides for an ITER pellet injector.
- Steady-state Electrical Power System – a U.S. contribution consisting of a steady-state electric power network similar in scale and function to an "auxiliary system" of a large power plant.
- Cooling Water System – the ITER tokamak water cooling system is a U.S. contribution including the primary heat transfer system, the chemical and volume control system, and the draining, refilling, and drying system.
- Diagnostics – a U.S. contribution involving 16% of the ITER Diagnostic effort providing six diagnostic systems such as visible and infrared cameras, toroidal interferometer/polarimeter, electron cyclotron emission, divertor interferometer, and residual gas analyzers; five cover plates on the tokamak vessel on which multiple diagnostics from U.S. and other parties are mounted; and integration of diagnostic systems from other ITER parties.

Activities in FY 2008 will include: complete the design for the central solenoid coil fabrication; complete preliminary design and analysis for the central solenoid structure; award procurement of cabling and jacket material for the toroidal field coil conductor; award procurement of strand for the toroidal field coil conductor; issue requests for proposals for first wall and shield module components and award contract to construct first articles; continue the planning, concept development and

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

preliminary design on the port limiter system; start preliminary design of the transmission lines for the ion and electron cyclotron heating systems, and diagnostics; continue conceptual designs for vacuum pumping and fueling systems; award procurements for components of the tokamak cooling water system; monitor design activities with the EU for the steady-state electrical power network; and complete most R&D activities. R&D activities will continue beyond FY 2008 in the areas of the port limiter system, diagnostics, and the tritium plant exhaust processing system.

The schedule and TEC funding profile for the U.S. Contributions to ITER MIE are reflected in the following tables. The MIE project cost estimate for U.S. Contributions to ITER is preliminary until the baseline scope, cost, and schedule for the MIE project is established at CD-2b.

U.S. Contributions to ITER

	Fiscal Quarter				
	Procurements Initiated	Procurements Complete	Personnel Assignments to Foreign Site Start	Personnel Assignments to Foreign Site Complete	Total Estimated Cost ($000)
FY 2006 Budget Request	3Q FY 2006	4Q FY 2012	2Q FY 2006	4Q FY 2013	1,038,000
FY 2007 Budget Request	4Q FY 2006	4Q FY 2012	2Q FY 2006	FY 2014	1,077,051
FY 2008 Budget Request	1Q FY 2008	4Q FY 2014	2Q FY 2006	FY 2014	1,078,230[a]

[a] The funding profile is a preliminary estimate. During FY 2007 and early FY 2008, U.S. reviews are scheduled to validate the cost and schedule estimates for the U.S. Contributions to ITER MIE project. In addition, international ITER project activities in FY 2007 and FY 2008 will also validate the international cost and schedule which can have an affect on the U.S. Contributions to ITER project. The performance baseline, including the funding profile, will be established at CD-2b, planned for late FY 2008. CD-1/2a/3a is planned for late FY 2007–early FY 2008 in order to take advantage of the planned international ITER design review scheduled to begin in early 2007 by the Director General of the ITER Organization. Note that the MIE OPC funding associated with this Total Estimated Cost is budgeted in the Enabling R&D subprogram.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

Financial Schedule

Total Project Costs (TPC)[a]

(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Cost	Total Project Costs
2006	15,866	3,449	19,315
2007	37,000	23,000	60,000
2008	149,500	10,500	160,000
2009	208,500	6,000	214,500
2010	208,500	821	209,321
2011	181,964	—	181,964
2012	130,000	—	130,000
2013	116,900	—	116,900
2014	30,000	—	30,000
Total	1,078,230	43,770	1,122,000

	FY 2006	FY 2007	FY 2008
Total, Facility Operations	**104,210**	**121,555**	**237,004**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
DIII-D	
The increase will support an additional 3 weeks of operation and complete the power systems infrastructure upgrade and modifications to the coil systems needed for long pulse operations. These enhancements will enable maximum utilization of the auxiliary heating systems that were improved in FY 2005 and FY 2006 and extension of advanced operating modes to longer pulse lengths.	+2,043

[a] The funding profile is a preliminary estimate incorporating the key results of the December 2005 negotiations. During FY 2007 and early FY 2008, U.S. reviews are scheduled to validate the cost and schedule estimates for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2007 and FY 2008 will also validate the international cost and schedule which can have an affect on the U.S. Contributions to ITER project. The performance baseline, including the funding profile, will be established at CD-2b planned for late FY 2008. Additionally, if there is a reduction in FY 2007 funding, following the reduction in FY 2006, the funding profile will be revised and the TPC will be affected. The Other Project Costs associated with the TEC funding are described in the Enabling R&D subprogram.

	FY 2008 vs. FY 2007 ($000)
Alcator C-Mod	
The increase will allow C-Mod to conduct 15 weeks of operation while performing major upgrades to support ITER-relevant research, including a new 4-strap ICRF antenna, a second lower hybrid wave launcher enabling compound spectra to be investigated, and a non-thermal electron cyclotron emission diagnostic.	+381
National Spherical Torus Experiment	
Nearly one-half of the increase results from transferring $750,000 of equipment funds for diagnostic upgrades from the research budget to the facility operations budget. The remainder ($800,000) provides for expected increases in electricity and cryogens and maintains staff at current levels.	+1,550
GPP/GPE/Other	
The decrease reflects the near completion of the move of fusion personnel and equipment from the Y–12 site to the ORNL site.	-1,025
U.S. Contributions to ITER (MIE Total Estimated Cost)	
This increase provides for the third year of funding for the Major Item of Equipment project and is consistent with the stated project cost and schedule profile. Activities in FY 2008 will include advancement and/or completion of various design and analysis activities and initiation of procurements for major U.S. components.	+112,500
Total Funding Change, Facility Operations	**+115,449**

Enabling R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Enabling R&D			
Engineering Research	17,316	15,495	16,002
Enabling R&D for ITER (Other Project Costs)	3,449	23,000	10,500
Materials Research	7,066	4,687	4,815
Total, Enabling R&D	27,831	43,182	31,317

Description

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

Benefits

The foremost benefit of this subprogram is that it enables the scientific advances in plasma physics accomplished within the Science subprogram. That is, the Enabling R&D subprogram develops, and continually improves, the hardware and systems that are incorporated into existing fusion research facilities, thereby enabling these facilities to achieve higher and higher levels of performance within their inherent capability. In addition, the Enabling R&D subprogram supports the development of new hardware that is incorporated into the design of next generation facilities, thereby increasing confidence that the predicted performance of these new facilities will be achieved. Finally, there is a broader benefit beyond the fusion program in that a number of the technological advances lead directly to “spin offs” in other fields, such as superconductivity, plasma processing and materials enhancements.

Supporting Information

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 and increasing amount of the research is oriented toward the technology needs of future experiments, such as ITER. Enabling R&D efforts provide both evolutionary development advances in present day capabilities that will make it possible to enter new plasma experimental regimes, such as burning plasmas, and nearer-term technology advancements enabling international technology collaborations that allow the U.S. to access plasma experimental conditions not available domestically. A part of this element is oriented toward investigation of scientific issues for innovative technology concepts that could make revolutionary changes in the way that plasma experiments are conducted, such as microwave generators with tunable frequencies and steerable launchers for fine control over plasma heating and current drive. This element includes research on blanket technologies that will be needed to produce and process tritium for self-sufficiency in fuel supply. This element also supports research on safety-related issues that enables both current and future experiments to be conducted in an environmentally sound and safe manner. Another activity is conceptual design of the most scientifically challenging systems for fusion research facilities that may be needed in the 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 of fusion.

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 uses both experimental and modeling activities, which makes it more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded by the Basic Energy Sciences program and other government-sponsored programs, as well as making it 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 nearer-term fusion devices, such as burning plasma experiments, 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 nanoscale design of advanced fusion materials with superior performance and lifetime.

Management of the diverse and distributed collection of technology R&D activities continues to be accomplished through a Virtual Laboratory for Technology (VLT), with community-based coordination and communication of plans, progress, and results.

In FY 2008, research efforts will continue supporting the development of enabling technologies that enhance plasma performance on both our current and planned domestic machines as well as for our international collaborations with existing facilities such as JET and possibly with new facilities such as Korea's KSTAR and China's EAST. In addition, resources will be used to continue to develop a data base for materials that can be used in future facilities, to address potential issues that may occur during ITER operation, and to develop the next generation of technology that could be tested in current facilities or in ITER. The Enabling R&D for ITER (Other Project Costs) element will continue to fund R&D in a number of areas, including magnets, first wall/shield modules, tritium processing, fueling and pumping, heating systems, and diagnostics, which directly support the U.S. ITER hardware contributions.

FY 2006 Enabling R&D Accomplishments

A number of technological advances were made in FY 2006. Examples include:

- Use of ITER as a testing environment for integrated first wall and tritium breeding blanket science and technology research has been a principal objective of ITER since its inception and has drawn considerable interest from all ITER parties. The U.S. fusion technology community, in a collaborative effort among researchers, have completed a draft technical plan and cost estimate for a U.S. ITER Test Blanket Module (TBM) program based on two TBM concepts (a dual-coolant liquid breeder concept and a helium-cooled ceramic breeder concept). While the TBM program is not part of the ITER MIE scope and it falls outside of the ITER TPC, the completion of this draft report is an important step toward preparing for possible U.S. participation in the ITER first wall/blanket testing program.
- First experiments studying the effects of strong magnetic fields on turbulent flow and heat transfer in pipes were performed this year at the University of California at Los Angeles (UCLA) as part of the

on-going JUPITER-II collaboration between the U.S. and Japan (DOE-MEXT). These novel experiments used a transparent electrolyte as a working liquid so that laser based velocity diagnostics could be used to map out details of the flow field for comparison to sophisticated Direct Numerical Simulation models of MHD turbulence. In addition, heat transfer experiments were also performed to directly correlate how modifications in ordinary turbulence by MHD effects reduce the heat transfer capability of the liquid. It was found that the heat transfer capability had been reduced by 32% at even very modest magnetic interaction.

- As part of the U.S.-Japan (DOE-JAEA) fusion materials collaboration, the first set of experiments exploring the transport and fate of helium in reduced activation ferritic-martensitic steels and nanostructured ferritic alloys was completed. Fusion relevant helium levels were investigated by applying thin nickel alumina coatings on transmission electron microscopy discs. Under irradiation, these coatings produced alpha particles that are deposited in the adjacent material. The effects of microstructural features on helium bubble density and size can be studied in great detail. This work has shown that nanostructured ferritic alloys more efficiently trap helium than conventional reduced activation ferritic-martensitic steels. Design of helium-tolerant microstructures will be possible as the result of this research.
- Massachusetts Institute of Technology (MIT), in collaboration with the Universities of Maryland and Wisconsin, Communications and Power Industries of Palo Alto, CA, Calabasas Creek Inc., and General Atomics, report operation of a 110 GHz, depressed collector gyrotron at a power level of 1.5 MW with an efficiency exceeding 50%. High power gyrotrons operating at greater than 50% efficiency are needed for heating large-scale plasmas, including the DIII-D tokamak and ITER. The improved efficiency was obtained with a new gyrotron resonator design that also yields reduced ohmic losses. The gyrotron, which has an internal mode converter, operated at MIT in three microsecond pulses of 96 kV and 40 A. Up to 25 kV of voltage depression was used to improve the efficiency. In the next step, these improved results should be tested in an industrial, long pulse version of the gyrotron.
- The pellet fueling scenario for ITER has been modeled using codes validated with DIII-D and other experimental results. The model shows that fuel from high field side launched pellets should be able to penetrate beyond the expected H-mode pedestal region into the core plasma and provide sufficient fueling to maintain ITER at high plasma density.
- The Divertor Materials Exposure Sample (DiMES) on DIII-D was used to measure carbon deposition in a gap between tiles (similar to that on ITER). The measured deposition profile was used to estimate tritium trapping on ITER and was found to be consistent with previous trapping estimates. The DiMES was also used to expose samples of diagnostic mirrors for ITER which produced an important new result which is that elevated temperatures greatly reduce the deposition of carbon on the mirror surface. This is good news for ITER diagnostics.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Engineering Research	**17,316**	**15,495**	**16,002**
▪ **Plasma Technology**	**14,787**	**12,945**	**13,452**

Plasma Technology efforts will focus resources on developing enabling technologies for current and future machines, both domestically and internationally, and on addressing potential ITER operational issues in the area of safety and plasma materials interactions. In addition, a new U.S.-Japan Collaborative Program (Jupiter III) will be initiated on plasma facing and blanket materials for use in future experiments and in testing high efficiency gyrotrons. During FY 2008, the following specific elements will be supported:

- Continue testing of a highly efficient 110 gigahertz, 1–1.5 megawatt industrial prototype gyrotron microwave generator, the most powerful and efficient of its kind for electron cyclotron heating of plasmas.
- Studies will continue in the Plasma Interaction with Surface and Components Experimental Simulator (PISCES) facility at the University of California at San Diego (UCSD), and the Tritium Plasma Experiment at the Idaho National Laboratory (INL), of tungsten-carbon-beryllium mixed materials layer formation and redeposition with attached hydrogen isotopes. Results will be applied to evaluate tritium accumulation in plasma facing components that will occur during ITER operation.
- In the Safety and Tritium Applied Research Facility (STAR) at INL, a new series of material science experiments will be initiated under the current cost-sharing collaboration with Japan (Jupiter III) to resolve key issues of tritium behavior in materials proposed for use in fusion systems.

Additional funds will be provided for research on plasma facing components, heating technologies, and blanket concepts that could be tested in ITER. Funds will also be provided for research in safety and plasma-surface interaction and modeling that will support potential issues that will be encountered during ITER operation.

▪ **Advanced Design**	**2,529**	**2,550**	**2,550**

Funding for this effort will continue to focus on studies of fusion concepts for the future. Systems studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics of such advanced magnetic confinement concepts will be conducted in an iterative fashion with the experimental community.

Enabling R&D for ITER (Other Project Costs)	**3,449**	**23,000**	**10,500**

Enabling R&D funds for ITER activities are identified in FY 2008 for R&D in support of equipment in a number of areas including magnets, first wall/shield modules, tritium processing, fueling and pumping, heating systems, and diagnostics, which would be provided by the U.S. to ITER. This R&D continues to be applicable to future burning plasma experiments.

	FY 2006	FY 2007	FY 2008
(dollars in thousands)			

The MIE project cost estimates for U.S. Contributions to ITER, including the Other Project Costs activities provided in the table below, are preliminary until the baseline scope, cost and schedule for the MIE project are established.

Financial Schedule

Total Project Costs (TPC)[a]

(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Cost	Total Project Costs
2006	15,866	3,449	19,315
2007	37,000	23,000	60,000
2008	149,500	10,500	160,000
2009	208,500	6,000	214,500
2010	208,500	821	209,321
2011	181,964	—	181,964
2012	130,000	—	130,000
2013	116,900	—	116,900
2014	30,000	—	30,000
Total	1,078,230	43,770	1,122,000

	FY 2006	FY 2007	FY 2008
Materials Research	**7,066**	**4,687**	**4,815**

Materials Research remains the key element in establishing the scientific foundations for safe and environmentally attractive uses of fusion as well as providing solutions for materials issues faced by other parts of the FES research program. The FY 2008 request will maintain a small, but highly beneficial Materials Research program that addresses material needs for nearer and longer term fusion devices. The funding will be used for both modeling and experimental activities aimed at the science of materials behavior in fusion environments, including research on candidate materials for the structural elements of fusion chambers. Two cost-shared international collaborations (DOE/JAEA and Jupiter III) focusing on irradiation testing of candidate fusion materials in U.S. facilities will continue.

	FY 2006	FY 2007	FY 2008
Total, Enabling R&D	**27,831**	**43,182**	**31,317**

[a] The funding profile is a preliminary estimate incorporating the key results of the December 2005 negotiations. During FY 2007 and early FY 2008, U.S. reviews are scheduled to validate the cost and schedule estimates for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2007 and FY 2008 will also validate the international cost and schedule which can have an affect on the U.S. Contributions to ITER project. The performance baseline, including the funding profile, will be established at CD-2b planned for late FY 2008. The Total Estimated Cost associated with the OPC funding is budgeted in the Facilities Operations subprogram.

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Engineering Research	
▪ **Plasma Technology**	
The increase will support both heating and magnet programs.	+507
Enabling R&D for ITER (Other Project Costs)	
The decrease is consistent with the revised stated cost and schedule estimate for the ITER MIE project. The FY 2008 OPC funding level is decreased as is customary in an MIE project when the design and R&D needs are resolved or completed and the project is moving into procurement and fabrication.	-12,500
Materials Research	
The increase is due to additional costs for international collaborations with Japan.	+128
Total Funding Change, Enabling R&D	**-11,865**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
General Plant Projects	1,791	1,810	1,900
Capital Equipment	39,603	57,765	169,050
Total, Capital Operating Expenses	41,394	59,575	170,950

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
NCSX (31MB), PPPL	101,971	92,401	41,318	17,019	15,900	15,900	FY 2009
U.S. Contributions to ITER (61PA), Cadarache, France	1,122,000[a]	1,078,230[a]	—	15,866	37,000	149,500	FY 2014
Total, Major Items of Equipment				32,885	52,900	165,400	

[a] Funding is for the third year of the Major Item of Equipment project, U.S. Contributions to ITER and is considered preliminary until the performance baseline is established at CD-2b, planned for late FY 2008. The funding cap of $1,122,000,000 TPC is maintained. The TPC funding cap could change if changes in escalation and/or fluctuations in the current exchange rates occur prior to CD-2b. The estimates incorporate the key results of the December 2005 negotiations and have been prepared based upon (1) U.S. industrial estimates for the hardware items the United States will contribute, (2) estimates for personnel to be assigned abroad consistent with previous experience during the ITER Engineering Design Activities, (3) U.S. cash contributions for a non-host participant in the ITER project, and (4) estimates for operation of the U.S. ITER Project Office including technical oversight of procurement.