Fusion Energy Sciences

Overview

The Fusion Energy Sciences (FES) program mission is to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation needed to develop a fusion energy source. This is accomplished through the study of plasma, the fourth state of matter, and how it interacts with its surroundings.

The next frontier for all the major fusion programs around the world is the study of the burning plasma state, in which the fusion process itself provides the dominant heat source for sustaining the plasma temperature (i.e., self-heating). Production of strongly self-heated fusion plasma will allow the discovery and study of a number of new scientific phenomena. These include the effects of highly energetic fusion produced helium particles on plasma stability and confinement; the strongly nonlinear coupling that will occur among fusion alpha particles, the pressure-driven self-generated current, turbulent transport, and boundary-plasma behavior; the properties of materials in the presence of high heat and particle fluxes and neutron irradiation; and the self-organized nature of plasma profiles over long time scales.

To achieve these research goals, FES invests in flexible U.S experimental facilities of various scales, international partnerships leveraging U.S. expertise, large-scale numerical simulations based on experimentally validated theoretical models, the development of advanced fusion-relevant materials, and the invention of new measurement techniques.

The knowledge base being established through FES research supports U.S. goals for future scientific exploration on ITER, a major international fusion facility currently under construction in St. Paul-lez-Durance, France. ITER will be the world's first magnetic confinement long-pulse, high-power burning plasma experiment aimed at demonstrating the scientific and technical feasibility of fusion energy. Execution and oversight of the U.S. contribution to the ITER project are carried out within FES.

To support the program mission and its major focus, the U.S. fusion program is constructed from four mutually supportive elements:

- Burning Plasma Science: Foundations;
- Burning Plasma Science: Long Pulse;
- Burning Plasma Science: High Power; and
- Discovery Plasma Science.

Highlights of the FY 2016 Budget Request

The most notable changes in the FY 2016 budget include:

- *Increase for the operation of the National Spherical Torus Experiment Upgrade (NSTX-U)* —After the first year of experimental operations with the upgraded device in FY 2015, funding for operations of the NSTX-U user facility will support 14 weeks of run time. Fabrication is supported for two important facility enhancements—a divertor cryopump for better control of the plasma density and a set of magnetic control coils to improve stable, high-performance operation.
- *Progress in hardware contributions for U.S. ITER Project*—Funding provided for critical path items will ensure that U.S. in-kind contributions maintain U.S. commitments to FY 2016 project needs. Funding is provided for ITER Project Office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including industrial procurements and fabrication of central solenoid magnet modules and structures, toroidal field magnet conductor fabrication and delivery, diagnostics, and tokamak cooling water system component procurement, fabrication, and delivery.

Fusion Energy Sciences
Funding ($K)

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Burning Plasma Science: Foundations					
Advanced Tokamak	100,036	100,036	105,348	92,486	-12,862
Spherical Tokamak	65,055	65,055	72,919	65,624	-7,295
Theory & Simulation	33,404	33,404	34,670	28,170	-6,500
GPE/GPP/Infrastructure	5,900	5,900	3,125	5,479	+2,354
Total, Burning Plasma Science: Foundations	**204,395**	**204,395**	**216,062**	**191,759**	**-24,303**
Burning Plasma Science: Long Pulse					
Long Pulse: Tokamak	7,348	7,348	7,695	6,045	-1,650
Long Pulse: Stellarators	5,175	5,175	6,419	5,069	-1,350
Materials & Fusion Nuclear Science	22,126	22,126	24,842	19,795	-5,047
Total, Burning Plasma Science: Long Pulse	**34,649**	**34,649**	**38,956**	**30,909**	**-8,047**
Discovery Plasma Science					
Plasma Science Frontiers	42,274	42,274	46,024	32,609	-13,415
Measurement Innovation	3,500	3,500	3,575	3,575	0
SBIR/STTR & Other	20,359	11,537	12,883	11,148	-1,735
Total, Discovery Plasma Science	**66,133**	**57,311**	**62,482**	**47,332**	**-15,150**

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[1] Funding reflects the transfer of SBIR/STTR to the Office of Science.

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Construction					
14-SC-60 International Thermonuclear Experimental Reactor (ITER)	199,500	199,500	150,000	150,000	0
Total, Construction	**199,500**	**199,500**	**150,000**	**150,000**	**0**
Total, Fusion Energy Sciences	**504,677**	**495,855**	**467,500**	**420,000**	**-47,500**

SBIR/STTR:
FY 2014 Transferred: SBIR: $7,719,000; STTR: $1,103,000
FY 2015 Enacted: SBIR $7,388,000 and STTR $1,019,000
FY 2016 Projected: SBIR: $7,642,000; STTR: $1,146,000

Fusion Energy Sciences
Explanation of Major Changes ($K)

	FY 2016 vs FY 2015
Burning Plasma Science: Foundations: Funding for advanced tokamak research is decreased as Alcator C-Mod operates for the final year and as DIII-D upgrades, operating time, and research are reduced. Funding for the operations of the NSTX-U user facility is decreased, but fabrication of two key facility enhancements is still supported. Funding for General Plant Projects (GPP) at Princeton Plasma Physics Laboratory (PPPL) is increased to enhance and modernize laboratory infrastructure.	-24,303
Burning Plasma Science: Long Pulse: No major changes	-8,047
Discovery Plasma Science: Operations and research at the Neutralized Drift Compression Experiment–II (NDCX-II) at Lawrence Berkeley National Laboratory cease. No new research awards as part of the SC/NNSA Joint Program for high energy density laboratory plasma science commence.	-15,150
Total Funding Change, Fusion Energy Sciences	**-47,500**

Basic and Applied R&D Coordination

FES carries out a discovery-driven plasma science research program in partnership with the National Science Foundation (NSF), with research extending to a wide range of natural phenomena, including the origin of magnetic fields in the universe and the heating of the solar corona. Also, FES operates a joint program with the National Nuclear Security Administration (NNSA) in High Energy Density Laboratory Plasma (HEDLP) physics. Both programs involve coordination of solicitations, peer reviews, and workshops. The Fusion Energy Sciences Advisory Committee (FESAC) provides technical and programmatic advice to FES and NNSA for the joint HEDLP program.

Program Accomplishments

ITER component production underway; first major deliveries made—The U.S. ITER Project delivered one 100-meter superconducting length of active conductor and the first of nine 800-meter production lengths of active conductor to the European Union's Toroidal Field Coil fabricator in Italy. It also delivered the first lot of high-voltage circuit breakers to the ITER site, which are part of the Steady State Electric Network. Fabrication of the first nuclear-grade Tokamak Cooling Water System drain tank (>61,000 gallon capacity) was completed.

Improved understanding of the effects of edge magnetic field perturbations on tokamak plasmas—A multi-institutional team of scientists achieved new insight into how three-dimensional magnetic perturbations applied at the tokamak edge can improve plasma confinement. Notably, suppression of undesirable instabilities localized at the edge was experimentally demonstrated on the DIII-D tokamak with as few as five of the full set of 12 magnetic feedback coils, thus indicating that suppression (and good plasma performance) can be maintained in ITER even if a partial failure of its planned magnetic feedback coil set were to occur.

Advanced scenario modeling for NSTX-U—The NSTX-U team significantly improved the TRANSP code, widely used in the U.S. and abroad for predictive modeling of tokamak plasma performance. The code is now capable of simulating how radio-frequency wave heating can affect the injection of beams of high-energy neutral particles, which can drive current. This is an important simulation capability for NSTX-U with its newly installed second neutral beam line and also for other tokamaks such as DIII-D. In addition, the code can now predict the level of feedback control on the plasma rotation that is needed for maintaining plasma stability.

Fusion modeling advanced with leadership-class computing—Participants in an FES-supported Scientific Discovery Through Advanced Computing (SciDAC) center carried out code optimizations in partnership with the Advanced Scientific Computing Research (ASCR) program and achieved a 400% processing speedup with excellent scalability on the TITAN supercomputer for simulations of edge plasma behavior, which strongly affects overall fusion confinement for the success of ITER.

Experiment mimics solar eruptions—In laboratory experiments on the Magnetic Reconnection Experiment facility at PPPL, scientists discovered new mechanisms for converting magnetic field energy into particle energy. The results provide improved understanding of what triggers coronal mass ejections, in which energetic plasma particles spewed from the Sun can disrupt terrestrial communications and power grids.

Creation of ultra-high-energy-density plasmas with table-top lasers—Researchers discovered that ultra-short (femtosecond) laser pulses with very high intensity can be trapped within an ordered array of nano-wires and then used to heat matter that is nearly solid to temperatures of tens of millions of degrees, leading to the creation of plasmas with exceedingly high (gigabar) pressures. This novel method thus allows the regime corresponding to the central spot of strongly compressed thermonuclear fusion plasmas to be approached simply with the use of table-top lasers.

Fusion Energy Sciences
Burning Plasma Science: Foundations

Description

The Burning Plasma Science: Foundations subprogram advances the predictive understanding of plasma confinement, dynamics, and interactions with surrounding materials. Among the activities supported by this subprogram are:

- Research at major experimental facilities aimed at resolving fundamental advanced tokamak and spherical torus science issues, including developing the predictive understanding needed for ITER operations and providing solutions to high-priority ITER concerns.
- Research on small-scale magnetic confinement experiments to elucidate physics principles underlying toroidal confinement and to validate theoretical models and simulation codes.
- Theoretical work on the fundamental description of magnetically confined plasmas and the development of advanced simulation codes on current and emerging high-performance computers.
- Research on technologies needed to support the continued improvement of the experimental program and facilities.
- Support for infrastructure improvements at Office of Science laboratories conducting fusion research.

Advanced Tokamak

The DIII-D user facility at General Atomics in San Diego, California, is the largest magnetic fusion research experiment in the U.S. and can magnetically confine plasmas at temperatures relevant to burning plasma conditions. Researchers from the U.S. and abroad perform experiments on DIII-D for studying stability, confinement, and other properties of fusion-grade plasmas under a wide variety of conditions. The DIII-D research goal is to establish the scientific basis to optimize the tokamak approach to magnetic confinement fusion. Much of this research concentrates on developing the advanced tokamak concept, in which active control techniques are used to manipulate and optimize the plasma to obtain conditions scalable to robust operating points and high fusion gain for ITER and future fusion reactors. Near-term targeted efforts address scientific issues important to the ITER design. Longer-term research focuses on advanced scenarios to maximize ITER performance. Another high-priority DIII-D research area is foundational fusion science, pursuing a basic scientific understanding across all fusion plasma topical areas.

The Alcator C-Mod user facility at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, is a compact tokamak device employing intense magnetic fields to confine high-temperature, high-density plasmas in a small volume. Key research areas are disruption mitigation, radio-frequency heating and current drive science, plasma edge physics, and plasma-material interactions. C-Mod research is organized around integrated operating scenarios at plasma conditions relevant to fusion energy production. The compact size and high magnetic field of the Alcator C-Mod tokamak make it useful for dimensionless scaling studies. It can operate at and above the ITER design values for magnetic field and plasma density, and it has all-metal walls that experience heat fluxes approaching those projected for ITER. Also, it produces tokamak plasmas with very high pressure, near that expected in burning plasmas. The Alcator C-Mod facility resumed operation in FY 2014 and will continue operation in FY 2015 to complete student research and critical experimental work before the facility ceases operations by the end of FY 2016.

The Enabling Research and Development (R&D) element develops the technology to enhance the capabilities for existing and next-generation fusion research facilities, enabling these facilities to achieve higher levels of performance and flexibility needed to explore new science regimes.

Small-scale tokamak plasma research projects provide data in regimes of relevance to the FES mainline tokamak magnetic confinement efforts and help confirm theoretical models and simulation codes in support of the FES goal to develop an experimentally-validated predictive capability for magnetically confined fusion plasmas. This activity consists of small-scale focused experiments.

Spherical Tokamak

The NSTX-U user facility at PPPL is designed to explore the physics of plasmas confined in a spherical torus (ST) configuration. A major advantage of this configuration is the ability to confine plasma at a pressure that is high compared to the magnetic field energy density, which could lead to the development of more compact and economical future fusion research facilities based on the ST concept. The ST configuration, with its very strong magnetic curvature, has different confinement and stability properties from those of conventional tokamaks.

The NSTX-U MIE project will be completed in FY 2015. The upgrade of the center stack assembly enables a doubling of the magnetic field and plasma current and an increase in the plasma pulse length from 1 to 5 seconds, making NSTX-U the world’s highest-performance ST. The addition of a second neutral beam system doubles the available heating power, which makes it possible to achieve higher plasma pressure and providing improved neutral beam current drive efficiency and current profile control, which are needed for achieving fully non-inductive operation. Together, these upgrades will support a strong research program to develop the improved understanding of the ST configuration required to establish the physics basis for next-step ST facilities and broaden scientific understanding of plasma confinement. The capability for controllable fully-non-inductive current drive will also contribute to an assessment of the ST as a potentially cost-effective path to fusion energy.

During its first year of research operations in FY 2015, the NSTX-U team will achieve magnetic fields and plasma currents about one and a half times higher than those prior to the upgrade project. During FY 2016, the NSTX-U team will achieve the design values for the magnetic field and plasma current, which are twice those achieved in NSTX.

Small-scale spherical torus plasma research projects doing focused experiments provide data in regimes of relevance to the FES spherical torus magnetic confinement program. This effort helps confirm theoretical models and simulation codes in support of the FES goal to develop an experimentally-validated predictive capability for magnetically confined fusion plasmas. It also involves high-risk, but high-payoff, experimental efforts useful to advancing spherical torus science.

Theory & Simulation

The Theory and Simulation element contributes to the FES goal of developing the predictive capability needed for a sustainable fusion energy source. This element includes two main interrelated but distinct activities: the Theory activity and the Scientific Discovery through Advanced Computing (SciDAC) activity.

The Theory activity is focused on advancing the scientific understanding of the fundamental physical processes governing the behavior of magnetically confined plasmas. The efforts supported by this activity range from small single-investigator grants mainly at universities to large coordinated teams at national laboratories, universities, and private industry, while the supported research ranges from fundamental analytic theory to mid- and large-scale computational work using high-performance computing resources. In addition to its scientific discovery mission, the Theory activity provides the scientific grounding for the physics models implemented in the advanced simulation codes developed under the SciDAC activity described below, and supports validation efforts at major experiments.

The FES SciDAC activity, a component of the Office of Science (SC)-wide SciDAC program, is aimed at advancing scientific discovery in fusion plasma science by exploiting leadership-class computing resources and associated advances in computational science. The eight multi-institutional and interdisciplinary centers in the FES SciDAC portfolio address challenges in magnetic confinement science and computational fusion materials science and are well-aligned with the needs and priorities of ITER and burning plasmas. Three of these centers are set up as partnerships between FES and ASCR. These include a new FES-ASCR partnership in the area of multi-scale integrated modeling for fusion energy science, which was added to the portfolio in FY 2014.

GPE/GPP/Infrastructure

Funding in this category provides support for general infrastructure repairs and upgrades for the PPPL site. This funding is based upon quantitative analysis of safety requirements, equipment reliability, and research needs.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Advanced Tokamak $105,348,000	**$92,486,000**	**-$12,862,000**
DIII-D Research ($36,065,000)	*DIII-D Research ($32,038,000)*	*DIII-D Research (-$4,027,000)*
DIII-D Operations ($43,885,000)	*DIII-D Operations ($39,310,000)*	*DIII-D Operations (-$4,575,000)*
Research is conducted in three program areas, with DIII-D staff and collaborator support for diagnostics and data analysis to exploit enhanced DIII-D operations in FY 2015: ▪ Dynamics and control studies to test transport models, evaluate plasma performance in ITER-like conditions, and begin exploring methods of active control to avoid disruptions and operate near stability boundaries under steady-state conditions. ▪ Boundary and pedestal research to assess the benefits of divertor geometry in dissipating heat flux, investigate fueling and Edge Localized Mode control at higher density, and develop compatible core-edge solutions for high-performance plasmas. ▪ Burning plasma physics research to explore and suppress energetic particle instabilities and to understand and control transport barrier formation and confinement transitions.	Twelve weeks of research operations at the DIII-D facility are planned for FY 2016, with experiments focusing on high-priority advanced tokamak issues. Areas of research will include studies of transport and radiative processes in detached divertor conditions, disruption physics and mitigation systems, methods to exploit 3D field control to enable robust high performance operations, and exploration of scenarios at high normalized magnetic pressure to evaluate the relevant transport, stability, and energetic ion physics. Targeted upgrades to the facility will involve completion and commissioning of an additional high-power microwave heating system, installation of new magnet power supplies for the 3D and shaping coils, and continued work on improving the neutral beam heating control system and designing the modifications necessary for a second off-axis neutral beam.	The DIII-D research level of effort and the number of research staff will be reduced, and the level of upgrade activity for the DIII-D facility will decrease. Operating time is reduced by three weeks.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Disruption studies will continue to be emphasized in order to guide the design of the ITER disruption mitigation system. The DIII-D user facility will operate for 15 weeks to support experiments. Infrastructure modifications to support an eighth gyrotron system and upgrades to the power supply systems for the field shaping and magnetic perturbation coils will continue.		
C-Mod Research ($9,460,000)	*C-Mod Research ($6,145,000)*	*C-Mod Research (-$3,315,000)*
C-Mod Operations ($12,800,000)	*C-Mod Operations ($11,855,000)*	*C-Mod Operations (-$945,000)*
C-Mod research continues to focus on resolving high-priority issues of ITER-relevant boundary and divertor physics, with the goal of completing specific high priority research tasks relevant to ITER for which C-Mod is uniquely suited. C-Mod scientists will initiate enhanced research collaborations on other experimental facilities. The C-Mod facility will operate for 12 weeks to support experiments and complete student research. Maintenance and refurbishment activities to support the safe and efficient operation of C-Mod will continue.	Five weeks of research operations at the Alcator C-Mod facility are planned for its final year of operation in FY 2016. Research will be focused on high-priority topics that exploit the unique capabilities of the facility. Experiments will be conducted to study disruption physics and mitigation techniques, develop the database for the critical interactions between the plasma and material components under ITER and reactor-relevant conditions, explore robust high-performance stationary regimes free of Edge-Localized Modes, and advance radiofrequency heating and current drive technology and physics understanding. The facility will be closed after final operations, and the research staff will complete analysis of existing data and begin making a transition to collaborations involving other research facilities.	The research level of effort, number of staff, and scope of facility refurbishments will be reduced in the final year of operation of the Alcator C-Mod facility. Operating time is reduced by seven weeks.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Enabling R&D ($2,165,000) Support is provided for research in superconducting magnet technology, and fueling and plasma heating technologies, to enhance the performance for existing and future magnetic confinement fusion devices.	*Enabling R&D ($2,165,000)* Support will continue to be provided for research in superconducting magnet technology, and fueling and plasma heating technologies, to enhance the performance for existing and future magnetic confinement fusion devices.	*Enabling R&D ($0)* No change.
Small-scale Experimental Research ($973,000) Small-scale tokamak plasma research provides data in regimes of relevance to the mainline tokamak magnetic confinement efforts and helps confirm theoretical models and simulation codes in support of the goal to develop an experimentally-validated predictive capability for magnetically confined fusion plasmas.	*Small-scale Experimental Research ($973,000)* Research will continue on providing data in regimes relevant to mainline tokamak confinement and experimentally validating models and codes.	*Small-scale Experimental Research: ($0)* No change.
Spherical Tokamak $72,919,000	**$65,624,000**	**-$7,295,000**
NSTX-U Research ($28,500,000) *NSTX-U Operations ($38,250,000)* *NSTX-U MIE ($3,470,000)* The NSTX-U research staff begins research on the enhanced facility. Initial experiments concentrate on developing operating scenarios for high-performance plasmas, assessing transport and stability at higher plasma current and magnetic field, developing advanced divertor configurations, advancing techniques for non-inductive start-up, and assessing neutral-beam injection for current ramp-up and sustainment.	*NSTX-U Research ($26,000,000)* *NSTX-U Operations ($36,925,000)* *NSTX-U MIE ($0)* During FY 2016, the NSTX-U team will extend performance to full field and current (1 Tesla, 2 mega Amps) and will address divertor heat flux mitigation and plasma confinement at full parameters. The team will also begin experiments on full non-inductive current drive and sustainment. Finally, the team will begin to develop scenarios for achieving and controlling high-performance discharges.	*NSTX-U Research (-$2,500,000)* *NSTX-U Operations (-$1,325,000)* *NSTX-U MIE (-$3,470,000)* Funding for the operations of the NSTX-U user facility is decreased; fabrication of two key facility enhancements is supported. The NSTX-U Major Item of Equipment (MIE) project is completed in FY 2015.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
With the completion of the MIE project, the operations team completes integrated systems testing and begins research operations, with a goal of 12 weeks of operation. Funding shifts from the MIE project back to facility operations. The design of facility modifications, including a divertor cryopump, a set of non-axisymmetric control coils, and a 1 megawatt electron cyclotron heating system, is initiated.	A total of 14 weeks of operation is planned in FY 2016. Operation is planned at full design values for the magnetic field and plasma current, which are twice those achieved prior to the upgrade. In mid-FY 2016, a shutdown is planned to install a cryopump in the lower divertor and a row of tungsten tiles on the cryo-baffle.	
Small-scale Experimental Research ($2,699,000) Small-scale tokamak plasma research provides data in regimes of relevance to the mainline spherical torus magnetic confinement efforts and helps confirm theoretical models and simulation codes in support of the goal to develop an experimentally-validated predictive capability for magnetically confined fusion plasmas.	*Small-scale Experimental Research ($2,699,000)* Research will continue on providing data in regimes relevant to mainline spherical torus confinement and experimentally validating models and codes.	*Small-scale Experimental Research ($0)* No change.
Theory & Simulation $34,670,000	**$28,170,000**	**-$6,500,000**
Theory ($25,170,000) The Theory activity continues to support fundamental research at universities, national laboratories, and private industry. Coordination between theory and experiment leading to model validation will be emphasized, especially in areas where the resolution of essential physics issues is urgently needed before first plasma in ITER.	*Theory ($21,170,000)* The Theory activity will continue to advance the scientific understanding of the fundamental physical processes governing the behavior of magnetically confined plasmas. Emphasis on addressing ITER priorities will continue to guide the selection of new and renewal awards via competitive merit reviews.	*Theory (-$4,000,000)* Approximately eight fewer awards to universities and private industry will be made compared to FY 2015. Efforts at the national laboratories will be level with FY 2015.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
SciDAC ($9,500,000)	*SciDAC ($7,000,000)*	*SciDAC (-$2,500,000)*
The FES SciDAC centers continue to contribute to the FES goal of developing a predictive capability for fusion plasmas. The two FES-ASCR partnerships selected in FY 2012 will undergo a mid-term progress review while the third partnership selected in FY 2014 enters its second year. The five centers selected in FY 2011 will undergo a merit review for a possible one-year extension of their research activities, to align their project periods with the SC-wide SciDAC program and strengthen their collaborations with computational scientists.	The five SciDAC centers, pending a positive outcome of the merit review held in FY 2015, will be entering the final year of their research activities, while the three FES–ASCR partnerships will continue their efforts in the areas of boundary physics, materials science, and multiscale integrated modeling. FES and ASCR will develop a plan emphasizing integration for the science areas represented by the entire FES SciDAC portfolio, and will initiate preparations for a competitive merit review.	The scope of the FES SciDAC portfolio will be narrowed.
GPE/GPP/Infrastructure $3,125,000	**$5,479,000**	**+$2,354,000**
Necessary facility and utility infrastructure improvements required to fully support NSTX-U operations are funded, while ensuring mission readiness and enhanced reliability. Several small projects will be executed to modernize and/or replace aging infrastructure elements such as electrical distribution and cooling water utilities and building heating, ventilation, and air conditioning systems. Environmental monitoring needs at PPPL are also supported.	Continued support of NSTX-U operations, as well as enhanced International Collaborations, will be provided through improvements to the Princeton Plasma Physics Laboratory Computer Center (PPPLCC) and establishment of remote control room configurations. Environmental monitoring needs at PPPL will continue to be supported.	Increased funding is provided for facility and utility improvements for supporting the full NSTX-U operations, enhancing International collaboration capabilities, addressing single-point failure liabilities, and replacing end-of-life critical physical plant infrastructure.

Burning Plasma Science: Long Pulse

Description

The Burning Plasma Science: Long Pulse subprogram explores new and unique scientific regimes that can be achieved with long-duration superconducting international machines and addresses the development of the materials required to withstand the extreme conditions in a burning plasma environment. The key objectives of this area are to utilize these new capabilities to accelerate our scientific understanding of how to control and operate a burning plasma, as well as to develop the basis for a future fusion nuclear science facility. This subprogram includes long-pulse international tokamak and stellarator research and fusion nuclear science and materials research.

Long Pulse: Tokamak

U.S. research teams will be supported to work on the long-pulse international tokamaks that are coming on-line either now or in the near future. These teams will build on the experience gained from U.S. fusion facilities to conduct long-pulse research on the international tokamaks. Long plasma pulse research will enable the exploration of new plasma physics regimes, and allow the U.S. fusion program to gain the knowledge needed to operate long plasma discharges in ITER and other fusion energy devices.

Long Pulse: Stellarator

Stellarators offer steady-state confinement regimes eliminating transient events such as harmful disruptions. The 3-D shaping of the plasma in a stellarator provides for a broader range in design flexibility than is achievable in a 2-D system. The U.S. collaboration on Wendelstein 7-X (W7-X) in Germany provides an opportunity to develop and assess 3D divertor configurations for long-pulse, high-performance stellarators. In this collaboration, the U.S. plans to develop control schemes to maintain plasmas with stable operational boundaries, including the challenges of control with superconducting coils and issues of the diagnosis-control cycle in long-pulse conditions. The collaboration will have key roles in developing the operational scenarios and hardware configuration for high-power, steady-state operation, an accomplishment that will advance the performance/pulse length frontier for fusion. The U.S. contributions during the W7-X construction phase have earned the U.S. formal partnership status, with opportunities for full U.S. participation in W7-X research and access to data.

The U.S. domestic stellarator program, with two small-size facilities, is focused on optimization of the stellarator concept through quasi-symmetric shaping of the toroidal magnetic field. A conventional stellarator lacks axial symmetry, resulting in reduced confinement of energetic ions, which are needed to heat the plasma. Quasi-symmetric shaping, invented in the U.S., provides an improved solution for stable, well confined, steady-state stellarator plasma confinement.

Materials & Fusion Nuclear Science

The fusion environment is extremely harsh in terms of temperature, particle flux, and neutron irradiation. The Materials and Fusion Nuclear Science element supports the development, characterization, and modeling of structural, plasma-facing, and blanket materials used in the fusion environment. Materials that can withstand this environment under the long-pulse or steady-state conditions anticipated in future fusion experiments are a prerequisite to the future of fusion research and development activities. Studies that help identify the various scientific challenges to fusion energy deployment and that determine how to address them in a safe and environmentally responsible manner are a key component of the Materials and Fusion Nuclear Science element.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Long Pulse: Tokamak $7,695,000	**$6,045,000**	**-$1,650,000**
Support continues for the two U.S. teams performing long-pulse plasma heating and control research on the Experimental Advanced Superconducting Tokamak (EAST) and Korea Superconducting Tokamak Advanced Research (KSTAR) facilities. Collaborations in support of ITER-relevant science are carried out.	Improved control systems for EAST and KSTAR will be commissioned. ITER operating scenarios will be explored and evaluated on EAST and KSTAR. Radio frequency heating and current drive and neutral beam injection actuator models for EAST and KSTAR will be developed and validated.	Collaborations will be slightly reduced, and no diagnostic fabrications are planned.
Long Pulse: Stellarators $6,419,000	**$5,069,000**	**-$1,350,000**
Superconducting Stellarator Research ($3,850,000) The design of the scraper element for the W7-X steady-state divertor, a tool that will permit early experimental investigation of the edge magnetic configuration in the first full W7-X research campaign, is completed. One or two new university collaborations on international facilities may be initiated.	*Superconducting Stellarator Research ($2,500,000)* Planned operations will be carried out on W7-X up to 10 seconds at 10 megawatts and 50 seconds at 1 megawatt of heating power. U.S. scientists will participate in experiments on the development of steady-state operating scenarios. The performance of inertially cooled divertor components will be evaluated.	*Superconducting Stellarator Research (-$1,350,000)* No additional hardware design activities are planned for W7-X. The university collaboration awards selected in FY 2015 will be fully funded in that year.
Compact Stellarator Research ($2,569,000) Compact stellarator research provides data in regimes of relevance to the mainline stellarator magnetic confinement efforts and helps confirm theoretical models and simulation codes in support of the goal to develop an experimentally validated predictive capability for magnetically confined fusion plasmas.	*Compact Stellarator Research ($2,569,000)* Research will continue on providing data in regimes relevant to mainline stellarator confinement and experimentally validating models and codes.	*Compact Stellarator Research ($0)* No change.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Materials & Fusion Nuclear Science $24,842,000	**$19,795,000**	**-$5,047,000**
Fusion Nuclear Science ($11,245,000)	*Fusion Nuclear Science ($9,835,000)*	*Fusion Nuclear Science (-$1,410,000)*
Key areas of interest are studying plasma-facing materials and plasma-material interaction under reactor-relevant plasma conditions, breeding and processing of fusion fuel, neutronics and safety research. Scoping studies characterize significant research gaps in the materials and fusion nuclear sciences research program.	The focus will remain the utilization of existing experimental capabilities to conduct research in the areas of plasma-facing materials and plasma-material interactions. Research toward understanding tritium retention and permeation, neutronics, and material-corrosion issues for blankets will continue. Scoping studies will continue on characterizing significant research gaps in the materials and fusion nuclear sciences program.	Efforts to produce prototypic conditions for plasma materials testing will decrease.
Materials Research ($13,597,000)	*Materials Research ($9,960,000)*	*Materials Research (-$3,637,000)*
Efforts focus on elucidating the response of materials to the extreme conditions created by a burning plasma. Key areas of interest are structural materials response under reactor-relevant plasma conditions.	The focus will remain the utilization of existing experimental capabilities to conduct research in the area of material response to simulated fusion neutron irradiation. Research toward structural materials that can withstand high levels of damage, increasing the ductility of tungsten, and modeling of helium damage in numerous materials will continue.	Efforts to produce prototypic conditions for structural materials testing will decrease.

Fusion Energy Sciences
Discovery Plasma Science

Description

Plasma science is not only fundamental to achieving the production and control of fusion energy, but also to understanding the nature of visible matter throughout the cosmos. Discoveries in plasma science are leading to an ever increasing array of practical applications ranging from energy efficient lighting to low-heat, chemical-free sterilization processes. The Discovery Plasma Science subprogram supports research that explores the fundamental properties and complex behavior of matter in the plasma state to improve the understanding required to control and manipulate plasmas for a broad range of applications.

The ability to create and manipulate plasmas with densities and temperatures spanning many orders of magnitude has led to the establishment of plasma science as a multi-disciplinary field, necessary for understanding the flow of energy and momentum in the universe as well as enabling the development of breakthrough technologies. The subprogram supports a rich portfolio of research projects and small-scale experimental facilities, exploring the diverse frontiers of plasma science. The portfolio of this subprogram is carried out through inter- and intra-agency partnerships at academic institutions, private companies, and national laboratories across the country. The Discovery Plasma Science subprogram is organized into two principal activities: Plasma Science Frontiers and Measurement Innovation.

Plasma Science Frontiers

The frontiers of plasma science exist at the extremes of the plasma state, ranging from the very small (several atom systems) to the extremely large (plasma structure spanning light years in length), from the very fast (attosecond processes) to the very slow (hours), from the diffuse (interstellar medium) to the extremely dense (diamond compressed to tens of gigabar pressures), and from the ultracold (tens of micro kelvin) to the extremely hot (stellar core). The Plasma Science Frontiers activities support research at the fore-front of each of these ranges, challenging our ability to produce and measure matter at the extremes. In addition to the experimental and diagnostic challenges, simulating such systems requires the development of sophisticated modeling tools and use of advanced computing platforms.

The Plasma Science Frontiers portfolio includes coordinated research activities in the following three areas:

- *General Plasma Science* – Understanding the behavior of non-neutral and single-component plasmas, ultra-cold neutral plasmas, dusty plasmas, and micro-plasmas, as well as the study of dynamical processes in classical plasmas including turbulence and turbulent transport, and plasma waves, structures, and flows.
- *High Energy Density Laboratory Plasmas* – Structural and dynamical studies of ionized matter at extreme densities and temperatures.
- *Exploratory Magnetized Plasma* – Research on complex, magnetized plasma systems that spontaneously evolve toward a state of long-range order through dissipative processes (e.g., compact toroidal plasma).

Through partnerships with the National Science Foundation (NSF), the National Nuclear Security Administration (NNSA), and the Office of Science’s Basic Energy Sciences (BES) program, this activity maintains a leadership role in the national stewardship of plasma science by leveraging access to best-in-class experimental facilities as well as by the stewardship and operation of world-class plasma science user facilities at the intermediate scale. Along with facilitating discovery, intermediate-scale platforms are also providing critical data for the verification and validation of advanced fusion modeling codes.

Measurement Innovation

The Measurement Innovation activity supports the development of novel and innovative diagnostic techniques and their application to new, unexplored, or unfamiliar plasma regimes or scenarios. The challenge is to develop diagnostics with the spatial, spectral, and temporal resolution necessary to validate plasma physics models used to predict the behavior of fusion plasmas. Advanced diagnostic capabilities successfully developed through this activity are migrated to domestic and international facilities, as part of the Burning Plasma Science: Foundations and Burning Plasma: Long Pulse subprograms. The implementation of mature diagnostics systems is supported via the research programs at FES user facilities.

SBIR/STTR & Other

Funding for SBIR/STTR is included in this subprogram. Other activities that are supported include research at Historically Black Colleges and Universities (HBCUs), the U.S. Burning Plasma Organization (USBPO), a national organization that coordinates research in burning plasma science, peer reviews for solicitations across the program, and the Fusion Energy Sciences Advisory Committee (FESAC).

Fusion Energy Sciences
Discovery Plasma Science

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Plasma Science Frontiers $46,024,000	**$32,609,000**	**-$13,415,000**
General Plasma Science ($15,800,000)	*General Plasma Science ($15,500,000)*	*General Plasma Science (-$300,000)*
Core research elements of this activity continue. With input from the NRC Plasma Science Committee, the program also supports multi-institutional teams targeting interdisciplinary connections, and intermediate-scale facilities expanding experimentally accessible parameters and providing broad access to users. National Undergraduate Fellowship for Fusion and Plasma Research (NUF) continues to support undergraduate research internships as it completes its merger with the Office of Science's Science Undergraduate Laboratory Internships (SULI) activity operated by the Workforce Development for Teachers and Scientists (WDTS).	Core research elements of this activity will continue. The establishment of one or more new intermediate-scale user facilities will be emphasized.	The Office of Science will complete the merger of the NUF with SULI within the WDTS program.
High Energy Density Laboratory Plasmas ($19,815,000)	*High Energy Density Laboratory Plasmas ($6,700,000)*	*High Energy Density Laboratory Plasmas (-$13,115,000)*
Research utilizing the Matter in Extreme Conditions (MEC) Instrument at the Linac Coherent Light Source (LCLS) at the Stanford National Accelerator Laboratory is emphasized, along with completion of phase two of the scheduled short-pulse laser upgrade to deliver 200	Research utilizing the MEC at LCLS will be emphasized, including continued support for the MEC beam-line science team and the HEDLP research group at SLAC, as well as grants for external HED science users of MEC.	Contraction of the HEDLP program will result in no new research awards as part of the SC/NNSA Joint Program in HEDLP science, no new research projects at DOE national laboratories, and the cessation of operations and research at the Neutralized Drift

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
terawatts on target and research awards for external HED science users of MEC. Fundamental HEDLP science is supported through academic awards as part of the SC/NNSA Joint Program in HEDLP and operation of the Neutralized Drift Compression Experiment-II.		Compression Experiment-II.
Exploratory Magnetized Plasma ($10,409,000)	*Exploratory Magnetized Plasma ($10,409,000)*	*Exploratory Magnetized Plasma ($0)*
Research on the Madison Symmetric Torus emphasizes measurement of the scaling of tearing mode fluctuations with current and temperature to support the validation of nonlinear MHD codes. Physics extensions beyond MHD will be studied by measuring the Hall dynamo and comparing it to extended MHD simulations. Other smaller-scale experiments in this portfolio support validation and verification of codes and models.	This portfolio will be evaluated through a competitive peer-review process. Future research direction and emphasis will be informed by the outcome of the review.	No change.
Measurement Innovation $3,575,000	**$3,575,000**	**$0**
Efforts continue toward developing innovative techniques to address current and emerging measurement needs in the FES program. A community-informed planning activity is assessing the need for long pulse, plasma control, disruption, and burning plasma diagnostics.	All core research elements of the Measurement Innovation activity will continue.	No change.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
SBIR/STTR & Other $12,883,000	**$11,148,000**	**-$1,735,000**
Funding supports all the elements in this category, including the USBPO activities, HBCUs, peer reviews for solicitations, and FESAC. SBIR/STTR funding is statutorily set at 3.3 percent of noncapital funding in FY 2015.	Funding will continue to support USBPO activities, HBCUs, peer reviews for solicitations, and FESAC. SBIR/STTR funding is statutorily set at 3.45 percent of noncapital funding in FY 2016.	Funding will decrease with the reduction in total FES noncapital funding.

Fusion Energy Sciences
Construction

Description

The exploration of high-power burning (self-heated) plasmas is the next critical area of scientific research for fusion. Previously the U.S. and European fusion programs had investigated burning plasmas at low power (10 megawatt level). The ITER facility, currently under construction in St. Paul-lez-Durance, France, will provide access to burning plasmas with fusion power output approaching reactor levels of hundreds of megawatts, for hundreds of seconds. ITER will thus be the first-ever facility capable of assessing the scientific and technical feasibility of fusion energy. As a collaborator in the ITER project, the U.S. contributes in-kind-hardware components, personnel, and direct funding to the ITER Organization (IO) for the ITER construction phase, as established by the terms of the ITER Joint Implementing Agreement. The key objective of these efforts is the completion of all activities associated with the U.S. Contributions to ITER project.

U.S. Contributions to ITER Project

The ITER international fusion project is designed to be the first magnetic confinement fusion facility to achieve a burning plasma. As ITER construction activities continue, careful and efficient management of the U.S. contributions to the international project by the U.S. ITER Project Office (USIPO) at Oak Ridge National Laboratory (ORNL) continue to be a high priority for FES.

ITER is designed to generate the world’s first sustained (300-second discharge, self-heated) burning plasma. It aims to generate fusion power 30 times the levels produced to date and to exceed the external power applied to the plasma by at least a factor of ten. ITER will be a powerful tool for discovery, capable of addressing the new challenges of the burning plasma frontier and assessing the scientific and technical feasibility of fusion energy.

The ITER Project is being designed and built by an international consortium consisting of the U.S., China, India, Japan, South Korea, the Russian Federation, and the European Union (the host). The U.S. is committed to the scientific mission of ITER and will work with ITER partners to accomplish this goal, while maintaining a balanced domestic research portfolio. Executing a program with well-aligned domestic and international components will sustain U.S. international leadership in fusion energy sciences. The U.S. magnetic fusion research program in experiment, theory, and computation is configured to make strong contributions to ITER’s science and to bring a high level of scientific return from it. ITER joins the broader FES research portfolio in elevating plasma sciences for both practical benefit and increased understanding.

The U.S. Contributions to ITER Project activity represents 9.09 percent of the ITER Project construction costs. The U.S. contributions, consisting of primarily of in-kind hardware components, with additional contributions of personnel and cash to the IO for the ITER construction phase, are established by the terms of the ITER Joint Implementing Agreement. In exchange for this contribution, the U.S. gains access to 100% of the ITER research output. ITER is similar to other modern large science projects being conducted as international collaborations that pool financial, technical, and scientific resources to achieve critical science at a scale beyond the reach of individual countries.

The U.S. contributions are managed by the USIPO at ORNL, in partnership with PPPL and Savannah River National Laboratory. The U.S. ITER Project differs from most other DOE and SC projects in the “hand-off” of U.S. in-kind hardware contributions to a central project team outside direct DOE oversight and in the risks associated with performing work that depends on the execution of project responsibilities by our international partners. The requested level of funding for FY 2016 will ensure that U.S. in-kind contributions fulfill U.S. commitments to FY 2016 project needs.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
U.S. Contributions to ITER Project $150,000,000	**$150,000,000**	**$0**
Funding is provided for ITER Project Office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including industrial procurements of central solenoid magnet modules and structures, toroidal field magnet conductor fabrication, diagnostics, and the tokamak cooling water system procurement.	Funding will be provided for ITER Project Office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including ongoing industrial fabrication of central solenoid magnet modules and structures, fabrication and delivery of the final lengths of toroidal field magnet conductors and components of the steady state electric network, development and design of diagnostics and associated port plugs, and continued procurement of the tokamak cooling water system.	No change.

Fusion Energy Sciences
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for and tracks progress toward achieving performance goals for each program. The following table shows the targets for FY 2014 through FY 2016.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**FES Facility Based Experiments—Experiments conducted on major fusion facilities (DIII-D, Alcator C-Mod, NSTX-U) leading toward predictive capability for burning plasmas and configuration optimization**		
Target	Conduct experiments and analysis to investigate and quantify plasma response to non-axisymmetric (3D) magnetic fields in tokamaks. Effects of 3D fields can be both beneficial and detrimental and research will aim to validate theoretical models in order to predict plasma performance with varying levels and types of externally imposed 3D fields. Dependence of response to multiple plasma parameters will be explored in order to gain confidence in predictive capability of the models.	Conduct experiments and analysis to quantify the impact of broadened current and pressure profiles on tokamak plasma confinement and stability. Broadened pressure profiles generally improve global stability but can also affect transport and confinement, while broadened current profiles can have both beneficial and adverse impacts on confinement and stability. This research will examine a variety of heating and current drive techniques in order to validate theoretical models of both the actuator performance and the transport and global stability response to varied heating and current drive deposition.	Conduct research to detect and minimize the consequences of disruptions in present and future tokamaks, including ITER. Coordinated research will deploy a disruption prediction/warning algorithm on existing tokamaks, assess approaches to avoid disruptions, and quantify plasma and radiation asymmetries resulting from disruption mitigation measures, including both pre-existing and resulting MHD activity, as well as the localized nature of the disruption mitigation system. The research will employ new disruption mitigation systems, control algorithms, and hardware to help avoid disruptions, along with measurements to detect disruption precursors and quantify the effects of disruptions.
Result	Met	TBD	TBD

	FY 2014	FY 2015	FY 2016
Endpoint Target	Magnetic fields are the principal means of confining the hot ionized gas of a plasma long enough to make practical fusion energy. The detailed shape of these magnetic containers leads to many variations in how the plasma pressure is sustained within the magnetic bottle and the degree of control that experimenters can exercise over the plasma stability. These factors, in turn, influence the functional and economic credibility of the eventual realization of a fusion power reactor. The key to their success is a detailed physics understanding of the confinement characteristics of the plasmas in these magnetic configurations. The major fusion facilities can produce plasmas that provide a wide range of magnetic fields, plasma currents, and plasma shapes. By using a variety of plasma control tools, appropriate materials, and having the diagnostics needed to measure critical physics parameters, scientists will be able to develop optimum scenarios for achieving high performance plasmas in ITER and, ultimately, in reactors.		
Performance Goal (Measure)	**FES Facility Operations—Average achieved operation time of FES user facilities as a percentage of total scheduled annual operation time**		
Target	≥ 90%	≥ 90%	≥ 90%
Result	Met	TBD	TBD
Endpoint Target	Many of the research projects that are undertaken at the SC scientific user facilities take a great deal of time, money, and effort to prepare and regularly have a very short window of opportunity to run. If the facility is not operating as expected the experiment could be ruined or critically set back. In addition, taxpayers have invested millions or even hundreds of millions of dollars in these facilities. The greater the period of reliable operations, the greater the return on the taxpayers' investment.		

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**FES Theory and Simulation—Performance of simulations with high physics fidelity codes to address and resolve critical challenges in the plasma science of magnetic confinement**		
Target	Understanding alpha particle confinement in ITER, the world's first burning plasma experiment, is a key priority for the fusion program. Linear instability trends and thresholds of energetic particle-driven shear Alfvén eigenmodes in ITER are determined for a range of parameters and profiles using a set of complementary simulation models (gyrokinetic, hybrid, and gyrofluid). Initial nonlinear simulations are carried out to assess the effects of the unstable modes on energetic particle transport.	Perform massively parallel plasma turbulence simulations to determine expected transport in ITER. Starting from best current estimates of ITER profiles, the turbulent transport of heat and particles driven by various micro-instabilities (including electromagnetic dynamics) will be computed. Stabilization of turbulence by nonlinear self-generated flows is expected to improve ITER performance, and will be assessed with comprehensive electromagnetic gyrokinetic simulations.	Predicting the magnitude and scaling of the divertor heat load width in magnetically confined burning plasmas is a high priority for the fusion program and ITER. One of the key unresolved physics issues is what sets the heat flux width at the entrance to the divertor region. Perform massively parallel simulations using 3D edge kinetic and fluid codes to determine the parameter dependence of the heat load width at the divertor entrance and compute the divertor plate heat flux applicable to moderate particle recycling conditions. Comparisons will be made with data from DIII-D, NSTX-U, and C-Mod.
Result	Met	TBD	TBD
Endpoint Target	Advanced simulations based on high physics fidelity models offer the promise of advancing scientific discovery in the plasma science of magnetic fusion by exploiting the SC high performance computing resources and associated advances in computational science. These simulations are able to address the multi-physics and multi-scale challenges of the burning plasma state and contribute to the FES goal of advancing the fundamental science of magnetically confined plasmas to develop the predictive capability needed for a sustainable fusion energy source.		

Performance Goal (Measure)	**FES Construction/MIE Cost & Schedule— Cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects**		
Target	< 10%	< 10%	< 10%
Result	Met	TBD	TBD
Endpoint Target	Adhering to the cost and schedule baselines for a complex, large scale, science project is critical to meeting the scientific requirements for the project and for being good stewards of the taxpayers' investment in the project.		

Fusion Energy Sciences
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
Capital Operating Expenses Summary							
Capital equipment	n/a	n/a	27,487	27,487	7,798	6,799	-999
General plant projects (GPP)	n/a	n/a	3,700	3,700	2,500	5,000	+2,500
Total, Capital Operating Expenses	**n/a**	**n/a**	**31,187**	**31,187**	**10,298**	**11,799**	**+1,501**
Capital Equipment							
Major items of equipment							
National Spherical Torus Experiment Upgrade (TPC $94,300)	83,665	56,495	23,700	23,700	3,470	0	-3,470
U.S. Contributions to ITER (TPC TBD)	TBD	673,385	0	0	0	0	0
Total MIEs	**n/a**	**729,880**	**23,700**	**23,700**	**3,470**	**0**	**-3,470**
Other capital equipment projects under $2 million TEC	n/a	n/a		671	5,269	5,199	-70
Total, Capital equipment	**n/a**	**n/a**		**24,371**	**8,739**	**5,199**	**-3,540**
General Plant Projects							
General Plant Projects under $2 million TEC	n/a	n/a	3,700	3,700	2,500	5,000	+2,500

Fusion Energy Sciences Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	200,967	192,145	215,970	176,431	-39,539
Scientific user facility operations	74,610	74,610	94,935	88,090	-6,845
Major items of equipment	23,700	23,700	3,470	0	-3,470
Other (GPP, GPE, and infrastructure)	5,900	5,900	3,125	5,479	+2,354
Construction	199,500	199,500	150,000	150,000	0
Total, Fusion Energy Sciences	**504,677**	**495,855**	**467,500**	**420,000**	**-47,500**

Scientific User Facility Operations and Research ($K)

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

Definitions:

Achieved Operating Hours – The amount of time (in hours) the facility was available for users.

Planned Operating Hours –

- For Past Fiscal Year (PY), the amount of time (in hours) the facility was planned to be available for users.
- For Current Fiscal Year (CY), the amount of time (in hours) the facility is planned to be available for users.
- For the Budget Fiscal Year (BY), based on the proposed budget request the amount of time (in hours) the facility is anticipated to be available for users.

Optimal Hours – The amount of time (in hours) a facility would be available to satisfy the needs of the user community if unconstrained by funding levels.

Percent of Optimal Hours – An indication of utilization effectiveness in the context of available funding; it is not a direct indication of scientific or facility productivity.

- For BY and CY, Planned Operating Hours divided by Optimal Hours expressed as a percentage.
- For PY, Achieved Operating Hours divided by Optimal Hours.

Unscheduled Downtime Hours - The amount of time (in hours) the facility was unavailable to users due to unscheduled events. NOTE: For type “A” facilities, zero Unscheduled Downtime Hours indicates Achieved Operating Hours equals Planned Operating Hours.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
DIII-D National Fusion Facility	**$74,958**	**$74,958**	**$79,950**	**$71,348**	**-$8,602**
Number of Users	576	576	579	545	-34
Achieved operating hours	756	756	N/A	N/A	N/A
Planned operating hours	720	720	600	480	-120
Optimal hours	1,000	1,000	1,000	1,000	0
Percent optimal hours	75.6%	75.6%	60%	48%	N/A
Unscheduled downtime hours	0	0	TBD	N/A	N/A
Alcator C-Mod	**$21,940**	**$21,940**	**$22,260**	**$18,000**	**-$4,260**
Number of Users	170	170	170	140	-30
Achieved operating hours	364	364	N/A	N/A	N/A
Planned operating hours	384	384	384	160	-224
Optimal hours	800	800	800	800	0
Percent optimal hours	45.5%	45.5%	48%	20%	N/A
Unscheduled downtime hours	20	20	TBD	N/A	N/A
National Spherical Torus Experiment-Upgrade	**$38,656**	**$38,656**	**$66,750**	**$62,925**	**-$3,825**
Number of Users	165	165	250	250	0
Achieved operating hours	0	0	N/A	N/A	N/A
Planned operating hours	0	0	480	560	+80
Optimal hours	0	0	500	1,000	+500
Percent optimal hours	0%	0%	96%	56%	N/A
Unscheduled downtime hours	0	0	TBD	N/A	N/A

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Total Facilities	**$135,554**	**$135,554**	**$168,960**	**$152,273**	**-$16,687**
Number of Users	911	911	999	935	-64
Achieved operating hours	1,120	1,120	N/A	N/A	N/A
Planned operating hours	1,104	1,104	1,464	1,200	-284
Optimal hours	1,800	1,800	2,300	2,800	+500
Percent of optimal hours[a]	62.2%	62.2%	73.1%	48%	N/A
Unscheduled downtime hours	20	20	N/A	N/A	N/A

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Number of permanent Ph.D.'s (FTEs)	710	710	724	603	-121
Number of postdoctoral associates (FTEs)	91	91	93	79	-14
Number of graduate students (FTEs)	264	264	268	195	-73
Other[b]	1,081	1,081	1,102	937	-165

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[a] For total facilities only, this is a "funding weighted" calculation FOR ONLY TYPE A facilities: $\frac{\sum_{1}^{n}[(\%OH\ for\ facility\ n)\times(funding\ for\ facility\ n\ operations)]}{Total\ funding\ for\ all\ facility\ operations}$

[b] Includes technicians, engineers, computer professionals, and other support staff.

14-SC-60, U.S. Contributions to ITER

1. Significant Changes and Summary

Significant Changes

This Construction Project Data Sheet (CPDS) is an update of the FY 2015 CPDS and does not include a new start for the budget year.

The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-1, Approve Alternative Selection and Cost Range, was approved on January 25, 2008, with a preliminary cost range of $1.45–$2.2 billion and projected completion date in FY 2014. Since CD-1, it has not been possible to baseline the project because of technical challenges, continued delays in the international ITER construction schedule, and lack of stable project funding. Until such time as CD-2 can be approved, the U.S. funding will be managed to address annual project needs and to allow flexibility to adapt to the changing state of the project. Since the project does not have CD-2 approval, the schedule and cost estimates contained in this PDS are identified as “TBD”. The current best estimate of the total cost range, prior to CD-2, is $4,000,000,000-$6,500,000,000.

The approving official for all critical decisions is the Director of the Office of Science (SC-1).

A Federal Project Director has been assigned to this project and has approved this CPDS.

Summary

The U.S. Contributions to ITER (U.S. ITER) is a U.S. Department of Energy project to provide the U.S. share of hardware (e.g., subsystems, equipment, and components), as well as cash contributions to support the ITER construction project in Cadarache, France. ITER is a major fusion research facility being constructed in France by an international partnership of seven governments. Since it will not result in a facility owned by the U.S. or located in the U.S., ITER is not classified as a capital asset project. Sections of this CPDS have been tailored accordingly to reflect the nature of this project.

The U.S. ITER project is managed as a DOE Office of Science (SC) project. The project began as a major item of equipment (MIE) in FY 2006, and was changed to a Congressional control point beginning in FY 2014. This did not change SC’s overall program and project management approach for the U.S. ITER Project. As with all SC projects, the principles of DOE Order 413.3B are applied in the effective management of the project, including critical decision milestones and their supporting prerequisite activities. Requirements for project documentation, monitoring and reporting, change control, and regular independent project reviews are being applied with the same degree of rigor as other SC projects. An approved FY 2015 Annual Performance Plan (APP) authorizes the work activities to be performed, as well as establishes high-level milestones for project performance against which progress will be measured. Progress and performance against the APP is reported regularly in monthly performance metrics and project status reports.

The U.S. ITER project is making significant progress in the areas of design completion and fabrication of hardware. As of the end of FY 2014, overall the U.S. ITER project is 25% complete; and the design of all twelve technical systems the U.S. is responsible for delivering, is 55% complete. Two of the largest U.S. systems, the Tokamak Cooling Water System (TCWS) and the Central Solenoid (CS) Magnets are in or beyond final design. Active fabrication is underway in four of the U.S. twelve hardware systems (TCWS, Steady State Electric Network (SSEN) Components, Toroidal Field (TF) Conductor and CS Magnets). The U.S. is on schedule to complete the fabrication of five nuclear-grade cooling water drain tanks and deliver them to the ITER site in FY 2015. These components, which are time critical for ITER construction sequencing and which are fabricated in accordance with French Nuclear regulations, will be one of the first major hardware components delivered to the site in France in FY 2015. The U.S. is also in the process of procuring major high-voltage electric power components (e.g., transformers, switch gear, voltage regulators). Multiple deliveries of U.S. electric power components to the ITER site in France began in FY 2014 and will continue through FY 2015. In addition, fabrication of TF conductor is well underway. Purchase of superconducting strand material is complete; cabling activities are well underway, and production of both non-active (sample) and active (superconducting) lengths of conductor are in progress. The U.S. has shipped finished lengths of both non-active (for winding trials) and active conductors to the European Union, one of the ITER Members responsible for TF Magnet fabrication. TF conductor shipments will continue through FY 2015.

Finally, preparations are well underway for the U.S. to begin fabrication of the world's largest superconducting magnets for the ITER CS Magnet system. The U.S. has contracted with General Atomics (GA) for the fabrication of the CS Magnet modules. The GA fabrication facility will be essentially complete by the end of FY 2014 with the installation and commissioning of multiple work stations needed for fabrication of each of the seven modules the U.S. is responsible for delivering. The U.S. is on schedule to achieve two major milestones in FY 2015 with the start and completion of fabrication of a mockup (non-active) coil to provide assurance of manufacturing processes, and most notably the start of winding the first production (active) module with superconducting CS conductor provided by the Japanese Domestic Agency. Initiation of fabrication activities in the GA facility represents the culmination of several years of preparation and a major investment for the U.S.

FY 2016 funding will support ITER Project Office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including ongoing industrial fabrication of central solenoid magnet modules and structures, fabrication and delivery of the final lengths of toroidal field magnet conductors and components of the steady state electric network, development and design of diagnostics and associated port plugs, and continued procurement of the tokamak cooling water system.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2006	7/5/2005		TBD	TBD		TBD	N/A	TBD
FY 2007	7/5/2005		TBD	TBD		TBD	N/A	2017
FY 2008	7/5/2005		1/25/2008	4Q FY 2008		TBD	N/A	2017
FY 2009	7/5/2005	09/30/2009[a]	1/25/2008	4Q FY 2010		TBD	N/A	2018
FY 2010	7/5/2005	07/27/2010[b]	1/25/2008	4Q FY 2011		TBD	N/A	2019
FY 2011	7/5/2005	05/30/2011[c]	1/25/2008	4Q FY 2011	04/12/2011[d]	TBD	N/A	2024
FY 2012	7/5/2005	07/10/2012[e]	1/25/2008	3Q FY 2012	05/02/2012[f]	TBD	N/A	2028
FY 2013	7/5/2005	12/11/2012[g]	1/25/2008	TBD[h]	04/10/2013[i]	TBD	N/A	2033
FY 2014	7/5/2005		1/25/2008	TBD	12/10/2013[j]	TBD	N/A	2034
FY 2015[k]	7/5/2005		1/25/2008	TBD		TBD	N/A	TBD

[a] Electron Cyclotron Heating Transmission lines (06/22/2009); Tokamak Cooling Water System (07/21/2009); CS Modules, Structures, and Assembly Tooling (09/30/2009)

[b] Ion Cyclotron Heating Transmission Lines (10/14/2009); First Wall / Blanket (02/02/2010); Tokamak Exhaust Processing (05/17/2010); Diagnostics: Residual Gas Analyzer (07/14/2010), Upper VIR (07/27/2010)

[c] Vacuum Auxilliary System (VAS) – Main Piping (12/13/2010); Diagnostics LFS (05/30/2011)

[d] Cooling Water Drain Tanks (04/12/2011);

[e] Diagnostics: Upper Port (10/03/2011), ECE (12/06/2011), Equatorial Port E-9 and TIP (01/02/2012), Equatorial Port E-3 (07/10/2012)

[f] Steady State Electrical Network (05/02/2012)

[g] VAS Supply (11/13/2012); Disruption Mitigation (12/11/2012); Pellet Injection (04/29/2013); Diagnostics: MSE (05/29/2013), CIXS (06/01/2013)

[h] The CD-2 date will be determined upon acceptable resolution of issues related to development of a high-confidence ITER Project Schedule and establishment of an approved funding profile.

[i] First Wall and Blanket (04/10/2013)

[j] CS Modules and Structures (11/18/2013); VAS Main Piping B-2, L-1, L-2 (12/10/2013)

[k] This project is pre-CD-2, and the schedule and cost estimate are preliminary.

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2016[a]	7/5/2005		1/25/2008	TBD		TBD	N/A	TBD

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection, Cost Range, and Start of Long-lead Procurements
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of Fabrication
CD-4 – Approve Project Completion

3. Project Cost History

It has not been possible to baseline the project due to both technical challenges and continued delays in the international ITER construction schedule. The factors that delayed CD-2 approval (e.g., schedule delays, design and scope changes, regulatory requirements, risk mitigations, and project management issues in the ITER Organization) have placed pressure on the cost range, resulting in increased estimates. The current best estimate of the total cost range, prior to CD-2, is $4,000,000,000-$6,500,000,000.

4. Project Scope and Justification

Introduction

ITER is an international partnership between seven Member governments (China, the European Union, India, Japan, the Republic of Korea, the Russian Federation, and the United States) aimed at demonstrating the scientific and technological feasibility of fusion energy for peaceful purposes. The *Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project* (ITER Agreement), signed on November 21, 2006, provides the legal framework for the four phases of the program: construction, operation, deactivation, and decommissioning. The ITER Agreement specifies that, as the Host, the European Union will bear five-elevenths (45.45%) of the ITER facility's construction cost, while the other six Members, including the U.S., will each support one-eleventh (9.09%) of the ITER facilities cost. The ITER Agreement also provides for operation, deactivation, and decommissioning of the facility to be funded through a different cost-sharing formula in which the U.S. will contribute a 13% share. Responsibility for ITER integration, management, design, licensing, installation, and operation rests with the ITER Organization (IO), which is an international legal entity located in France.

Scope

ITER Construction Project Scope

The U.S. ITER project includes three major elements:

- Hardware components, built under the responsibility of the U.S., then shipped to the ITER site for IO assembly, installation, and operation.
- Funding to the IO to support common expenses, including ITER research and development (R&D), IO staff and infrastructure, IO-provided hardware, on-site assembly/installation/testing of all ITER components, and IO Central Reserve, which serves as a contingency fund.
- Other costs, including R&D and conceptual design related activities.

The U.S. ITER project hardware scope is limited to design, fabrication, and delivery of mission-critical tokamak subsystems and is described below.

- **Tokamak Cooling Water System**: manages the thermal energy generated during the operation of the tokamak.

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[a] This project is pre-CD-2, and the schedule and cost estimate are preliminary.

- **15% of ITER Diagnostics**: provides the measurements necessary to control, evaluate, and optimize plasma performance and to further the understanding of plasma physics.
- **Disruption Mitigation Systems ($20M cost cap)**: limit the impact of plasma disruptions to the tokamak vacuum vessel, blankets, and other components.
- **Electron Cyclotron Heating Transmission Lines**: bring additional power to the plasma and deposits power in specific areas of the plasma to minimize instabilities and optimize performance.
- **Tokamak Exhaust Processing System**: separates hydrogen isotopes from tokamak exhaust.
- **Fueling System (Pellet Injection)**: injects fusion fuels in the form of deuterium-tritium ice pellets into the vacuum chamber.
- **Ion Cyclotron Heating Transmission Lines**: bring additional power to the plasma.
- **Central Solenoid Magnet System**: confines, shapes and controls the plasma inside the vacuum vessel.
- **8% of Toroidal Field (TF) Conductor**: component of the TF magnet that confines, shapes, and controls the plasma.
- **75% of the Steady State Electrical Network**: supplies the electricity needed to operate the entire plant, including offices and the operational facilities.
- **Vacuum Auxiliary System**: creates and maintains low gas densities in the vacuum vessel and connected vacuum components.
- **Roughing Pumps**: evacuate the tokamak, cryostat, and auxiliary vacuum chambers prior to and during operations.

Justification

The purpose of ITER is to investigate the burning plasma regime that exists in the performance region between the current scientific knowledge base and that needed for a practical fusion power. There are two parts of this need that will be achieved by ITER. The first part is to investigate the fusion process in the form of a "burning plasma," in which the heat generated by the fusion process exceeds that supplied from external sources (i.e., self-heating). The second part of this need is to sustain the burning plasma for a long duration (e.g., several hundred to a few thousand seconds), during which time equilibrium conditions can be achieved within the plasma and adjacent structures. ITER is the necessary next step to establish the confidence in proceeding with development of a demonstration fusion power plant.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Hardware			
FY 2006	13,754	13,754	6,169
FY 2007	34,588	34,588	24,238
FY 2008	25,500	25,500	24,122
FY 2009	85,401	85,401	26,278
FY 2010	85,266	85,266	46,052
FY 2011	63,875	63,875	84,321
FY 2012	91,716	91,716	99,229
FY 2013	107,660	107,660	110,298
FY 2014[a]	161,605	161,605	153,367

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[a] Appropriations prior to FY 2014 reflect major item of equipment funding. Starting in FY 2014, this project is funded as a Congressional control point.

(dollars in thousands)

	Appropriations	Obligations	Costs
FY 2015	125,654	125,654	128,704
FY 2016	105,223	105,223	124,402
Subtotal	900,242	900,242	827,180
Outyears	TBD	TBD	TBD
Total, Hardware	TBD	TBD	TBD
Cash Contributions			
FY 2006	2,112	2,112	2,112
FY 2007	7,412	7,412	7,412
FY 2008	2,644	2,644	2,644
FY 2009	23,599	23,599	23,599
FY 2010	29,734	29,734	29,734
FY 2011	3,125	3,125	3,125
FY 2012	13,214	13,214	13,214
FY 2013	13,805	13,805	13,805
FY 2014[a]	32,895	32,895	32,895
FY 2015	18,985	18,985	18,985
FY 2016	44,777	44,777	44,777
Subtotal	192,302	192,302	192,302
Outyears	TBD	TBD	TBD
Total, Cash Contributions	TBD	TBD	TBD
Total, TEC	TBD	TBD	TBD
Other project costs (OPC)			
FY 2006	3,449	3,449	1,110
FY 2007	18,000	18,000	7,607
FY 2008	-2,074	-2,074	7,513
FY 2009	15,000	15,000	5,072
FY 2010	20,000	20,000	7,754
FY 2011	13,000	13,000	10,032
FY 2012	70	70	22,322
FY 2013	2,535	2,535	5,760
FY 2014[a]	5,000	5,000	2,726
FY 2015	5,361	5,361	5,499
FY 2016	0	0	574
Subtotal	80,341	80,341	75,969
Outyears	TBD	TBD	TBD
Total, OPC	TBD	TBD	TBD

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[a] Appropriations prior to FY 2014 reflect major item of equipment funding. Starting in FY 2014, this project is funded as a Congressional control point.

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Total Project Costs (TPC)			
FY 2006	19,315	19,315	9,391
FY 2007	60,000	60,000	39,257
FY 2008	26,070	26,070	34,279
FY 2009	124,000	124,000	54,949
FY 2010	135,000	135,000	83,540
FY 2011	80,000	80,000	97,478
FY 2012	105,000	105,000	134,765
FY 2013	124,000	124,000	129,863
FY 2014[a]	199,500	199,500	188,988
FY 2015	150,000	150,000	153,188
FY 2016	150,000	150,000	169,753
Subtotal	1,172,885	1,172,885	1,095,451
Outyears	TBD	TBD	TBD
Total, TPC	TBD	TBD	TBD

6. Details of the 2014 Project Cost Estimate

The current best estimate of the total cost range, prior to CD-2, is $4,000,000,000–$6,500,000,000. This range was determined under the assumption that the annual funding level will not exceed $225,000,000 per year starting in FY 2014 through first plasma; and taking into account risks associated with assembly and operations costs, the international project schedule, nuclear construction, and technical challenges in providing U.S. project hardware scope.

7. Schedule of Appropriation Requests

(dollars in thousands)

Request Year		Prior Years	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Outyears	Total
FY 2006	TEC	889,000	120,000	29,000	0	0	0	0	1,038,000
	OPC	74,400	6,200	3,400	0	0	0	0	84,000
	TPC	963,400	126,200	32,400	0	0	0	0	1,122,000
FT 2007	TEC	800,151	130,000	116,900	30,000	0	0	0	1,077,051
	OPC	44,949	0	0	0	0	0	0	44,949
	TPC	845,100	130,000	116,900	30,000	0	0	0	1,122,000
FY 2008	TEC	801,330	130,000	116,900	30,000	0	0	0	1,078,230
	OPC	43,770	0	0	0	0	0	0	43,770
	TPC	845,100	130,000	116,900	30,000	0	0	0	1,122,000
FY 2009[b]	TEC	266,366	0	0	0	TBD	TBD	TBD	TBD
	OPC	38,075	0	0	0	TBD	TBD	TBD	TBD
	TPC	304,441	0	0	0	TBD	TBD	TBD	TBD

[a] Appropriations prior to FY 2014 reflect major item of equipment funding. Starting in FY 2014, this project is funded as a Congressional control point.

[b] The Prior Years column for FY 2009 through FY 2012 reflects the total of appropriations and funding requests only through the year of that row. Thus, for example, in the FY 2010 row, it reflects only funding from FY 2006 to FY 2010.

Request Year		Prior Years	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Outyears	Total
					(dollars in thousands)				
FY 2010	TEC	294,366	0	0	0	TBD	TBD	TBD	TBD
	OPC	70,019	0	0	0	TBD	TBD	TBD	TBD
	TPC	364,385	0	0	0	TBD	TBD	TBD	TBD
FY 2011	TEC	379,366	0	0	0	TBD	TBD	TBD	TBD
	OPC	65,019	0	0	0	TBD	TBD	TBD	TBD
	TPC	444,385	0	0	0	TBD	TBD	TBD	TBD
FY 2012[a]	TEC	304,566	90,000	0	0	TBD	TBD	TBD	TBD
	OPC	60,019	15,000	0	0	TBD	TBD	TBD	TBD
	TPC	364,385	105,000	0	0	TBD	TBD	TBD	TBD
FY 2013	TEC	371,366	104,930	140,965	0	TBD	TBD	TBD	TBD
	OPC	73,019	70	9,035	0	TBD	TBD	TBD	TBD
	TPC	444,385	105,000	150,000	0	TBD	TBD	TBD	TBD
FY 2014	TEC	371,366	104,930	105,572	225,000	TBD	TBD	TBD	TBD
	OPC	73,019	70	70	0	TBD	TBD	TBD	TBD
	TPC	444,385	105,000	105,642[b]	225,000	TBD	TBD	TBD	TBD
FY 2015[c]	TEC	377,010	104,930	121,465	194,500	144,639	TBD	TBD	TBD
	OPC	67,375	70	2,535	5,000	5,361	TBD	TBD	TBD
	TPC	444,385	105,000	124,000	199,500	150,000	TBD	TBD	TBD
FY 2016[d]	TEC	377,010	104,930	121,465	194,500	144,639	150,000	TBD	TBD
	OPC	67,375	70	2,535	5,000	5,361	0	TBD	TBD
	TPC	444,385	105,000	124,000	199,500	150,000	150,000	TBD	TBD

8. Related Operations and Maintenance Funding Requirements

The U.S. Contributions to ITER operations is assumed to begin with initial commissioning activities and continue for a period of 15 to 25 years. The fiscal year in which commissioning activities begin depends on the international ITER project schedule and is therefore TBD.

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	TBD
Expected Useful Life (number of years)	15–25
Expected Future start of D&D for new construction (fiscal quarter)	TBD

9. D&D Funding Requirements

Since ITER is being constructed in France by a coalition of countries and will not be a DOE asset, the “one-for-one” requirement is not applicable to this project.

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[a] The FY 2012 request was submitted before a full-year appropriation for FY 2011 was in place, and so FY 2011 was TBD at that time. Hence, the Prior Years column for FY 2012 reflects appropriations for FY 2006 through FY 2010 plus the FY 2012 request.

[b] The FY 2013 amount shown in the FY 2014 request reflected a short-term continuing resolution level annualized to a full year and based on the FY 2012 funding level for ITER.

[c] Prior to FY 2015, the requests were for a major item of equipment broken out by TEC, OPC, and TPC.

[d] Prior to FY 2015, the requests were for a major item of equipment broken out by TEC, OPC, and TPC.

The U.S. Contributions to ITER Decommissioning are assumed to begin when operations commence and continue for a period of 20 years. The U.S. is responsible for 13 percent of the total decommissioning cost.

The U.S. Contributions to ITER Deactivation are assumed to begin 20 years after commissioning and continue for a period of 5 years. The U.S. is responsible for 13 percent of the total deactivation cost.

10. Acquisition Approach for US Hardware Contributions

The U.S. ITER Project Office (USIPO) at Oak Ridge National Laboratory, with its two partner laboratories (Princeton Plasma Physics Laboratory and Savannah River National Laboratory), will procure and deliver in-kind hardware in accordance with the Procurement Arrangements established with the IO.

The USIPO will subcontract with a variety of research and industry sources for design and fabrication of its ITER components, ensuring that designs are developed that permit fabrication, to the maximum extent possible, under fixed-price subcontracts (or fixed-price arrangement documents with the IO) based on performance specifications, or more rarely, on build-to-print designs. USIPO will use cost-reimbursement type subcontracts only when the work scope precludes accurate and reasonable cost contingencies being gauged and established beforehand.

USIPO will utilize best value, competitive source selection procedures to the maximum extent possible, including foreign firms on the tender/bid list where appropriate. Such procedures shall allow for cost and technical trade-offs during source selection.

For the large-dollar-value subcontracts (and critical path subcontracts as appropriate), USIPO will utilize unique subcontract provisions to incentivize cost control and schedule performance.

In addition, where it is cost effective and it reduces risk, the USIPO will participate in common procurements led by the IO, or request the IO to perform activities that are the responsibility of the U.S.