The Administration's Proposed Budget for Fusion Energy Sciences in FY 2016

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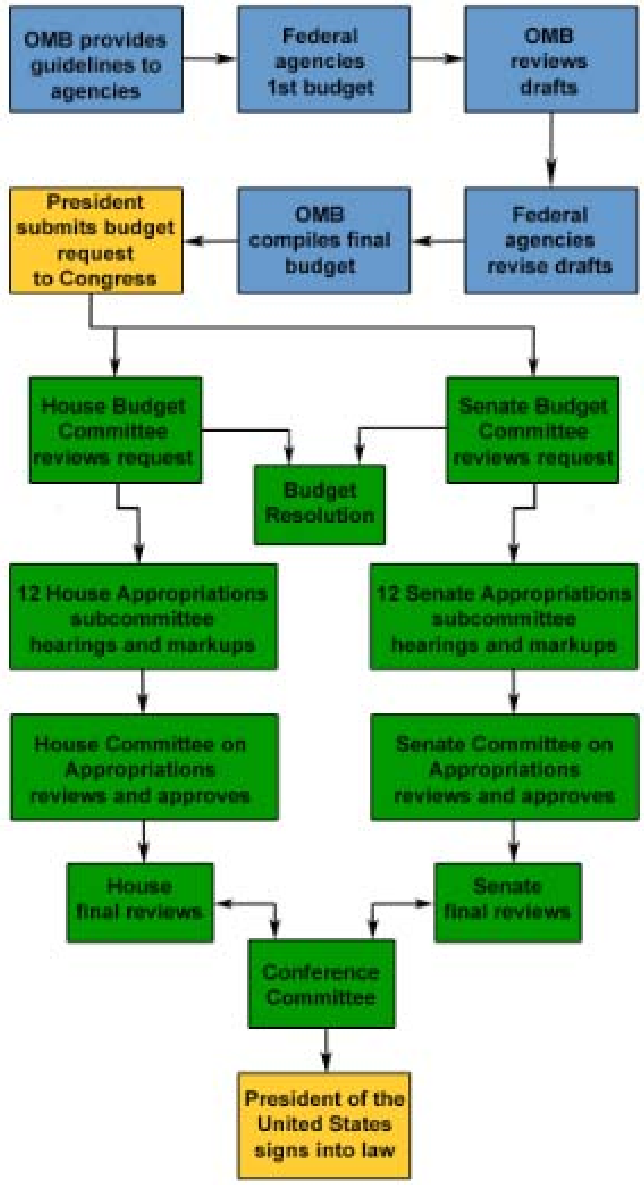
This rollout of the President's budget to Congress is one step in a complex process

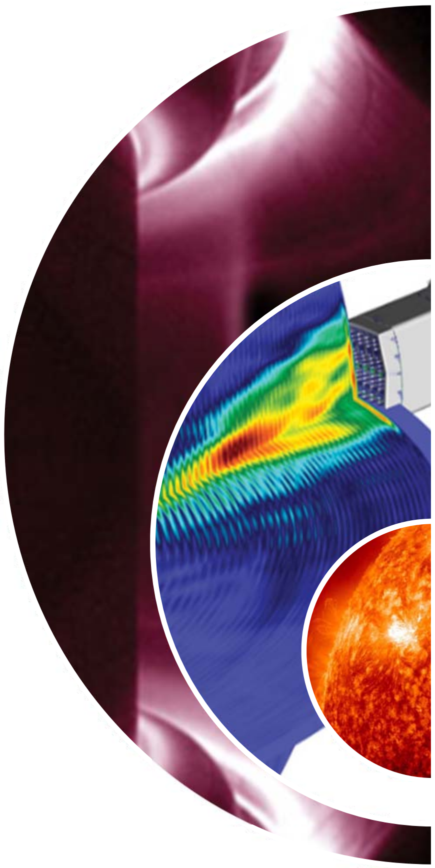
We are here



This budget proposal reflects a commitment to burning plasma and discovery science, and continuing concern about the ITER Project

- **Burning Plasma Science: Foundations**
  - This budget supports research campaigns on NSTX-U (14 weeks), DIII-D (12 weeks), & Alcator C-Mod (5 weeks)
  - Overall, 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 supported
  - Funding for General Plant Projects at PPPL is increased to enhance and modernize laboratory infrastructure
- **Burning Plasma Science: Long Pulse**
  - Support continues for U.S. research collaborations on international machines, such as EAST (China), KSTAR (Korea), and W7-X (Germany)
- **Discovery Plasma Science**
  - General plasma science activities continue, including the partnership with NSF
  - Operations and research on NDCX-II at LBNL are not funded
  - HEDLP research is focused on MEC at LCLS
  - There is no budget for new research awards as part of the SC/NNSA Joint Program for HEDLP science.
- **Burning Plasma Science: High Power**
  - The ITER budget request is constant, supporting the Administration commitment to meeting the FY 2016 needs of the project while accounting for weak international project execution
  - The US is committed to ITER's goals, but is concerned about the status and progress of the project
  - While the US ITER Project is performing well, review and on-the-ground assessments reveal that ITER has significant problems to overcome
  - The Administration is focused on doing what it can to improve international project execution

New FES budget structure is organized along scientific topical lines



Burning Plasma Science

New budget structure was approved in FY 2015

Foundations

Focusing on domestic capabilities; major and university facilities in partnership, targeting key scientific issues. Theory and computation focus on questions central to understanding the burning plasma state

Challenge: Understand the fundamentals of transport, macro-stability, wave-particle physics, plasma-wall interactions

Long Pulse

Building on domestic capabilities and furthered by international partnership

Challenge: Establish the basis for indefinitely maintaining the burning plasma state including: maintaining magnetic field structure to enable burning plasma confinement and developing the materials to endure and function in this environment

High Power

ITER is the keystone as it strives to integrate foundational burning plasma science with the science and technology girding long pulse, sustained operations.

Challenge: Establishing the scientific basis for attractive, robust control of the self-heated, burning plasma state

Discovery Science

Plasma Science Frontiers and Measurement Innovation

General Plasma Science, HEDLP, Exploratory Magnetized Plasma, and Diagnostics

FY 2016 Budget Request Summary

Budget Categories	FY 2015 request	FY 2015 enacted	FY 2016 request
Burning Plasma: Foundations	187,909	216,062	191,759
Burning Plasma: Long Pulse	30,909	38,956	30,909
Burning Plasma: High Power	150,000	150,000	150,000
Discovery Plasma Science	47,182	62,482	47,332
Total	416,000	467,500	420,000

$K through-out

Burning Plasma Science

Foundations

Advanced Tokamak (DIII-D, C-Mod, Smaller Scale) & Spherical Tokamak (NSTX-U and Smaller Scale)

- *Highly collaborative; strong university partnerships*
- *High scientific complementarity between these facilities*
- *High potential for growing student engagement on our nation's major fusion science experimental facilities*

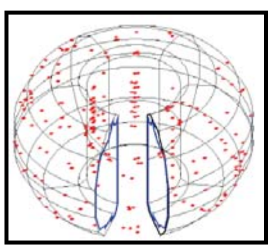
Theory and Simulation

- *US strength in engaging with experiment to develop predictive understanding*
- *Essential if high-risk gaps in fusion are to be closed*
- *Leverages DOE investments in leadership-class computing resources*

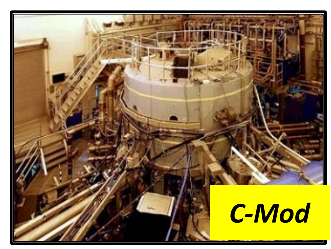
Foundations: Advanced Tokamak

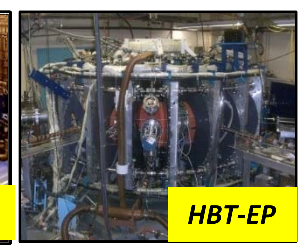
Collectively addresses optimization of the tokamak approach to magnetic confinement fusion, including addressing near-term scientific issues for ITER and developing advanced scenarios. Also, the AT line works in concert with the ST line to reveal fundamentals about toroidal confinement overall.

Budget Element	FY 2015 Request	FY 2015 Enacted	FY 2016 Request	FY 2016 Budget Highlights
DIII-D Research	32,038	36,065	32,038	Conduct experiments on transport in detached divertor conditions, disruption mitigation, 3D field control, and high-beta plasma performance.
DIII-D Ops	37,385	43,885	39,310	12 weeks of operation. Support for targeted upgrades.
C-Mod Research	6,145	9,460	6,145	Focus on high-priority topics, including ELM-free stationary regimes, disruptions, and RF heating and current drive.
C-Mod Ops	11,855	12,800	11,855	5 weeks of operation. 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.
Small-scale AT	973	973	973	Provide AT-relevant data . Validate models and codes.
Enabling R&D	2,165	2,165	2,165	Research in superconducting magnet technology, and fueling and plasma heating technologies



Red dots are sensors on DIII-D tokamak for three-dimensional magnetic field structure measurements





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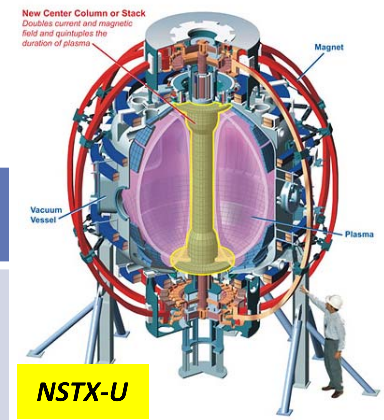
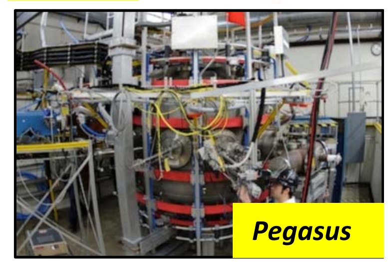
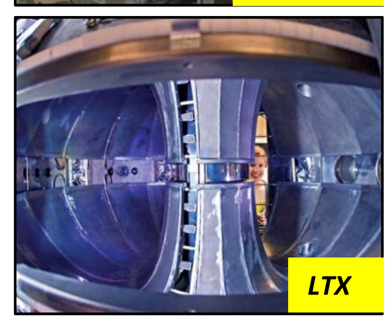
Foundations: Spherical Tokamak

The collective effort explores the physics of plasma confined in a low aspect ratio geometry at high pressure. Also, the ST line works in concert with the AT line to reveal fundamentals about toroidal confinement overall.

Budget Element	FY 2015 Request	FY 2015 Enacted	FY 2016 Request	FY 2016 Budget Highlights
NSTX-U Research	26,000	28,500	26,000	Address divertor heat flux mitigation at full parameters, explore non-inductive current drive and sustainment, develop high-performance discharge scenarios.
NSTX-U Operations	33,884	38,250	36,925	14 run weeks. Extend operation to full field and current (1 T, 2 MA). In mid-FY16, install cryo-pump and tungsten tiles.
NSTX-U MIE	3,470	3,470	0	MIE upgrade project is completed in mid FY 2015.
Small-scale ST	2,699	2,699	2,699	Targeted research on startup, liquid materials, and ultra-low aspect ratio exploration. Validate models and codes.







Upgraded NSTX-U capabilities will enable access to new scientific regimes

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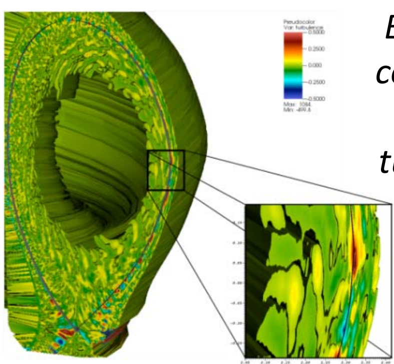
The multi-year upgrade project will be completed in mid-FY 2015, which will double the magnetic field strength and plasma current and lead to five times the pulse length

The newly installed center stack for Princeton's National Spherical Torus Experiment

Foundations: Theory and Simulation

Advance scientific understanding of fundamental physical processes governing the behavior of magnetically confined plasmas and develop predictive capability by exploiting leadership-class computing resources.

Budget Element	FY 2015 Request	FY 2015 Enacted	FY 2016 Request	FY 2016 Budget Highlights
Theory	21,170	25,170	21,170	Emphasis on research relevant to burning plasmas and ITER and on closing gaps in critical areas.
SciDAC	7,000	9,500	7,000	Total of 8 centers: FY 2016 will be the last year of 5 FES-funded SciDAC centers and the 3 joint FES-ASCR centers.



Edge-core coupling of plasma turbulence

Burning Plasma Science

Long Pulse

Long-Pulse Tokamaks & Long-Pulse Stellarators

- *Using partnerships on international facilities where US expertise is valuable and desired*
- *Creating opportunities for continued US leadership this decade in areas critical to fusion science*
- *Generating access for our scientists and students to what are becoming leading research endeavors around the globe*

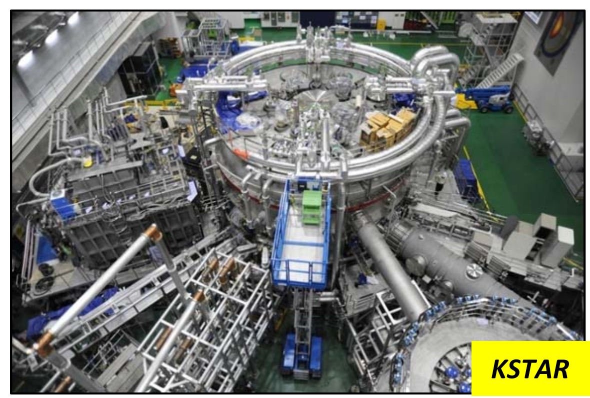
Materials and Fusion Nuclear Science

- *Investments will enable US leadership in fusion nuclear materials science and plasma-material interactions*

Long Pulse: Tokamak

Two U.S. teams are performing long-pulse plasma heating and control research on the Experimental Advanced Superconducting Tokamak (EAST) and Korea Superconducting Tokamak Advanced Research (KSTAR) facilities.

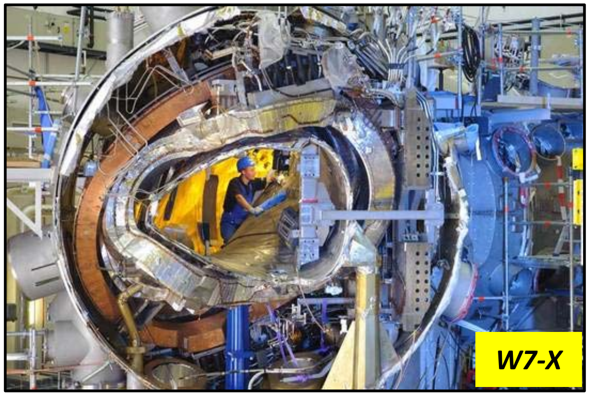
Budget Element	FY 2015 Request	FY 2015 Enacted	FY 2016 Request	FY 2016 budget highlights
Long-Pulse Tokamak	6,045	7,695	6,045	Commission improved control systems. Explore ITER-relevant operating scenarios. Develop RF heating/current drive and NB actuator models.

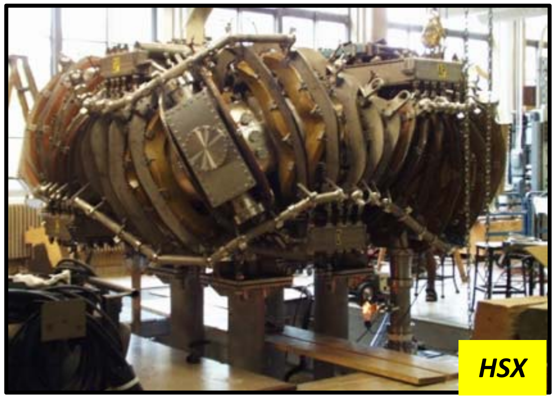


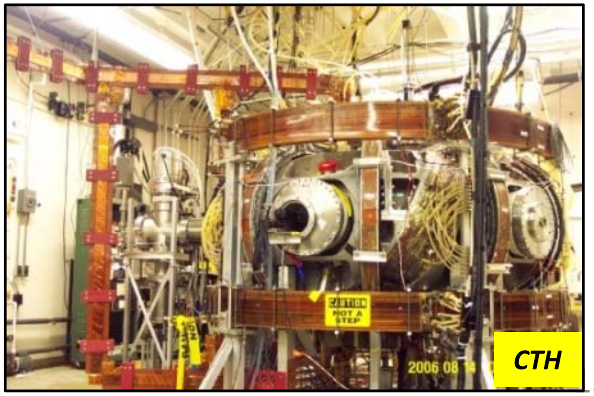
Long Pulse: Stellarator

A U.S. team is collaborating on the superconducting Wendelstein 7-X facility in Germany. The U.S. domestic effort focuses on optimizing the stellarator concept through compact quasi-symmetric magnetic field shaping.

Budget Element	FY 2015 Request	FY 2015 Enacted	FY 2016 Request	FY 2016 budget highlights
Superconducting Stellarator Research	2,500	3,850	2,500	Participate in W7-X experiments on steady-state operating scenarios and plasma control
Compact Stellarator Research	2,569	2,569	2,569	Provide data relevant to mainline stellarator efforts. Validate models and codes.



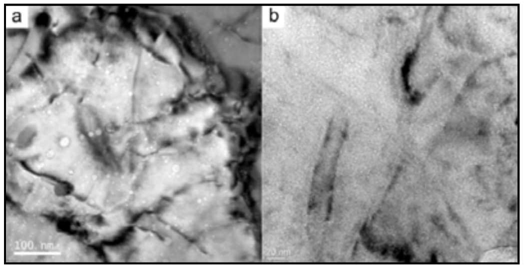




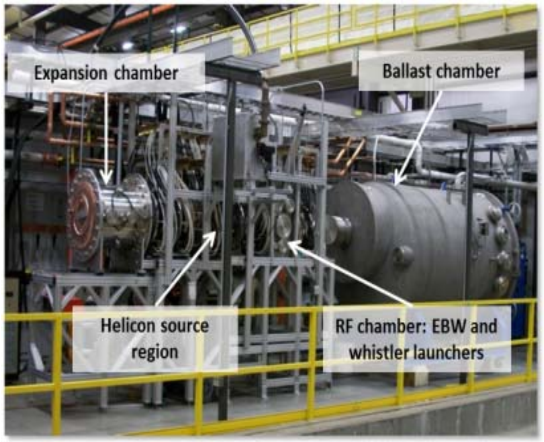
Long Pulse: Materials and Fusion Nuclear Science

This research supports the development, characterization, and modeling of structural, plasma-facing, and blanket materials that can be used in the extreme fusion environment.

Budget Element	FY 2015 Request	FY 2015 Enacted	FY 2016 Request	FY 2016 budget highlights
Fusion Nuclear Science	9,835	11,245	9,835	Study plasma-facing materials and PMI. Understand tritium retention, neutronics, and blanket corrosion issues. Scoping studies.
Materials Research	9,960	13,597	9,960	Research on structural materials. Study helium damage.



Two fusion material samples exposed to simultaneous helium implantation and ion irradiation. (a) shows localized large, damaging bubble formation; (b) shows manageable small bubbles evenly dispersed over the material



Physics Integration Experiment (PhIX) at ORNL to test materials under high heat flux

Discovery Plasma Science

Plasma Science Frontiers

- *General plasma science portfolio: FES stewardship of non-MFE plasma science areas*
- *High energy density laboratory plasma research: matter at extreme conditions*
- *Exploratory magnetized plasma: small/intermediate-scale MFE experimental research; platforms for verification & validation; study of plasma self-organization*

Measurement Innovation

- *High-impact R&D on new plasma diagnostic techniques*

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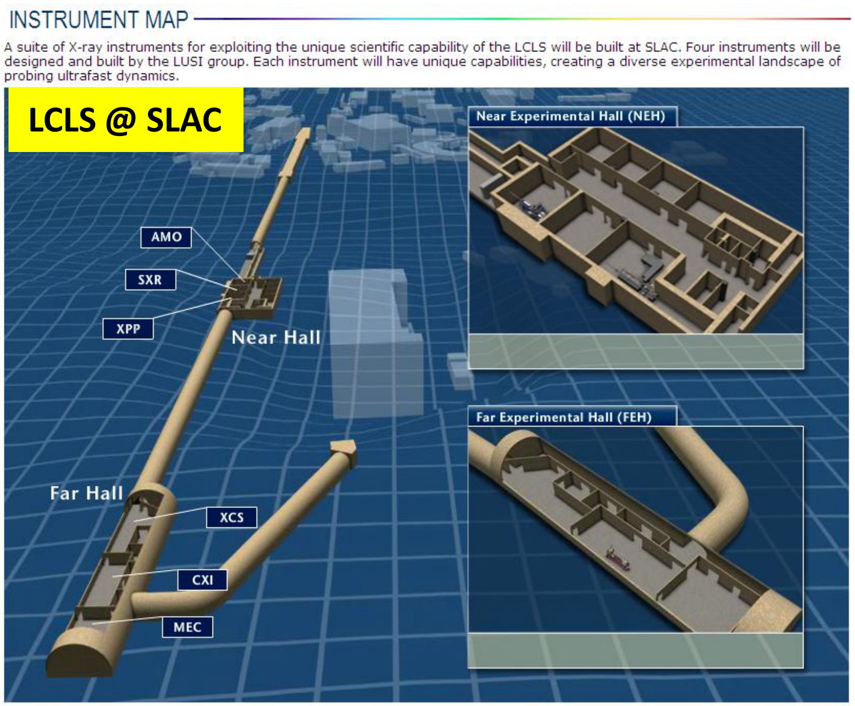
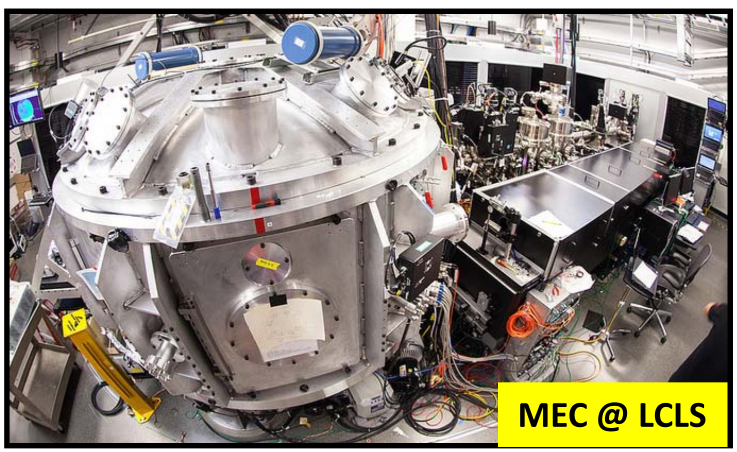
Discovery Plasma Science: Plasma Science Frontiers & Measurement Innovation

This 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.

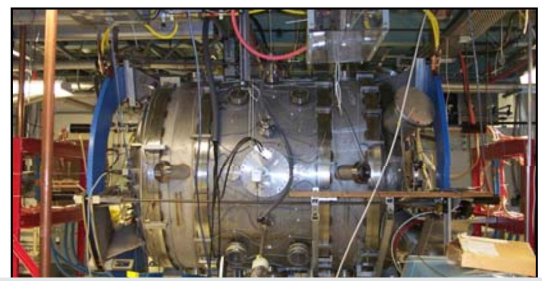
Budget Element	FY 2015 Request	FY 2015 Enacted	FY 2016 Request	FY 2016 budget highlights
General Plasma Science	15,500	15,800	15,500	Research on basic plasma behaviors, including low temperature plasmas. Continue NF-DOE Partnership. NUF joins SULI in WDTS program.
High Energy Density Laboratory Plasmas	6,700	19,815	6,700	Emphasis on MEC research. No new awards through SC/NNSA Joint Program. NDCX-II operations cease.
Exploratory Magnetized Plasma	10,409	10,409	10,409	Research on MST and self-organized compact tori.
Measurement Innovation	3,575	3,575	3,575	Continue developing innovative techniques.

Some Plasma Science Frontier activities





Large Plasma Device @ UCLA Basic Plasma Science Facility



Magnetic Recconnection Experiment (MRX) @ PPPL

Center for Predictive Control of Plasma Kinetics: Multi-Phase and Bounded Systems

psc

Department of Energy Plasma Science Center

Burning Plasma Science

High Power

US Contributions to the international ITER Project

- U.S. ITER Project requirements and plans
- Concerns and approach regarding the international project

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The state of play of the international ITER project prompts the Administration to maintain its present pace of contributions, but still meet the project's needs for FY 2016

Project construction	FY 2015 Request	FY 2015 Enacted	FY 2016 Request
U.S. ITER	150,000	150,000	150,000

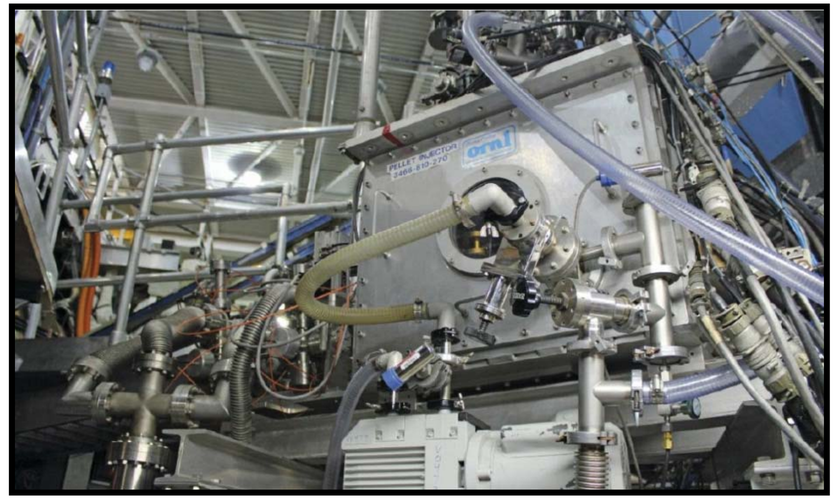
- Funding is provided for critical path items to ensure that U.S. in-kind contributions maintain U.S. commitments to FY 2016 project needs. Funding is also provided for ITER Project Office operations, the U.S. cash contribution, and continued progress on in-kind contributions.

- **The U.S. ITER Project Office is on track.** FY 2016 scope includes 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, procurement of piping for the tokamak cooling water system, and development and design of the remaining US hardware contributions.

- **The funding request for the U.S. ITER Project** is driven by the U.S. best estimate of the ITER construction schedule. The requested level of funding will allow the U.S. to meet its obligations, based on the recent reviews, and will mitigate risk to the U.S. if the project schedule continues to slip.

U.S. fabrication of ITER hardware is progressing

Toroidal field conductor jacketing at
High Performance Magnetics (Tallahassee, FL)



Pellet injector to feed ITER with frozen fuel pellets,
developed by ORNL (Oak Ridge, TN)

Toroidal field cable produced at
New England Wire Technologies (Lisbon, NH)

Installation of the first winding station for the central solenoid
at General Atomics (San Diego, CA)

ITER recent developments

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- **New Director-General nominated:**
  - Dr. Bernard Bigot was nominated as the new Director-General at the Nov 19-20 ITER Council meeting; his appointment will be acted upon at an extraordinary Council meeting on March 5
  - He will visit Washington, DC, later this week to discuss his vision
  - He has proposed an action plan to the Council
- **Project schedule:**
  - The ITER Organization and seven Domestic Agencies are engaged in constructing a realistic construction schedule
- **Management Assessment responses:**
  - Corrective action plans have been developed and are being implemented for the recommendations of the 2013 Management Assessment report
- **The Administration is fully engaged and is monitoring the progress of these activities closely**

Bernard Bigot
Currently Administrator-General of the French Atomic and Alternative Energies Authority (CEA)

Annual Joint Research Target for FES facility-based experiments

FY 2015 Joint Research Target (underway this year)

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.

FY 2016 Joint Research Target (planned for next year)

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.

Final report for FES 2014 Joint Research Target
Quantify plasma response to non-axisymmetric (3D) magnetic fields in tokamaks
E. J. Strait et al. (31 contributors), 30 September 2014
http://science.energy.gov/~/media/fes/pdf/program-news/JRT_Final_2014_rs.pdf

Annual Theory/Simulation Performance Target

FY 2015 Theory & Simulation Performance Target (underway this year)

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.

FY 2016 Theory & Simulation Performance Target (planned for next year)

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.

Final report for FES 2014 Theory & Simulation Performance Target
Understanding alpha particle confinement in ITER
by G. Y. Fu et al. (10 contributors), 14 October 2014
http://science.energy.gov/~/media/fes/pdf/program-news/FES_TheoryMilestone_2014_finalreport.pdf

Responding to Congress's request

- In response to the Congressional language in the FY 2014 Appropriations, a high level document regarding strategic priorities is currently under internal review.

- The Fusion Energy Sciences program office is working with the community to launch a series of technical workshops, to be held in late spring/summer 2015. These workshops will review recent progress, potentially broaden connections between the fusion energy sciences portfolio and related fields, and identify scientific research opportunities.

- Output from these workshops will serve as vital input into future planning

Community engagement workshops

- **The topics of the workshops are as follows:**
  - *Integrated Simulations for Magnetic Fusion Energy Sciences*
  - *Transients*
  - *Plasma-Materials Interaction*
  - *Plasma Science Frontiers (2 workshops)*

- **Each workshop will deliver a written report, prepared by its program committee**
  - Each program committee will consist of a group of community scientists selected for topical expertise who will lead/participate in the workshop).
  - The reports will address the scientific challenges, as well as ideas for potential implementation options

- **Anticipate an announcement from FES later this week**

Regarding the next FESAC meeting

- **Next meeting is being planned for March 12-13, to be confirmed**
  - Location details will be announced soon

- **Agenda items:**
  - The report of the 2014 Committee of Visitors
  - New charge for a report about FES science contributions and technology discoveries beyond fusion energy
  - Update on community engagement technical workshops

Thank you