

Fusion Energy Sciences Overview

James W. Van Dam
Acting Associate Director
Office of Science
Fusion Energy Sciences



U.S. DEPARTMENT OF
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FESAC Meeting
February 1-2, 2018

Super Blue Blood Moon Eclipse – 31 Jan 2018



Outgoing FESAC members: Thank you



Arati Dasgupta



John Foster



Chris Hegna



Valerie Izzo



Linda Sugiyama

Retiring Member	Institution	On FESAC Since
Arati Dasgupta	NRL	2014
John Foster	U. Michigan	2013
Chris Hegna	U. Wisconsin-Madison	2014
Valerie Izzo	UCSD	2014
Linda Sugiyama	MIT	2013

Sincere thanks to all of them for their service



New FESAC members



Sigrid Close



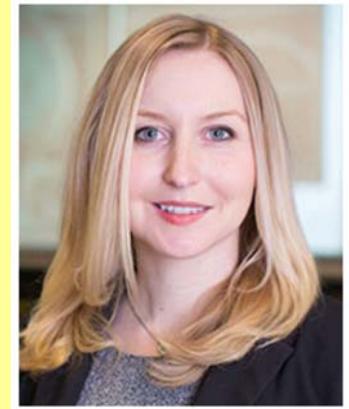
Diane Demers



Paul Terry



Mitchell Walker



Anne White

New Member	Institution
Sigrid Close	Stanford U.
Diane Demers	Xantho Technologies
Paul Terry	U. Wisconsin-Madison
Mitchell Walker	Georgia Tech
Anne White	MIT

Ex officio Members
John Cary (APS-DPP)
Arnold Lumsdaine (ANS-FED)
John Verboncoeur (IEEE-Nuclear & Plasma Science)



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1. Budget Update



FY 2018 Presidential budget request was submitted to Congress on March 16, 2017

BUDGET OF THE U. S. GOVERNMENT
**A New Foundation For
American Greatness**

Fiscal Year 2018



Office of Management and Budget

“This budget, therefore, includes \$639 billion for the Department of Defense—a \$52 billion dollar increase from the 2017 annualized continuing resolution level. This increase will be offset by targeted reductions elsewhere.” [page 2]

DOE proposed budget is \$28B (which is -\$1.7B, -6%)

SC proposed budget is \$4.47B (which is -\$0.9B, -17%)

FES proposed budget is \$310M (which is -\$70M, -18%)



Office of Science FY 2018 President's Request

	FY 2017	FY 2018		
	Enacted Approp.	President's Request	House Mark	Senate Mark
ASCR.....	647,000	722,010	694,200	763,000
BES.....	1,871,500	1,554,500	1,871,500	1,980,300
BER.....	612,000	348,950	582,000	633,000
FES.....	380,000	309,940	395,000	232,000
HEP.....	825,000	672,700	825,000	860,000
NP.....	622,000	502,700	619,200	639,200
WDTS.....	19,500	14,000	19,500	19,500
SLI.....	130,000	76,200	105,600	143,000
S&S.....	103,000	103,000	103,000	103,000
PD.....	182,000	168,516	177,000	177,000
Subtotal, Science.....	5,392,000	4,472,516	5,392,000	5,550,000
Rescission of PY Bal.....	-1,028 ^a
Total, Science.....	5,390,972	4,472,516	5,392,000	5,550,000

^a Rescission of PY funds in the amount -\$239 for PY 2012 and older: -\$239 for FY 2013 and -\$550 for FY 2014 - FY 2016.



Current FY 2018/2019 budget status

- **DOE has been operating under Continuing Resolutions**
 - Until December 8, 2017; until January 19, 2018; and now until February 8
- **Limited funding actions during the CRs:**
 - Grants and cooperative agreements are being processed following a priority order based on the starting date of their FY 2018 budget periods
 - Labs and large cooperative agreements are being funded incrementally
 - Under the CR, ITER is being funded incrementally
- **Submission of the President's FY 2019 budget request to Congress is now scheduled for February 12**



- During FY 2016 and again in FY 2017, FES held individual Budget Planning Meetings with lab, university, and major facility research groups, plus several community organizations
 - In response to COV suggestion to broaden the BPMs
 - Useful information for planning the next budgets
 - Last year, surveyed participants for comments
- Plan to hold such meetings again this year, to prepare for FY 2020 budget request
 - Guidance letter(s) will be forthcoming



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2. Programmatic Updates & Highlights



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DIII-D program and facility enhancements to address key scientific issues for fusion energy

DIII-D Program Elements

FY17

FY18

FY19

FY20-21

Prepare Burning Plasma Scenarios

- Transient Control (ELMs)
- Transient Control (Disruptions)
- Transport (pedestal, Te/Ti, rotation)



Super-SPA supply (ASIPP)



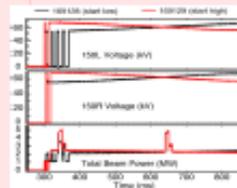
Increased electron Heating/current drive



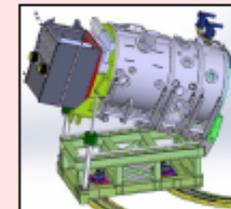
Super-SPA #2

Determine Path to Steady State

- High β Operation
- Fast Ion Transport
- Current Profile Control



Real-time NBI voltage modulation



Increased co-contr, off-axis current drive

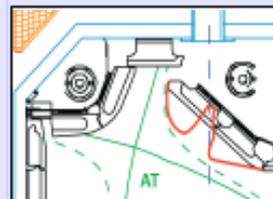


New helicon system

Develop PMI-Boundary Solutions

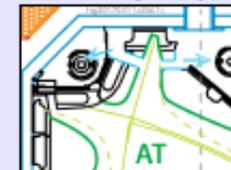
- Model Validation
- Divertor Configuration Changes
- PMI Studies and Material Evaluation

Upper divertor closure

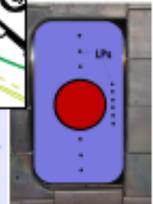


Tile Thermal Upgrade

SAS with pumping



Surface Station

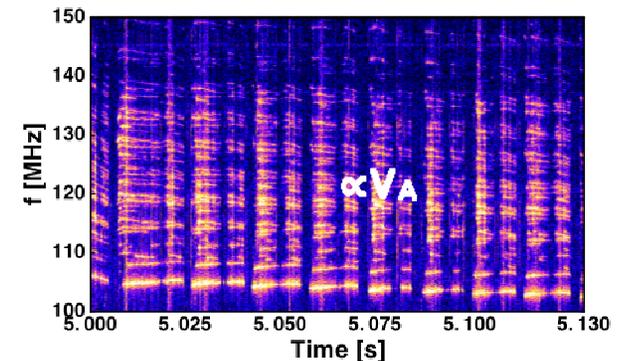


DIII-D in FY 2018 will run 18 weeks, then go into Long Torus Opening for facility enhancements

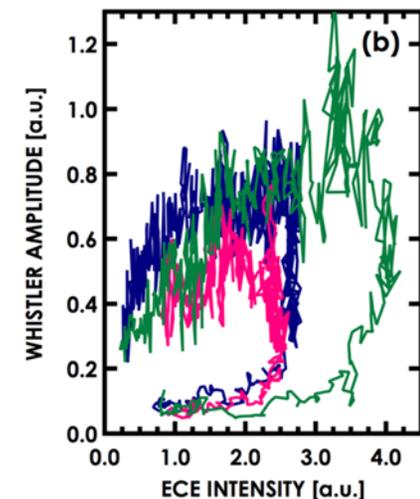


Frontier science campaign on DIII-D

- In FY 2017, FES supported a new initiative to carry out experiments on DIII-D focusing on frontier plasma science, with input solicited from the university community to identify experiments not directly related to fusion energy issues
- Four experiments were performed:
 - Interaction of Alfvén/whistler fluctuations and runaway electrons
 - Self-consistent chaos in magnetic field dynamics
 - Self-organization of kink-unstable flux ropes; and
 - Impact of magnetic perturbations on turbulence
- The initiative was very successful and resulted in a post-deadline invited paper at the 2017 APS-DPP meeting
- Plans are underway to continue this initiative in FY 2018, contingent upon budget authority



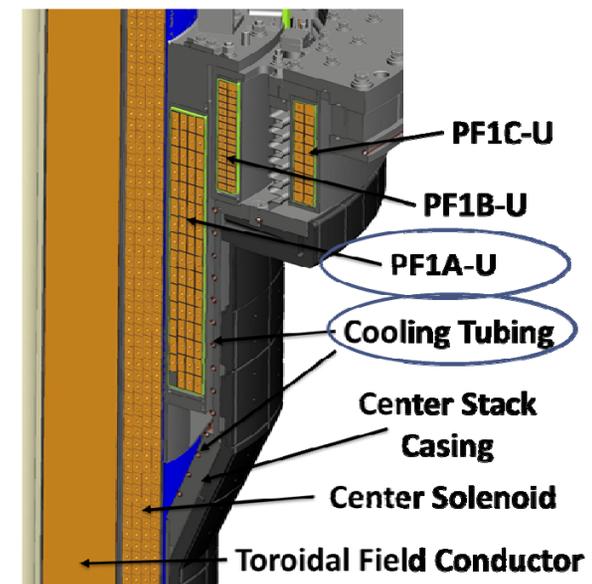
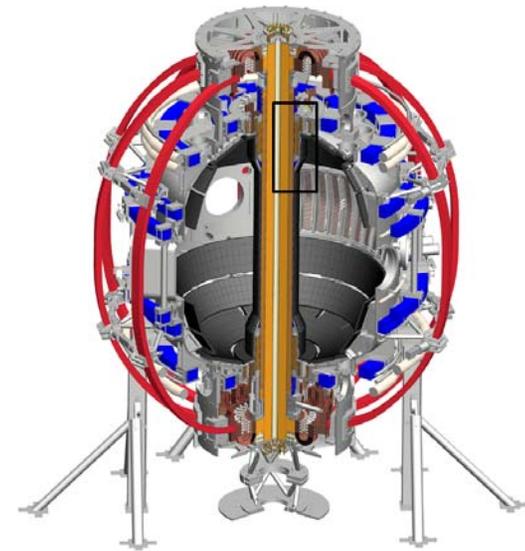
Whistler frequency bands showing intermittency from sawtooth and whistler scattering



Predator-prey limit cycles between whistler wave amplitude and electron cyclotron emission – related to scattering of runaways



- **Research operation of NSTX-U:**
 - Plasma operations commenced after the completion of the NSTX Upgrade project.
 - However, after ten weeks of experimental operation, a series of hardware failures rendered the machine inoperable, stopping operations prematurely in 2016.
- **In response, SC directed PPPL to:**
 - Conduct an independent investigation of all policy and procedural causes of the NSTX-U project difficulties
 - Identify all design, construction, and operational deficiencies with the NSTX-U facility.
- **These activities led to the development by PPPL of a corrective action plan and proposed recovery activities to address the necessary repairs and engineering issues for NSTX-U**
 - During FY 2017, 12 Design Verification and Validation Reviews, Extent of Condition Review, Extent of Cause Review, etc., were carried out
 - An Integrated Corrective Action Plan was developed





- **SC Office of Project Assessment has been charged to conduct a review assessment of:**
 1. Science mission need for ST/NSTX-U
 2. Cost/schedule/scope
 3. Laboratory capabilities
- **This assessment will be performed in two phases:**
 - Feb 6-8
 - March 14-16

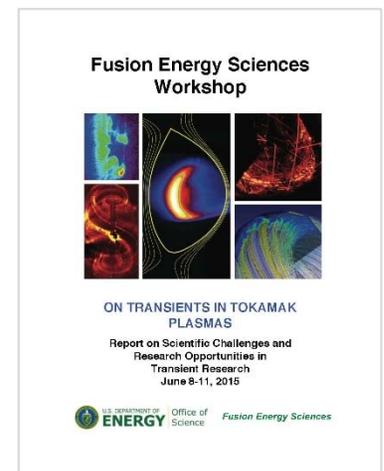
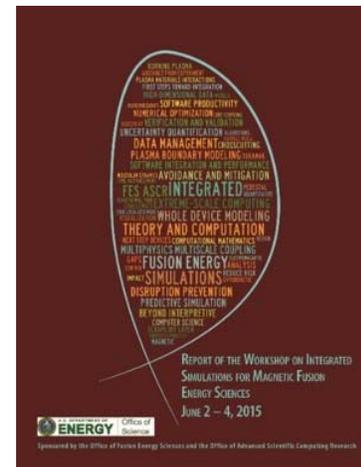


New SciDAC portfolio addresses priorities identified in community workshops

- FES SciDAC portfolio was recompeted in FY 2017
 - FES and ASCR jointly invested **\$24M** in FY 2017 to support **seven** multi-institutional and interdisciplinary SciDAC partnerships
 - An **eighth** project is being supported by FES, starting in FY 2018
 - 11 universities, 8 DOE national laboratories, and 5 private industry institutions (including small businesses) in 13 states are involved
- The research activities of the eight partnerships will be coordinated to accelerate progress toward Whole-Device Modeling
- The new portfolio strengthens the U.S. domestic fusion program, advances U.S. world-leadership and competitiveness in fusion simulations, and addresses research opportunities identified in recent community workshops



27-petaflop Titan @ OLCF

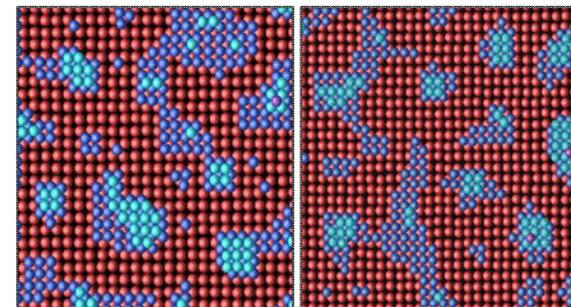
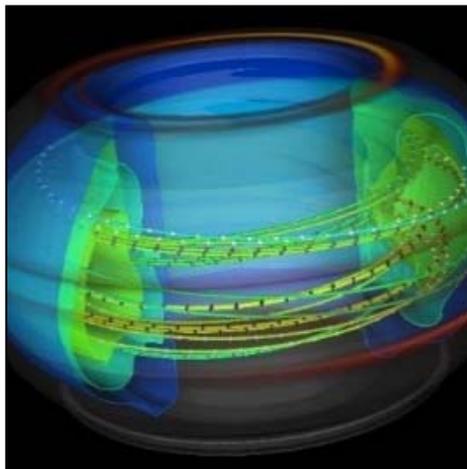
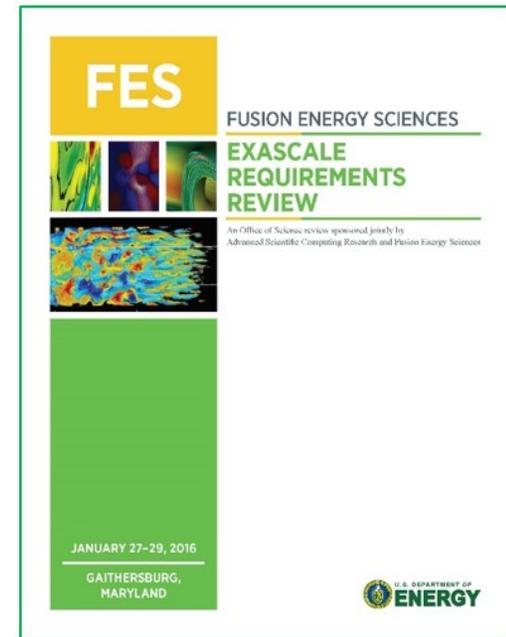


2015 community workshops on Integrated Simulations for Magnetic Fusion Energy Sciences and Transients in Tokamak Plasmas



Fusion presence in Exascale activities

- The upcoming Exascale era will enable transformative advances in predictive power for fusion systems, based on fundamental science and high-performance computing
- Community studies identified priorities and challenges
- Two fusion-relevant multi-institutional efforts are part of the DOE Exascale Computing Project (ECP)
- University participation is through subcontracts with the DOE Labs



High-Fidelity Whole-Device Modeling of Magnetically Confined Fusion Plasma
(led by PPPL)

Molecular Dynamics at the Exascale: Spanning the Accuracy, Length and Time Scales for Critical Problems in Materials Science
(led by LANL; addresses needs of BES, FES, and NE)

- **QIS**—which includes quantum science and instrumentation for next-generation computing, information, and other fields—has been identified as an important cross-cutting topic with potential impact across all SC program offices
 - A “Dear Colleague Letter” was issued recently by SC, encouraging the submission of innovative research ideas in QIS
-
- In 2018, FES will be exploring its role in QIS, joining the other SC programs
 - An FES Roundtable meeting is planned:
 - To identify fundamental science supported by FES that could advance QIS development
 - Explore QIS applications that could have a transformative impact on FES mission areas, including fusion and discovery plasma science



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Programs | Laboratories | User Facilities

Accelerating Quantum Information Science
The Office of Science releases a Dear Colleague Letter on Accelerating Development of and Research Impacts from Quantum Information Science (QIS)

<https://science.energy.gov/>



Department of Energy
Office of Science
Washington, DC 20585

November 29, 2017

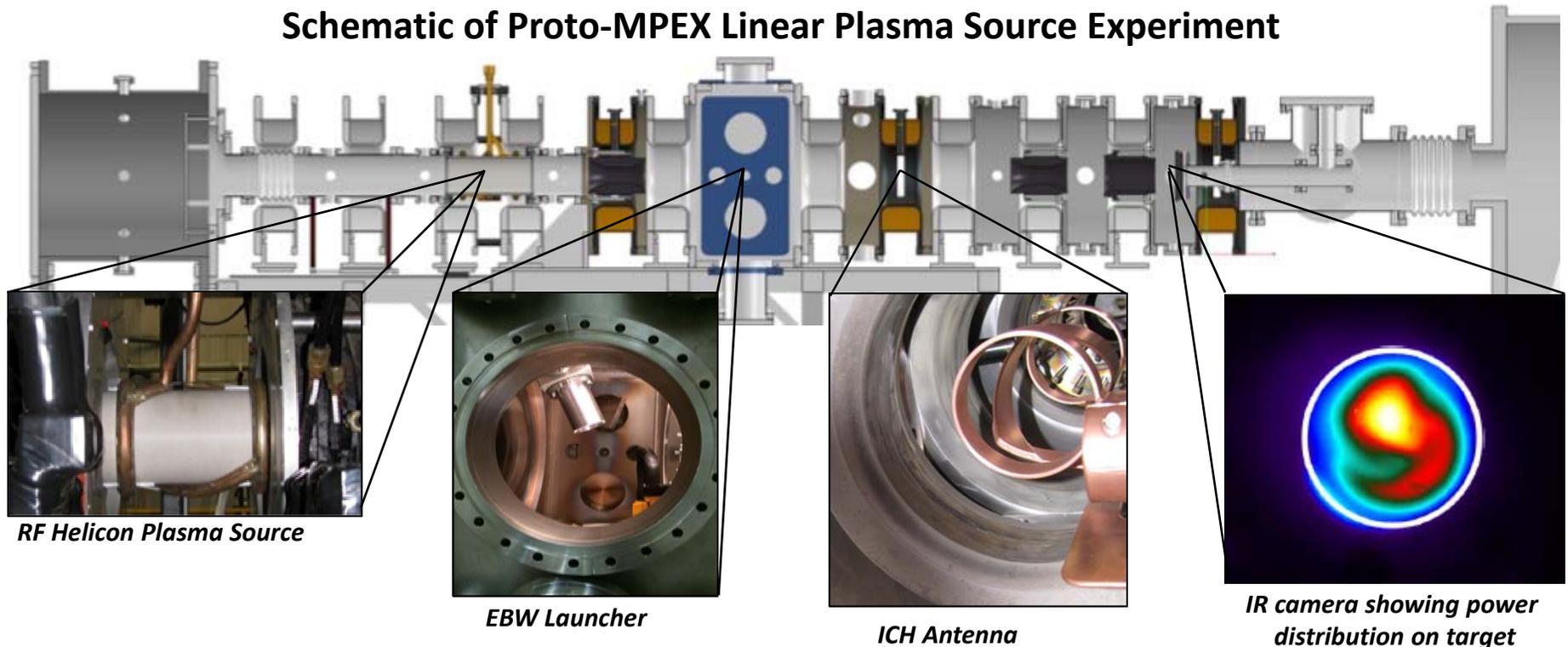
Dear Colleague Letter on Accelerating Development of and Research Impacts from Quantum Information Science (QIS)

Dear Colleagues:

Quantum science and instrumentation for next-generation computing, information, and other fields—the core of “quantum information science” (QIS)—constitutes a rapidly-developing interdisciplinary field, with substantial intersections with the missions, interests, capabilities, and portfolios of the program offices within the Department of Energy’s (DOE’s) Office of Science (SC), and significant implications for the Nation as a whole. Novel approaches to fundamental science and to applications such as sensing, communications, simulation, and computing are enabled by understanding and manipulation of the uniquely quantum phenomena of superposition, entanglement, and squeezing. The Office of Science has interests, expertise, and capabilities in a wide range of QIS-related topics, including frontier computing, machine learning, optimization, quantum materials, isotopic separation,



Schematic of Proto-MPEX Linear Plasma Source Experiment

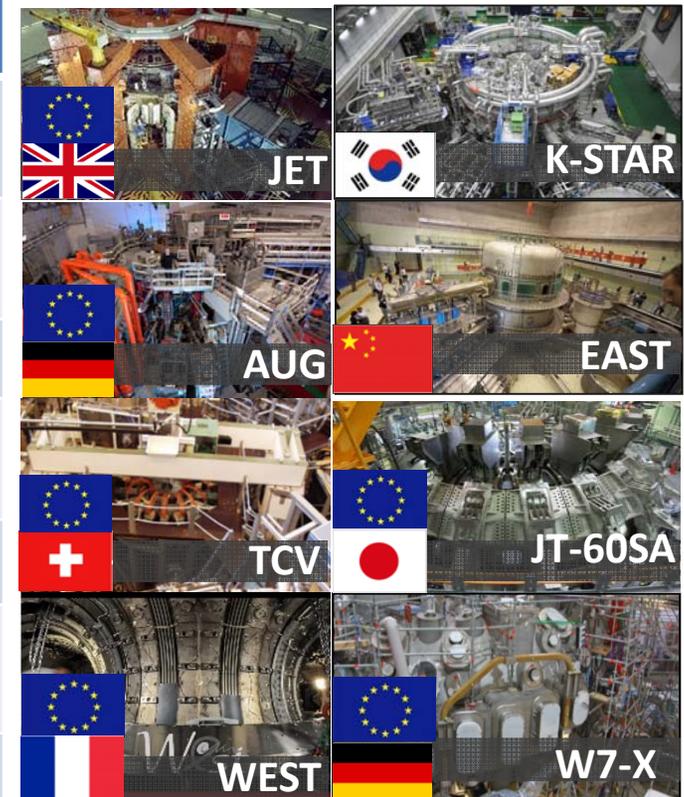


- The PMI workshop report pointed to the need for an experimental facility capable of simulating steady-state, divertor-like plasmas for reactor-relevant PMI, divertor plasma physics, and fusion materials science studies
- ORNL and partner institutions continue high-priority research and development to finalize scientific proof-of-principle for an innovative, high-intensity linear plasma source capable of producing the extreme plasma parameters required for PMI research relevant to future fusion devices

International collaborative research

Multi-disciplinary teams of U.S. scientists and students are leveraging U.S. capabilities to lead research overseas on unique facilities

Facility	Research Area	Institutions
EAST KSTAR	Control of long pulse tokamak scenarios	GA, Lehigh, LLNL, MIT, ORNL, PPPL, UCLA, & U Texas-Austin
EAST	Control of plasma-material interactions	PPPL, JHU, LANL, MIT, ORNL, U Tennessee, & UIUC
KSTAR	Disruption physics	Columbia, MIT, PPPL
W7-X	3D, steady-state stellarators	PPPL, ORNL, Auburn, LANL, MIT, Wisconsin, Xantho Tech.
JT-60SA	Energetic ion physics	GA, UC-Irvine
JET, AUG TCV	Research in support of burning plasma physics	ORNL, PPPL, GA, MIT, UCSD, Wisconsin, U Texas-Austin
WEST	Burning plasma technology testbed	ORNL, MIT





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U.S. remote control rooms enhance utilization of international & domestic research facilities



MIT

PPPL

GA

- U.S. teams at **GA** completed a week of experiments in FY 2017 during EAST third shift and can lead experiments at KSTAR
- **PPPL** and collaborators can lead experiments on KSTAR & connect to W7-X, DIII-D
- Remote control room at **MIT** is being designed, with assembly to commence in Spring FY 2018

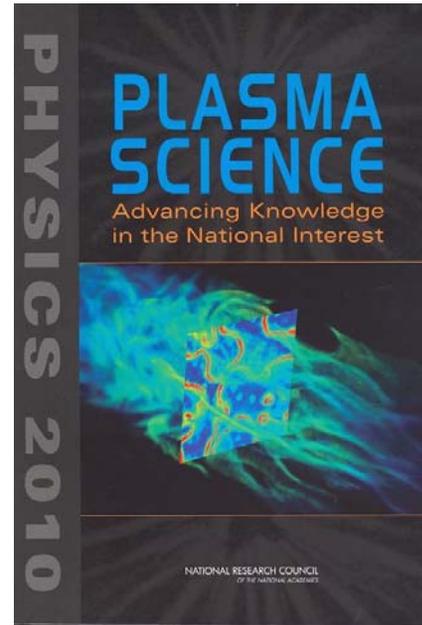
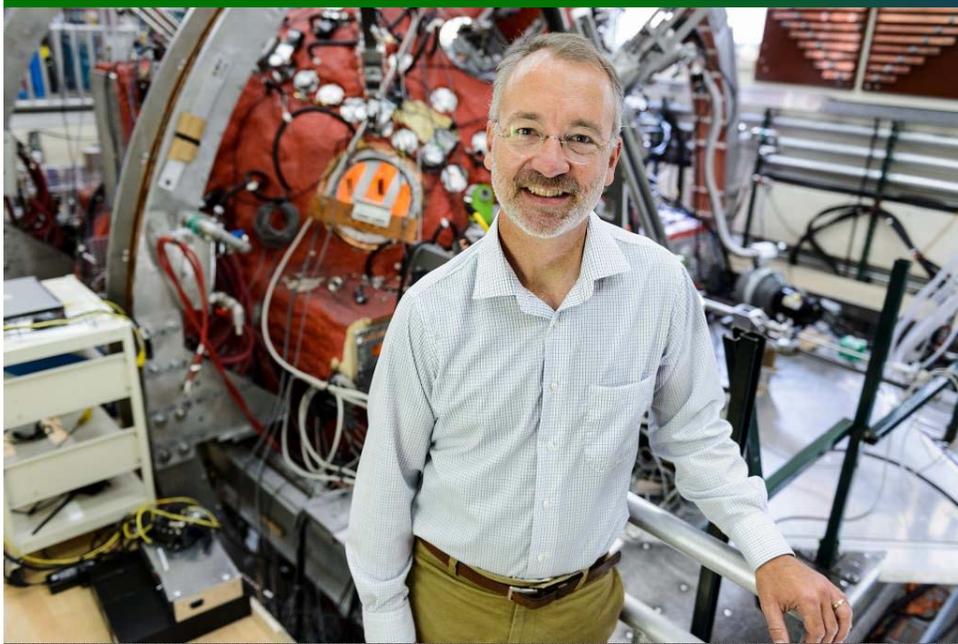




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A new intermediate-scale facility was awarded by FES for the first time in nearly two decades



The DOE Office of Fusion Energy Sciences has awarded \$12.5 million FY17 funds over five years to the University of Wisconsin–Madison to develop an intermediate-scale, integrated, collaborative plasma science user facility that will expand the frontiers of plasma astrophysics. Two existing experiments, the Big Red Plasma Ball and the Madison Symmetric Torus, are combined into the new Wisconsin Plasma Physics Laboratory (WiPPL). The new project will join the expertise of more than two dozen UW–Madison scientists and technicians with outside plasma scientists, who will gain access to the facility and establish new collaboration.

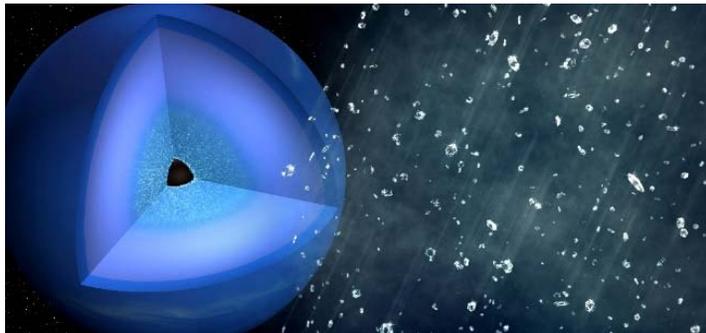
“Several areas of basic plasma science would benefit from new intermediate-scale facilities.”(2010 Decadal Study)

“There is a need for creation and exploration of new regimes in the laboratory.” (2016 PSF Report)

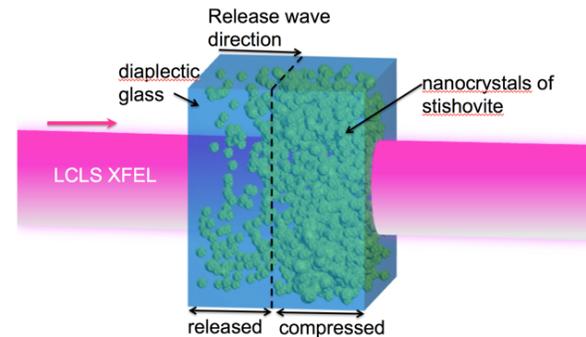


The Matter in Extreme Conditions (MEC) instrument is the world leader for its class of high energy density science

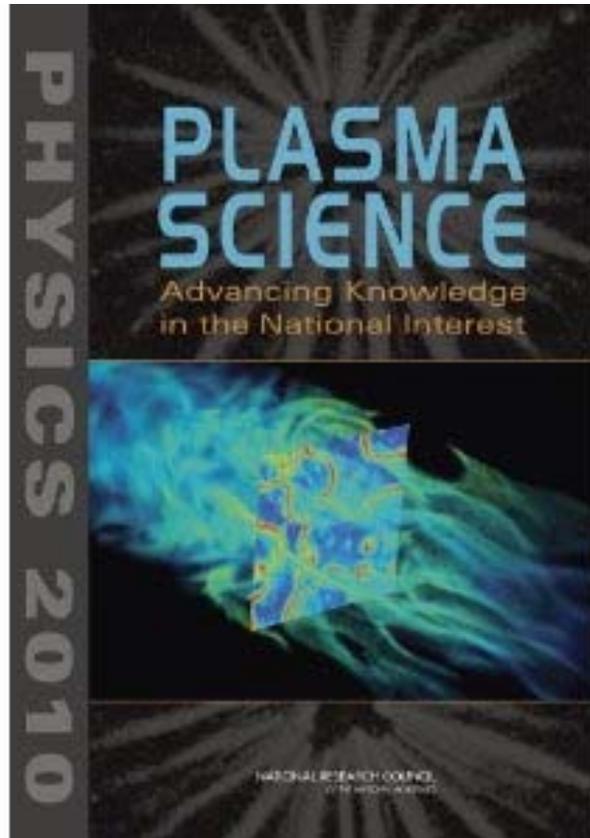
The MEC instrument is host to a wide range of innovative studies



Observation of “diamond rain” that forms in the interior of Icy Giant Planets



Using the LCLS x-ray free electron laser, scientists mapped—for the first time—the metastable silica high-pressure phase behavior under shock wave compression and release



2010 Plasma Decadal Survey
(Chair: Steve Cowley)

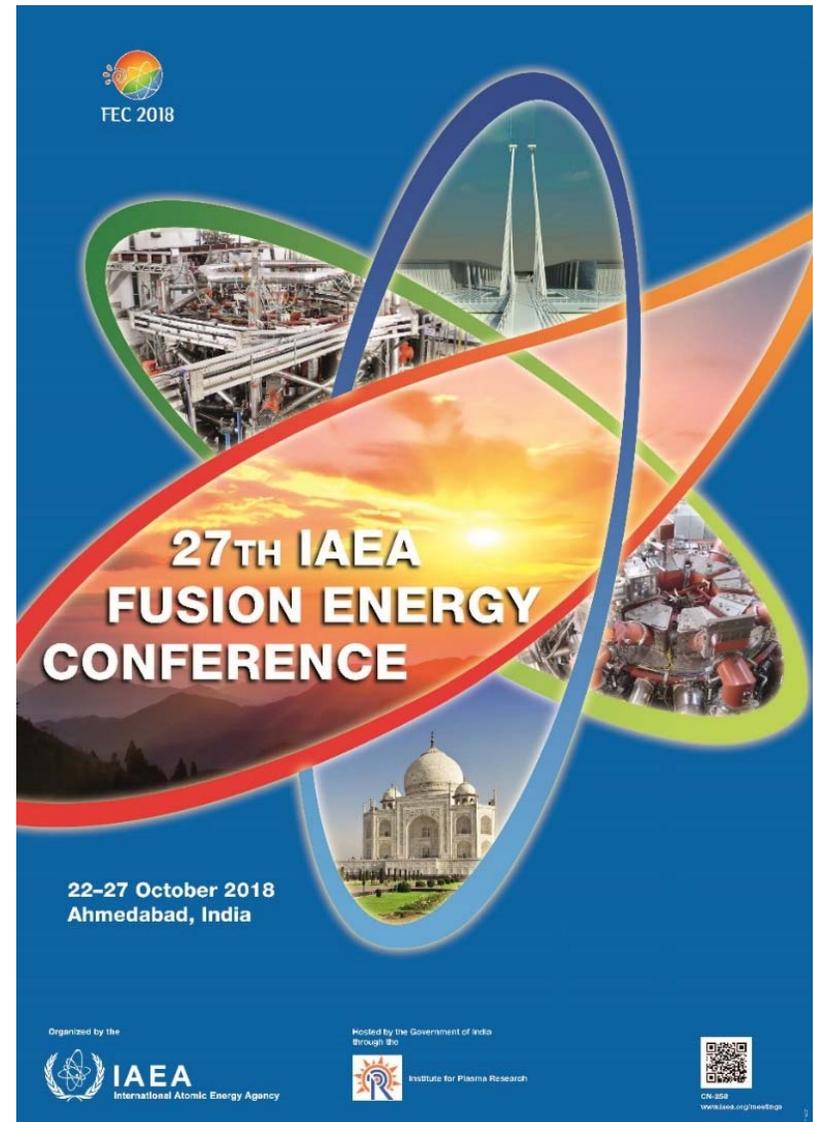
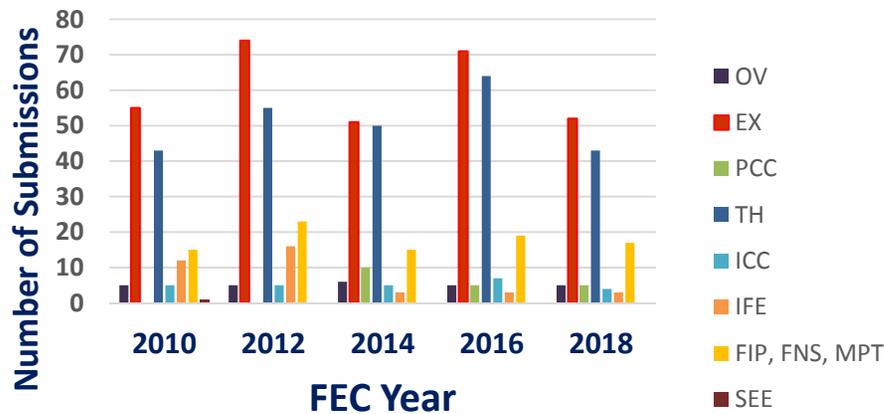
- **Charge and Statement of Task are finalized**
 - Objective: conduct a study of the past progress and future promise of plasma science and technology and provide recommendations to balance the objectives of the field in a sustainable and healthy manner over the long term
- **Multiple sponsors**
 - DOE: FES, HEP, NNSA, ARPA-E
 - NSF
 - DOD: AFOSR, ONR
- **Decadal Survey will be performed over 24 months**



2018 IAEA Fusion Energy Conference

- **27th IAEA Fusion Energy Conference** will be held Oct 22-27, 2018, in **Ahmedabad, India**
- The 17-member **U.S. Paper Selection Committee** met in Germantown, January 30-31, to assess and prioritize the submissions
- The **International Programme Committee** will meet **April 23-27** at the IAEA HQ in Vienna, to finalize the conference program

US Submission Trends*





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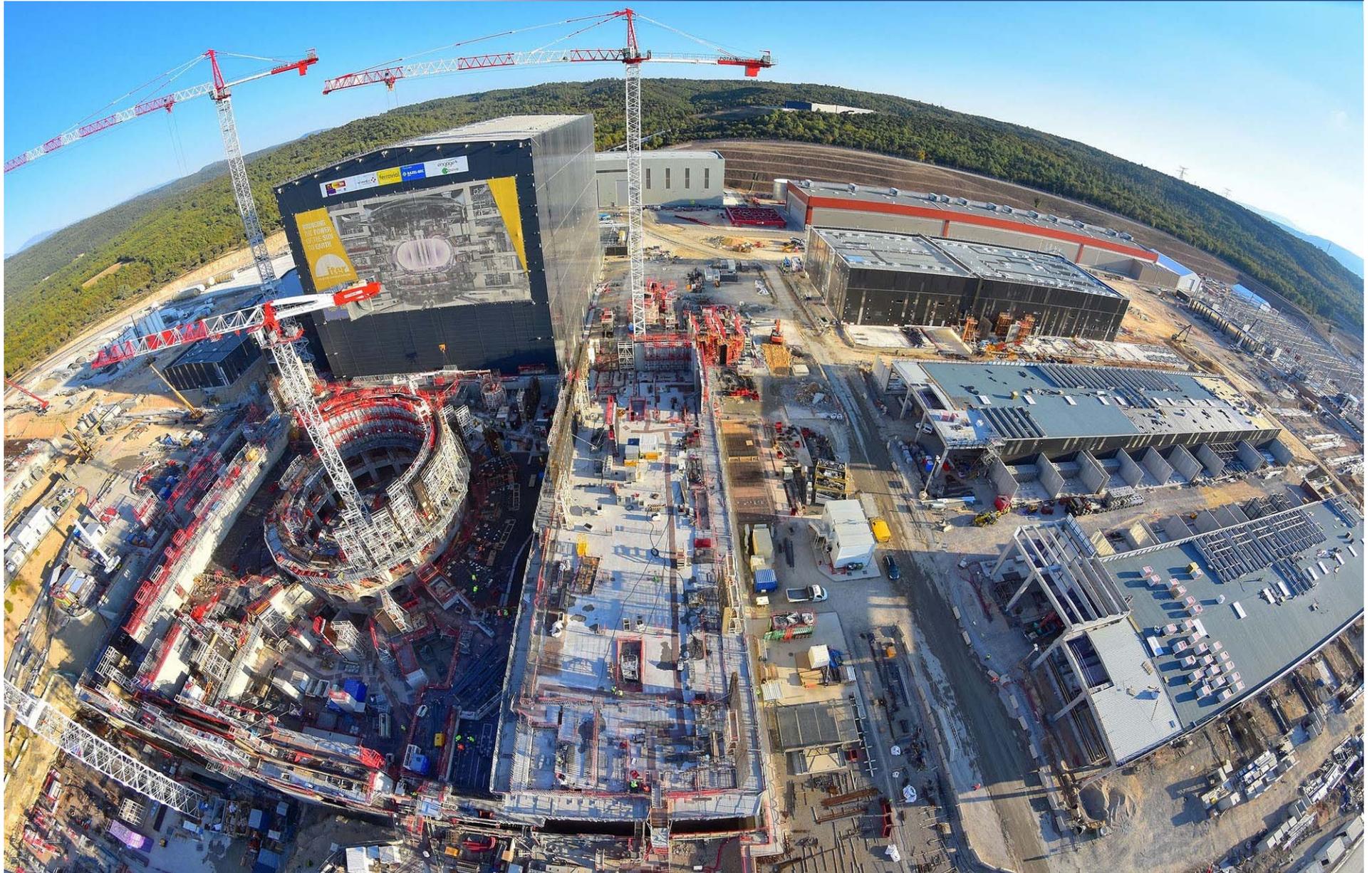
3. ITER Updates



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ITER Organization announced 50% completion to First Plasma in December 2017





Examples of U.S. hardware for ITER: First Plasma Sub-Project deliveries 30% complete



Piping fabrication in the U.S. for the Tokamak Cooling Water System at Schulz Xtruded Products in Robinsonville, MS



Central Solenoid Module 1 after completing heat treatment at General Atomics Poway, CA facility



U.S. completed Central Solenoid Assembly Structure



U.S. Toroidal Field Conductor fabrication completed and shipped to EU winding facility in 2017



U.S. completed delivery of Steady State Electrical Network to the ITER site in 2017



Fabrication of central solenoid modules is progressing



1: Conductor receiving inspection

2: Winding (2)

3: Joint & Terminals Preparation

4: Stack and Join / Helium Penetrations

5: Reaction Heat Treatment

6: Turn Insulation

7: Ground Insulation

8: Vacuum Pressure Impregnation

9: Helium Piping & Measurement

10: Final Test at 50kA, full force

Mock-Up

Module #1

Module #2

Module #3

Module #4

Module #5

Module #6

Module #7: 3/7 conductor spools received



November 2016



January 2018

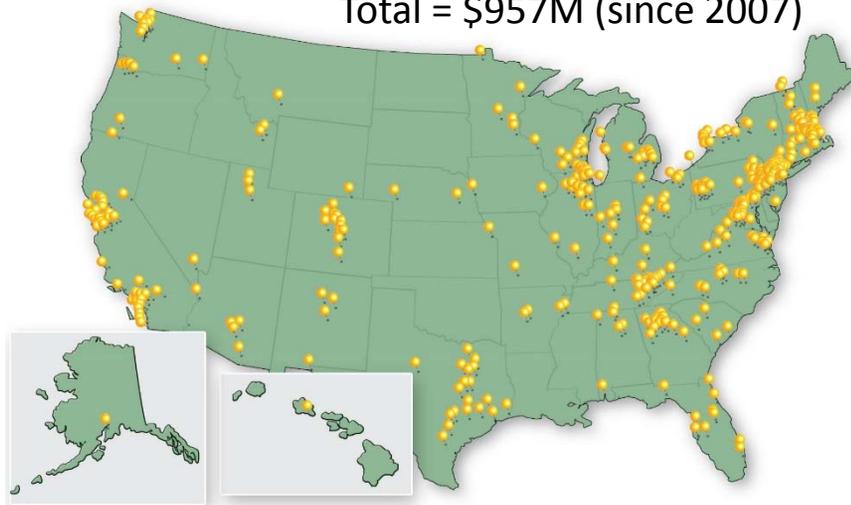


Progress of U.S. ITER project

80% of fabrication awards for U.S. ITER project remain in the U.S.

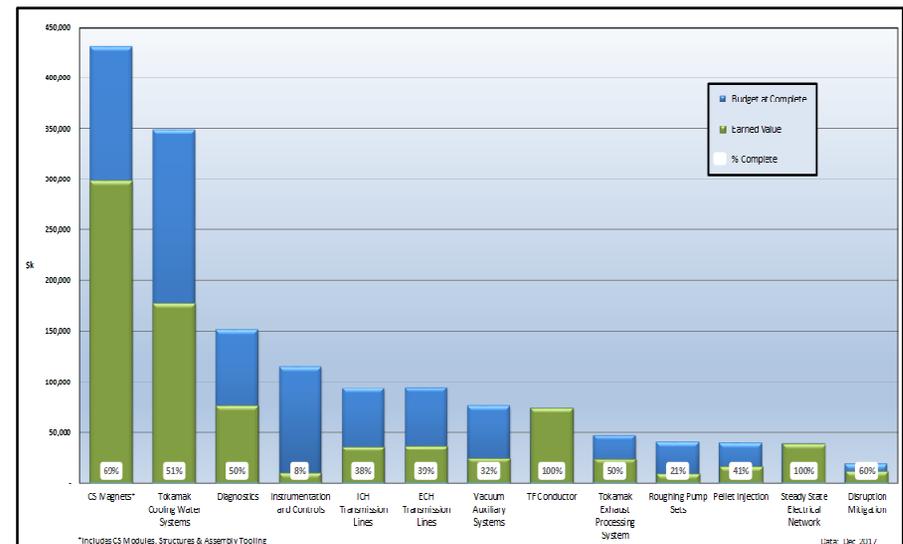
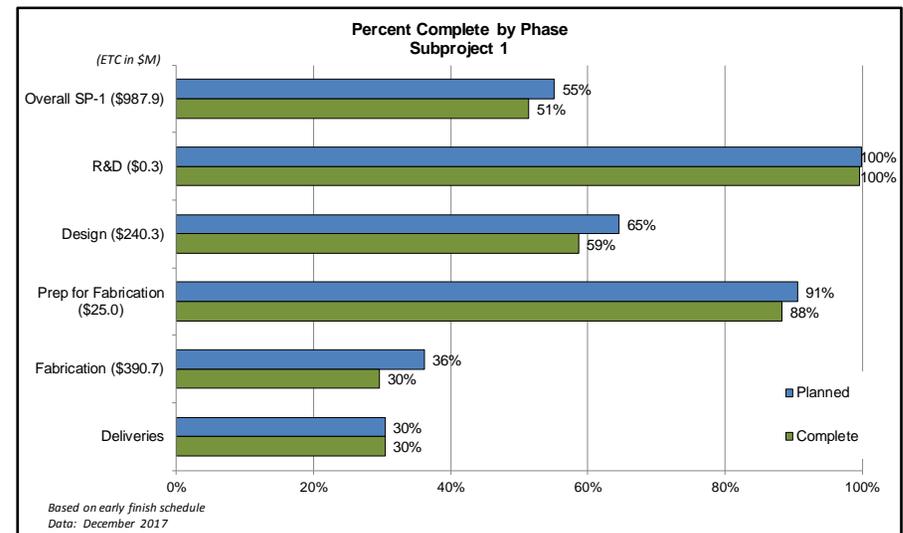
- 600+ contracts to U.S. industry, universities, and national laboratories in 44 states
- 500+ direct jobs, 1100+ indirect jobs per year

Total = \$957M (since 2007)



Data as of September 30, 2017

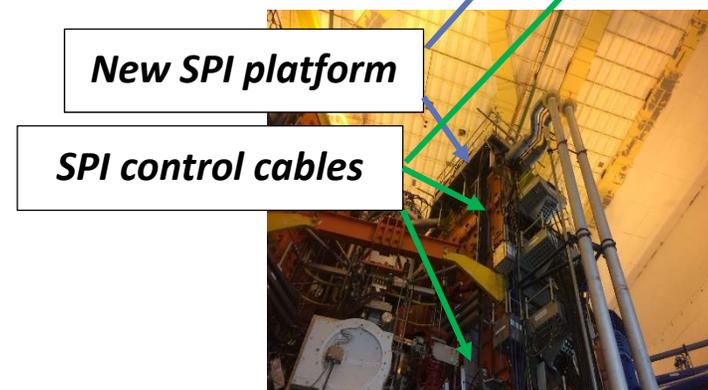
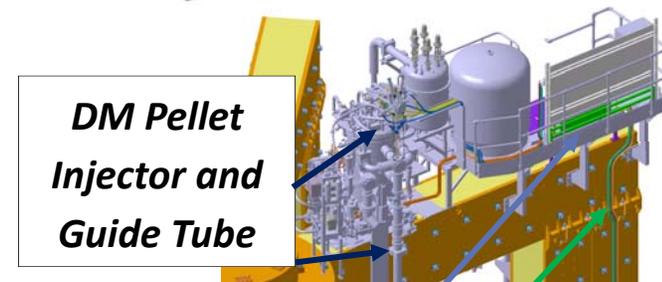
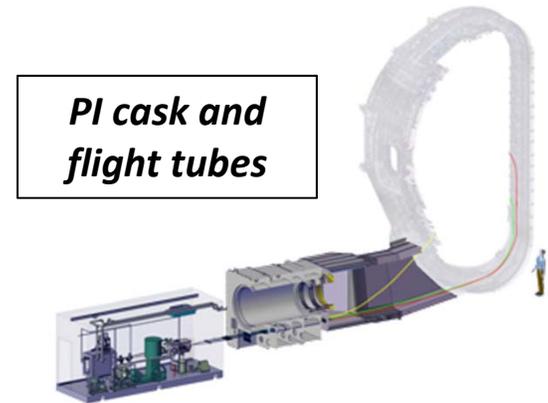
U.S. ITER Subproject-1 (First Plasma) is 50% done



Progress on pellet injection for ITER disruption mitigation

- **Pellet Injection for ITER**
 - Pellet injection is now primary disruption mitigation method for ITER
 - IO held preliminary design review of pellet injection flight tubes and cask
- **Disruption Mitigation for ITER**
 - JET SPI commissioning is on target to complete in May 2018. Disruption mitigation experiments utilizing JET-SPI are scheduled June-September 2018.
 - An ITER Disruption Mitigation Task Force was established by the ITER Organization

SPI on JET is a large collaborative effort involving JET/EUROfusion, ORNL, USIPO, ITER Org, EC, and US DOE





National Academy burning plasma interim report was issued on December 21, 2017

PREPUBLICATION COPY – SUBJECT TO FURTHER EDITORIAL CORRECTION

INTERIM REPORT OF THE COMMITTEE ON A STRATEGIC PLAN FOR U.S. BURNING PLASMA RESEARCH

Committee on a Strategic Plan for U.S. Burning Plasma Research
Board on Physics and Astronomy
Division on Engineering and Physical Sciences

A Consensus Study Report of
The National Academies of
SCIENCES • ENGINEERING • MEDICINE

THE NATIONAL ACADEMIES PRESS
Washington, DC
www.nap.edu

The interim report notes that:

- Burning plasma research is essential to the development of magnetic fusion energy
- The U.S. has contributed leading advances in burning plasma science
- ITER is the only existing project to create burning plasma at reactor scale
- The U.S. should develop a national strategic plan leading to a fusion demonstration device

Full report is expected by the end of 2018

Talk later in this meeting by M. Mauel and M. Shochet (co-leads of the NAS committee)



- **Two workshops so far:**
 - Madison, WI workshop (June 2017)
 - Austin, TX workshop (December 2017)
- **Thanks to:**
 - Organizing committee (co-leads D. Maurer, M. Wade, J. Menard)
 - Also to the plenary speakers, discussion session leaders, and summary speakers
 - All who submitted white papers and other input (extensive)
- **Discussion ongoing about further community activities**
 - H. Neilson has replaced J. Menard

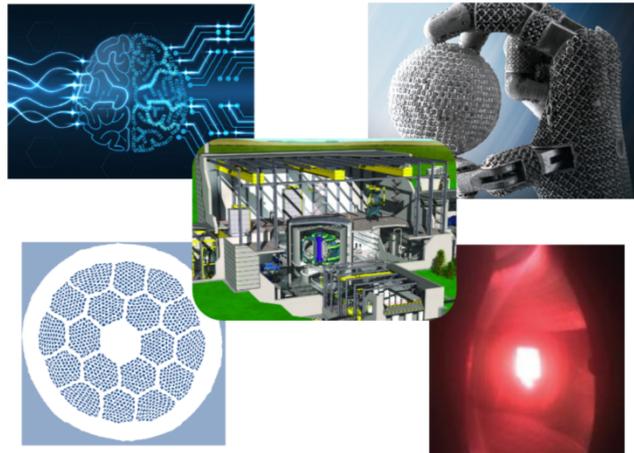
Talk later in this meeting by M. Wade



FESAC subcommittee on Transformative Enabling Capabilities toward Fusion Energy

FUSION ENERGY SCIENCES ADVISORY COMMITTEE REPORT

Transformative Enabling Capabilities for
Efficient Advance Toward Fusion Energy



Feb. 2018

- Report to be received and discussed by FESAC at this meeting
- Much appreciation to all the members of the subcommittee (and to the co-chairs: Rajesh Maingi and Arnie Lumsdaine)

Talk later in this meeting by
R. Maingi and A. Lumsdaine



Committee of Visitors charge to FESAC

- **Every program element of SC is to be reviewed by a COV at least once every three years**
 - https://science.energy.gov/~media/sc-2/pdf/presentations/guidance_for_doe_sc_cov_reviews_v1.pdf
- **CHARGE: The panel should evaluate:**
 - The efficiency and quality of the processes used by FES to solicit, review, recommend, monitor, and document awards and declinations for universities, national laboratories, and industry
 - The breadth, depth, and quality of the resulting program portfolio, and the program's national and international standing
 - FES's management of its portfolio of line item construction and Major Items of Equipment projects, including the U.S. Contributions to ITER project
- **The evaluation should:**
 - Review FES program for FYs 2014-2017
 - Also comment on FES's progress in addressing action items from the previous COV review.
 - Focus on high-level, major recommendations (and not too many!)



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4. People



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DOE leadership updates

Mr. **Dan Brouillette** was sworn in as the Deputy Secretary of the U.S. Department of Energy on August 7, 2017



Mr. **Paul Dabbar** was sworn in as Undersecretary for Science on November 7, 2017

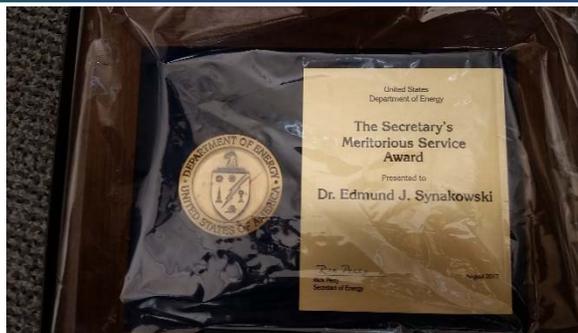
Dr. **J. Stephen Binkley** continues as the Deputy Director for Science Programs, Office of Science





FES personnel changes

- **Ed Synakowski**, FES Associate Director since 2009, left federal service in August 2017 to join the University of Wyoming as the VP for Research & Economic Development
- **Jim Van Dam** is the Acting Associate Director for FES
- **John Mandrekas** is the Acting FES Research Division Director



Other transitions:



Sean Finnegan left FES to join NNSA



Long-time FES program managers Steve Eckstrand, Al Opdenaker, and Francis Thio retired





2017 Early Career Research Awards



Dr. Jason Trelewicz
Stony Brook Univ.
Plasma-facing materials
applications



Dr. Julia Mikhailova
Princeton University
Attosecond light-field control
of high-density plasmas



Dr. Juan Trelles
U. Massachusetts-Lowell
Plasmas in contact with liquids



Dr. David Green (ORNL)
Simulation of magnetically
confined fusion plasmas



Dr. Frederico Fiuza (SLAC)
Particle acceleration in
HED plasmas



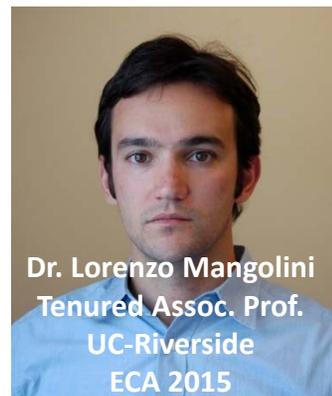
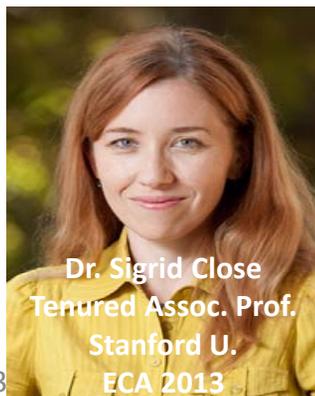
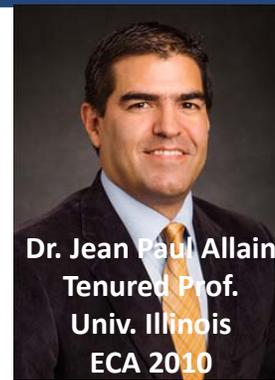
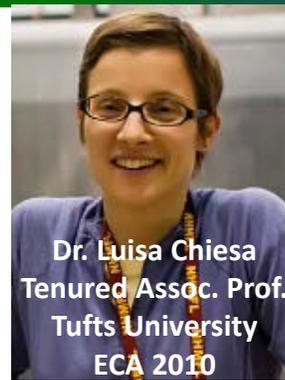
Dr. Adam Sefkow (U. Rochester)
Hybrid fluid-kinetic modeling
efforts for HEDP and ICF Science



U.S. DEPARTMENT OF
ENERGY

Office of Science

Among 23 university Early Career awardees, so far 12 who were up for tenure have achieved it





U.S. DEPARTMENT OF **ENERGY**

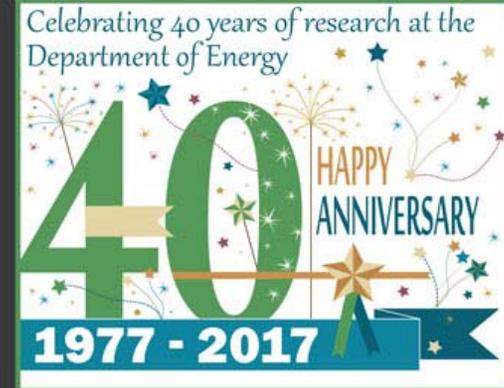
Office of Science

DOE celebrated its 40th anniversary

DOE 40th Anniversary

THE OFFICE OF SCIENCE PRESENTS: Research milestones over the past 40 years

1977 - 2017



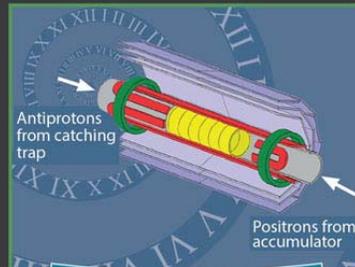
THE OFFICE OF SCIENCE PRESENTS:
RESEARCH MILESTONES OVER THE PAST
FORTY YEARS



DOE 40th Anniversary

Office of Science • **1978**
RESEARCH MILESTONE •

N.J. Fisch, PRL 41(13), 873 (1978)
Confining a tokamak plasma with rf-driven currents



DOE 40th Anniversary

Office of Science • **2010**
RESEARCH MILESTONE •

G.B. Andresen et al., *Nature* 468, 673 (2010)
Trapped antihydrogen



DOE 40th Anniversary

Office of Science • **1990**
RESEARCH MILESTONE •

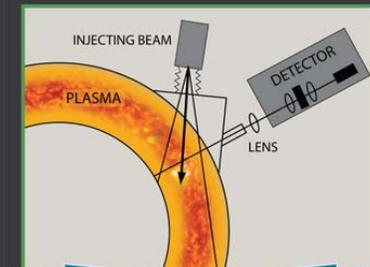
R.J. Groebner et al., PRL 64, 3015 (1990)
Role of edge electric field and poloidal rotation in the L-H transition



DOE 40th Anniversary

Office of Science • **1994**
RESEARCH MILESTONE •

J.D. Strachan et al., PRL 72, 3526 (1994)
Fusion power production from TFTR plasmas fueled with deuterium and tritium



DOE 40th Anniversary

Office of Science • **1989**
RESEARCH MILESTONE •

F.M. Levinton et al., PRL 63, 2060 (1989)
Magnetic field pitch-angle measurements in the PBX-M tokamak using the motional Stark effect



Please send scientific highlights to us

- SC home page has:
 - Science Highlights (carousel)
 - Featured Articles
 - Science Headlines
 - University Research
- SC Science Highlights are linked to the FES Highlights webpage

The screenshot shows the U.S. Department of Energy Office of Science website. At the top, there is a navigation bar with tabs for Programs, Laboratories, User Facilities, Universities, Funding Opportunities, News, and About. Below this is a search bar and a 'GO' button. The main content area is titled 'Science Highlights' and features a carousel of news items. Each item includes a date, a title, a brief description, and a 'Read More' link. The items shown are:

- 01.16.18 | SCIENCE HIGHLIGHT: **Superconducting Tokamaks Are Standing Tall**. Plasma physicists significantly improve the vertical stability of a Korean fusion device.
- 12.19.17 | SCIENCE HIGHLIGHT: **Microwaves Can Plug Leaks in Fusion Plasmas**. Microwave heating significantly alters Alfvén waves, offering insights into the physics of the waves themselves.
- 12.19.17 | SCIENCE HIGHLIGHT: **Currents Always Find the Fastest Detour**. Scientists map electrical currents emanating from the boundary of a tokamak plasma, providing new information for reactor design.
- 12.19.17 | SCIENCE HIGHLIGHT: **New Physics Understanding Provides Attractive Path for Developing Fusion Energy via a Steady-State Tokamak**. International collaborators advance physics basis for tokamak plasma confinement at low rotation, potentially benefiting a fusion reactor.

 On the left side of the page, there is a sidebar with links to News Home, Featured Articles, Science Headlines, Science Highlights (highlighted), Presentations & Testimony, News Archives, and Communications and Public Affairs. At the bottom left, there is a 'CONTACT INFORMATION' box for the Office of Science.

Thanks to G. Navratil for his talk earlier in this meeting