

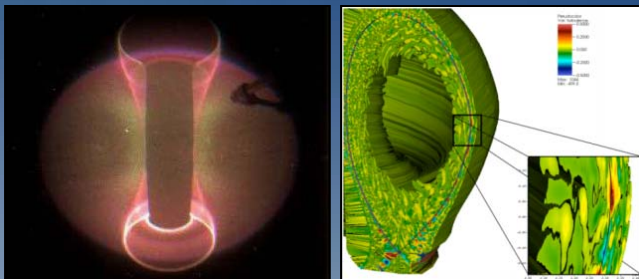


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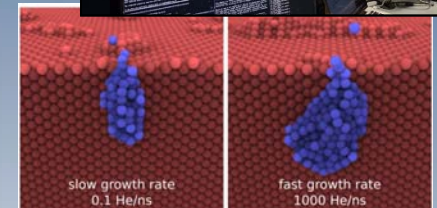
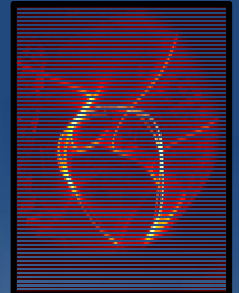
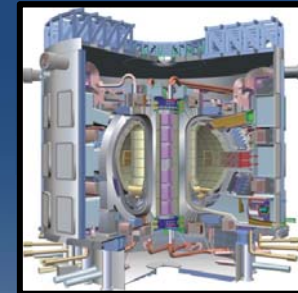
*Establishing the scientific basis for fusion energy  
and for understanding the plasma universe*

# FUSION ENERGY SCIENCES: Updates and issues, and opportunities for FESAC



**E. J. Synakowski**  
Fusion Energy Sciences  
Associate Director  
Office of Science  
U.S. Department of Energy

**Fusion Energy Sciences Advisory  
Committee  
February 1, 2017**





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## Outgoing FESAC members: Thank you



**Amitava Bhattacharjee**



**Jin-Soo Kim**



**Mark Koepke**



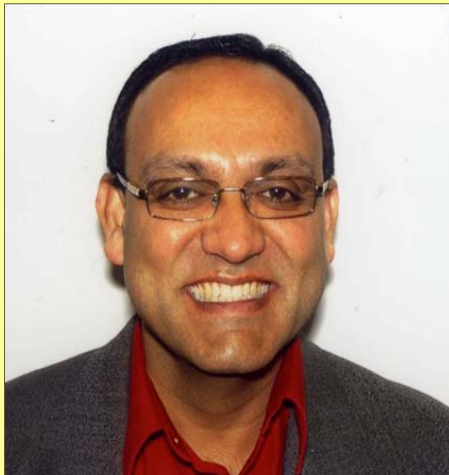
**Ellen Zweibel**

Retiring Member	Institution	On FESAC Since
Amitava Bhattacharjee	Princeton Plasma Physics Laboratory	June 2013
Jin-Soo Kim	FAR-TECH, Inc.	June 2013
Mark Koepke	West Virginia University	June 2013
Ellen Zweibel	University of Wisconsin	June 2013

***Sincere thanks to all of them for their service***



# New FESAC members as of December 2016



**Rajesh Maingi (PPPL)**



**Thomas Sunn Pedersen (IPP Greifswald)**



**Susana Reyes (LBNL)**



**Amy Wendt (Wisconsin)**

## **New FESAC chair**

- Don Rej (LANL)

## **New FESAC deputy chair**

- Steve Knowlton (Auburn, emeritus)

## **Three *ex officio* members**

- Earl Scime (Chair of APS-DPP)
- Arnold Lumsdaine (Chair of ANS-FED)
- John Verboncoeur (Immediate Past President of IEEE-Nuclear and Plasma Science Society)



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## FY 2017 appropriations: we are currently in a Continuing Resolution

- Presently through April 28
- Ultimately full year? We don't know
- FES is allocating resources as they are made available to us, at about the FY 2017 Congressional Request level
- ITER has been allocated \$50M thus far and requires additional resources if it is to stay on track with the recently baselined plan



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## Formulating the FY 2018 budget benefited from FES Budget Planning Meetings in FY 2016

- FES hosted 19 individual meetings with university, lab, and industry research groups, as well as other community research coordination groups (USBPO, National Stellarator Coordinating Committee, Theory Coordinating Committee)
- Feedback received concerning this new style of budget planning meetings has been quite positive
- This year, we are planning the same kind of approach
- Schedule for release of the FY 2018 budget has not yet been established





## Progress Continues at the ITER Site and at Manufacturers around the World

- The pace of construction has accelerated.
- Design is largely completed, and fabrication of components is well under way, with on-site deliveries that began in 2015.
- The ITER Council approved the new project baseline schedule through First Plasma (2025) at its meeting in November 2016.
- Full D-T operations should begin in 2035..
- DG Bernard Bigot, appointed in March 2015, has:
  - reformed the organizational management,
  - brought on a construction manager.
- The project is now being managed with a full understanding of the importance of project risk management and of keeping to cost and schedule.







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# ITER's progress has been impressive



February 2015



October 2016

*Many thanks to DG Bigot for his sharing the latest on the ITER story with you today*



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# U.S. ITER Participation: From the Secretary's Report to Congress (May 2016)

Department of Energy | May 2016

Report on the U.S. Participation in the ITER Project

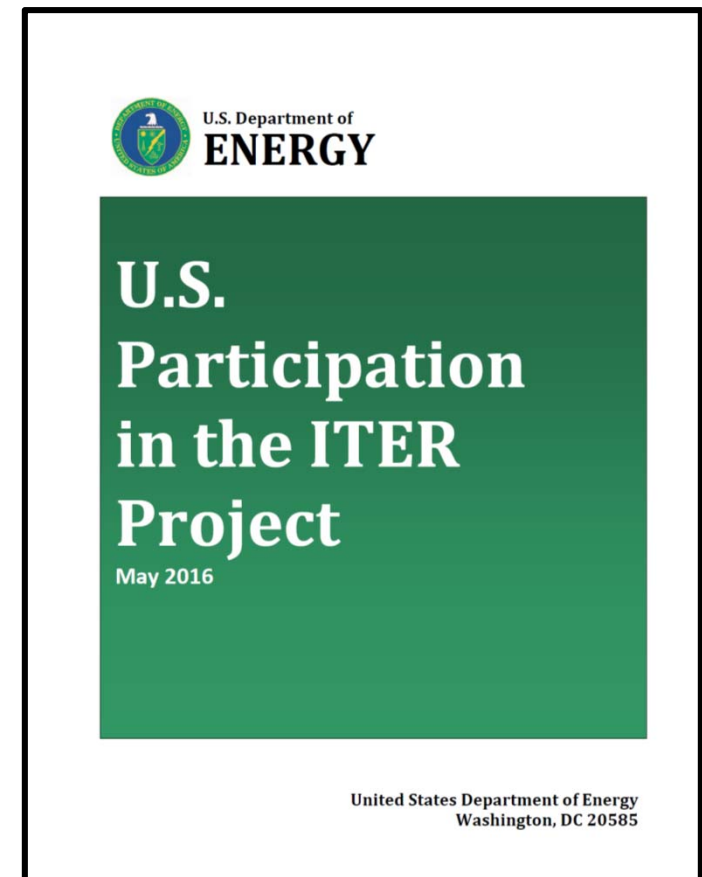
## Message from the Secretary

**ITER remains the best candidate today to demonstrate sustained burning plasma, which is a necessary precursor to demonstrating fusion energy power.** Having fully assessed the facts regarding the U.S. contributions to the ITER project, **I recommend that the U.S. remain a partner in the ITER project through FY 2018** and focus on efforts related to First Plasma. The U.S. along with all ITER Members across the world have witnessed and acknowledged the significant progress made at ITER by the new leadership, but there is still much that remains to be done. **Prior to the FY 2019 budget submittal (late in calendar year 2017 to early 2018), I recommend that the U.S. re-evaluate its participation** in the ITER project to assess if it remains in our best interests to continue our participation. My recommendation to support First Plasma cash and in-kind contributions is predicated on continued and sustained progress on the project, increased transparency of the ITER project risk management process, as well as a suite of management reforms proposed in this report that we expect will be agreed upon by the ITER Council. **At this time, our continued participation in the fashion recommended is consistent with DOE's science mission and is in the best interest of the nation.** The report discusses the critical issues that factored in this recommendation. [**bold** added for emphasis here]

Sincerely,

Ernest J. Moniz

[http://science.energy.gov/~media/fes/pdf/DOE\\_US\\_Participation\\_in\\_the\\_ITER\\_Project\\_May\\_2016\\_Final.pdf](http://science.energy.gov/~media/fes/pdf/DOE_US_Participation_in_the_ITER_Project_May_2016_Final.pdf)







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## US ITER Project has achieved a major milestone, as directed in the Secretary's report

- In response to the Secretary's memo to Congress in May, the U.S. Contributions to ITER First Plasma subproject was approved by the DOE Deputy Secretary on January 13, 2017, for several Critical Decisions (CDs):
  - Revised CD-1: alternative selection and cost range
  - CD-2: performance baseline
  - CD-3: start of construction
- The U.S. ITER Project had previously achieved CD-1 in January 2008 with a cost range of \$1.45-2.2B
  - Based on further independent project reviews, the cost range was revised in December 2016 to \$4.7-6.5B.



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The Secretary's report to Congress also states that DOE will seek an NAS study

***From the body of the report:***

- The DOE will request that the National Academies perform a study of how to best advance the fusion energy sciences in the U.S., given the developments in the field since the last Academy studies in 2004, the specific international investments in fusion science and technology, and the priorities for the next ten years developed by the community and FES that were recently reported to Congress.
- This study will address the scientific justification and needs for strengthening the foundations for realizing fusion energy given a potential choice of U.S. participation or not in the ITER project, and will develop future scenarios in either case.



## STATEMENT OF TASK

**“Specifically, the committee will prepare an interim report that will:**

1. Describe and assess the current status of U.S. research that supports burning plasma science, including current and planned participation in international activities, and describe international research activities broadly.
2. Assess the importance of U.S. burning plasma research to the development of fusion energy as well as to plasma science and other science and engineering disciplines.

**“The committee will also prepare a final report, building on the interim report, which will:**

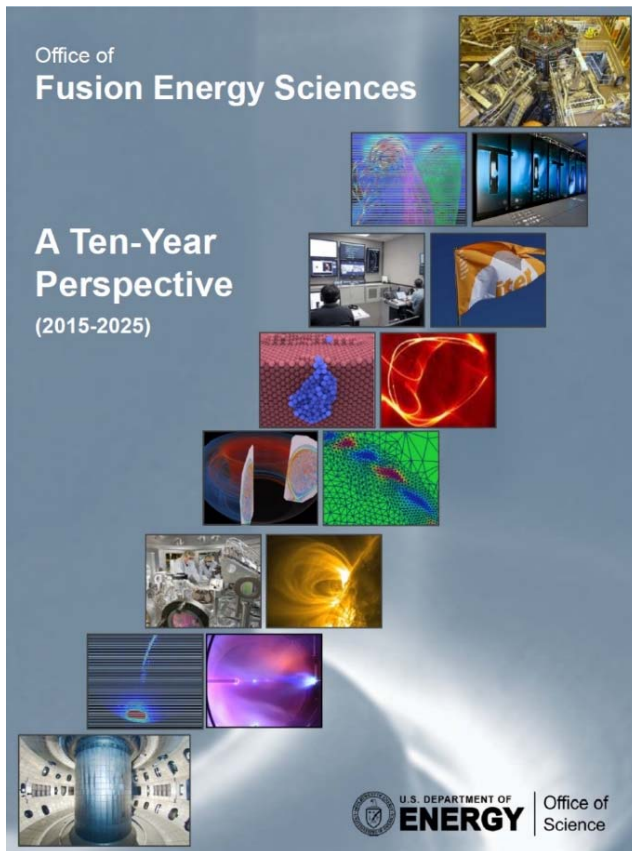
1. Consider the scientific and engineering challenges and opportunities associated with advancing magnetic confinement fusion as an energy source, including the scientific and technical developments since the 2004 NAS study on burning plasma research.
2. In two separate scenarios in which, after 2018, (1) the United States is a partner in ITER, and (2) the United States is not a partner in ITER: provide guidance on a long-term strategic plan for a national program of burning plasma science and technology research which includes supporting capabilities and which may include participation in international activities, given the U.S. strategic interest in realizing economical fusion energy in the long term.”





# The NAS study will use as input the Ten Year perspective submitted to Congress in 2015

- **Several critically important areas for the U.S. fusion energy sciences enterprise over the next decade**
  - **Massively parallel computing** with the goal of validated whole-fusion-device modeling
  - **Materials science** for greatly improved plasma confinement and heat exhaust
  - **Transient events**, predicted and controlled, for confidence in machine designs and operation with stable plasmas
  - **Discovery in plasma science** to address frontier science issues of the visible universe and help attract a new generation of plasma/fusion scientists
  - **FES user facilities** kept world-leading through operations support and regular upgrades
  - **Leveraging resources** among agencies and institutions and strengthening partnerships with international research facilities





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## The Office of Science has issued a charge to you regarding the potential of enabling science and technology breakthroughs

- “...It is necessary that the US program be in the best position possible to lever the science and technology that will be advanced through burning plasma research on ITER. It will be important that we are involved in pursuits that give us the best chance of enabling the knowledge gained through ITER research to be effectively levered towards attractive fusion energy.
- “I am asking FESAC to identify the most promising transformative enabling capabilities for the U.S. to pursue that could promote efficient advance towards fusion energy, building on burning plasma science and technology. Your considerations should be broad, addressing advances that may occur in areas of engineering, technology, and science. Examples of focus areas could include liquid metals, additive manufacturing, high critical-temperature superconductors, exascale computing, materials by design, machine learning and artificial intelligence, and novel measurements. Please comment on the promise, level of maturity, development requirements, risks and uncertainties, and time horizon for each. Please consider global strengths and gaps in identifying areas of particular opportunity for the U.S.
- “We particularly seek examination of developments that can bring the tokamak and stellarator concepts closer to producing fusion power practically. Identification of R&D that may have general impact that both includes and extends beyond these concepts is welcome, but an assessment of various types of magnetic confinement devices is not to be performed...”

*This output of this study can serve as input into the NAS burning plasma study*



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## Schedule for the upcoming Plasma Science Decadal Study

- Anticipate launching towards the end of 2017, after the NAS Burning Plasma Study is underway
- We are in discussion with the NAS and the other agencies that may support this study about how and when to best proceed

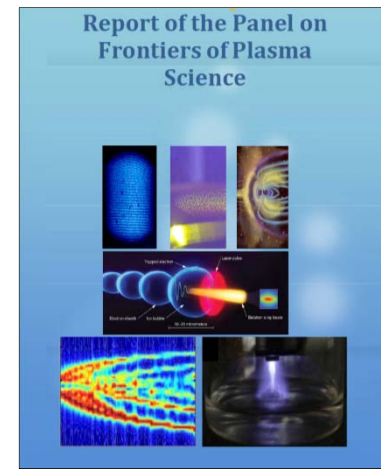
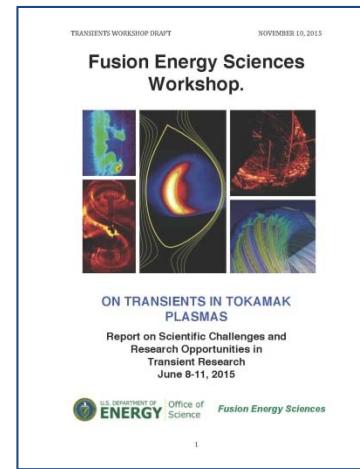
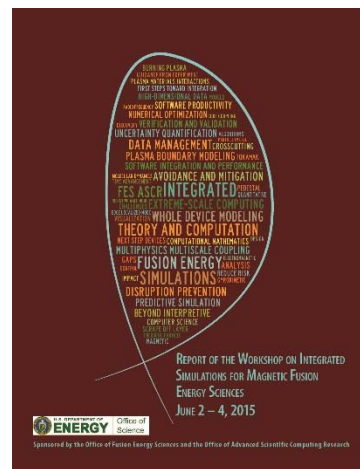
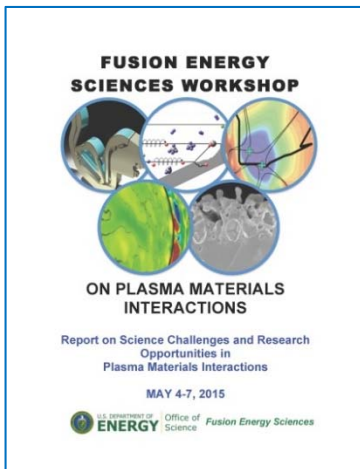




# Reports from Community Engagement Workshops influenced activities initiated by FES

- In 2015, FES sought community input about scientific challenges and opportunities through a series of technical workshops on priority research areas.
- The final reports are available from the FES website (<http://science.energy.gov/fes/community-resources/workshop-reports/>) and the USBPO site (<https://www.burningplasma.org>)

Workshop	Date	Location	Chair / Co-Chair
Workshop on Plasma-Materials Interactions	May 4-7, 2015	PPPL	Rajesh Maingi (PPPL) / Steve Zinkle (Tennessee)
Workshop on Integrated Simulations for Magnetic Fusion Energy Sciences	June 2-4, 2015	Rockville, MD	Paul Bonoli (MIT) / Lois McInnes (ANL)
Workshop on Transients	June 8-12, 2015	General Atomics	Charles Greenfield (GA) / Raffi Nazikian (PPPL)
Workshops on Plasma Science Frontiers (two)	August 20-21 & Oct. 22-23, 2015	Washington, DC area	Fred Skiff (Iowa) / Jonathan Wurtele (UC Berkeley)





## Theory and Simulation: Response to Community Workshops

- **SCREAM Center:** A national team, co-led by Princeton University and LANL, was jointly funded by FES and ASCR for two years under the SciDAC program to carry out computational research on runaway electrons during disruptions in tokamak plasmas
  - Addresses several priority research directions from the *Integrated Simulations* and *Transients* community workshops
- **SciDAC-4 solicitation:** A joint FES-ASCR Funding Opportunity Announcement and a companion Lab Announcement were issued for the re-competition of the FES SciDAC portfolio
  - The solicitation has been structured to focus on the leading PRDs from the three MFE community workshops
- **New theory grants,** enabled by the additional funds provided by Congress in FY 2016, were selected emphasizing their relevance to the PRDs of the three MFE workshops



### **Simulation Center for Runaway Electron Avoidance & Mitigation (SCREAM)**

*D. Brennan, Oct 2016*

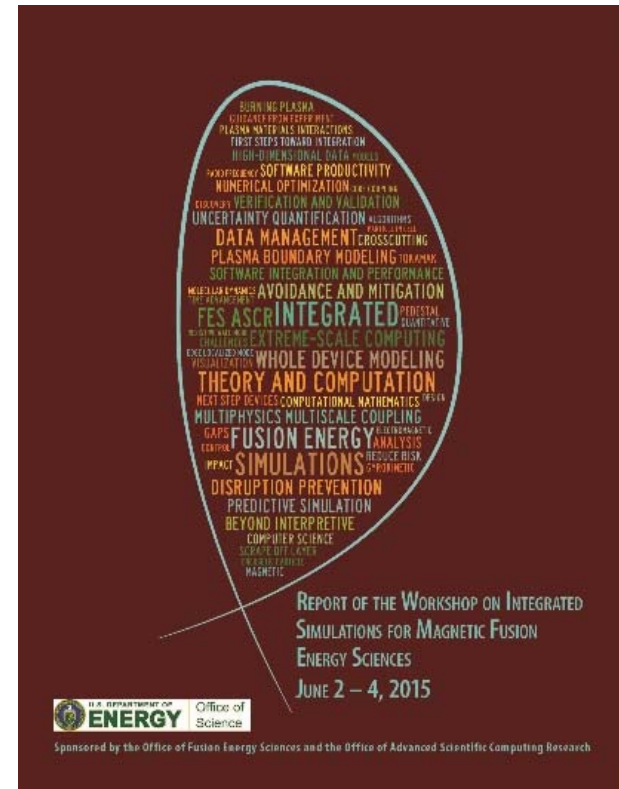


**SciDAC**

Scientific Discovery through Advanced Computing



- The FES Scientific Discovery through Advanced Computing (SciDAC) portfolio is under review as part of the SC-wide SciDAC-4 re-competition
- A joint FES / ASCR Funding Opportunity Announcement and a companion LAB Announcement entitled “*Integrated Simulation Partnerships in Fusion Energy Sciences*” were issued on November 16, 2016
- The focus is on integrated simulations and Whole Device Modeling (WDM), following the recommendations from the 2015 FES / ASCR community workshop
  - *also addresses priorities identified in the Transients and PMI workshops*
- Preproposals have already been received and full proposals are due on February 21, 2017
- Selection of the new FES / ASCR SciDAC partnerships is expected by mid-2017



[Report of the 2015 workshop on Integrated Simulations for Magnetic Fusion Energy Sciences](#)





## FES Exascale Requirements Review Meeting (January 2016):

- Part of a series of exascale requirements reviews for each of the SC program offices
- Scope: Identify forefront scientific challenges and opportunities in fusion energy and plasma sciences whose resolution is essential to meeting the FES mission and could be aided by exascale computing over the next decade

## Exascale Computing Project (ECP)

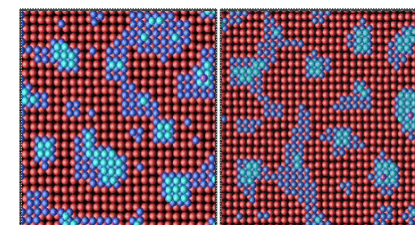
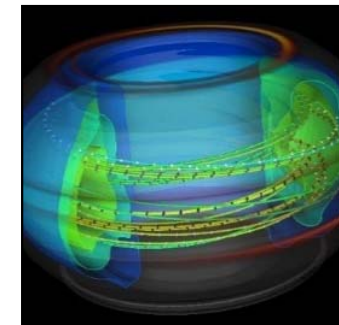


- Component of the DOE Exascale Program, set up as an SC/NNSA partnership
- Follows a co-design approach to achieve capable exascale computing systems
- Two projects with fusion relevance are among the ECP application development awards selected in 2016:
  - **High-Fidelity Whole Device Modeling of Magnetically Confined Fusion Plasma**, PI: Amitava Bhattacharjee (PPPL) with ANL, ORNL, LLNL, Rutgers, UCLA, & University of Colorado
  - **Molecular Dynamics at the Exascale: Spanning the Accuracy, Length and Time Scales for Critical Problems in Materials Science**, PI: Arthur Voter (LANL) with SNL & UTK – *addresses needs of BES, FES, and NE*

[www.ExascaleProject.org](http://www.ExascaleProject.org)



Workshop report will be available soon





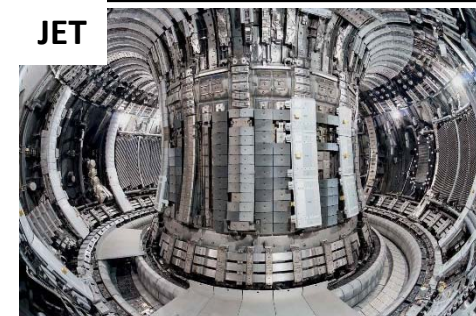
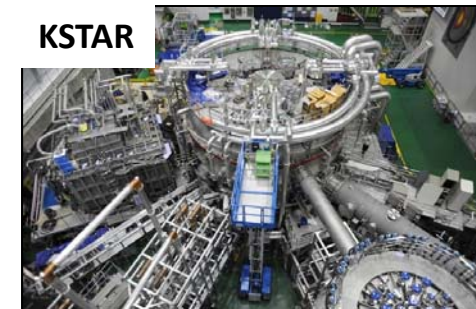
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## International Collaborative Research: Response to Community Workshops

Multi-institutional teams are a central component of FES research activities. In the FY 2016 Long Pulse Tokamak re-competition, two new efforts were approved and one was renewed, with workshop PRDs taken into account.

Project	U.S. Partner Institutions
Control and Extension of High Performance Scenarios to Long Pulse (renewal)	GA (lead), Lehigh Univ, LLNL, MIT, ORNL, PPPL, UCLA, & Univ Texas
Control of the Plasma Material Interface for Long Pulse Optimization in EAST	PPPL (lead), JHU, LANL, MIT, ORNL, UT-K, & UIUC
Disruption Prediction and Avoidance in High Beta Long Pulse KSTAR Plasmas	Columbia (lead), MIT, PPPL



Also, a collaborative effort was initiated to build, install, and operate a shattered pellet injector on JET to test disruption mitigation for ITER. Partners are ORNL, USIPO, USDOE, JET/EUROfusion, European Comm., & ITER Org.

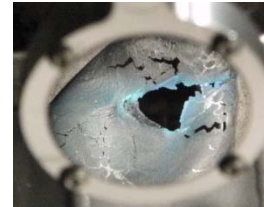


# PMI Research and Technology: Response to Community Workshops

- **PMI on DIII-D:**
  - High-Z metal ring campaign and upper divertor modification were accelerated
  - New PMI collaboration grants were awarded
- **Lithium Tokamak Experiment:** neutral beam heating/fueling upgrade to explore confinement improvements due to low recycling liquid Li walls
- **Facility and infrastructure upgrades** at national laboratories in support of the PMI mission

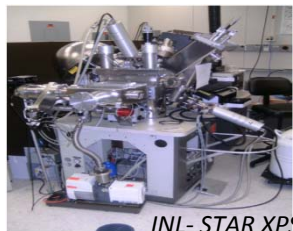
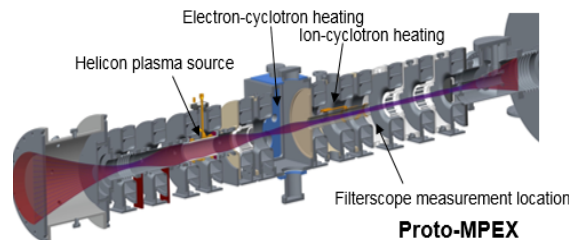
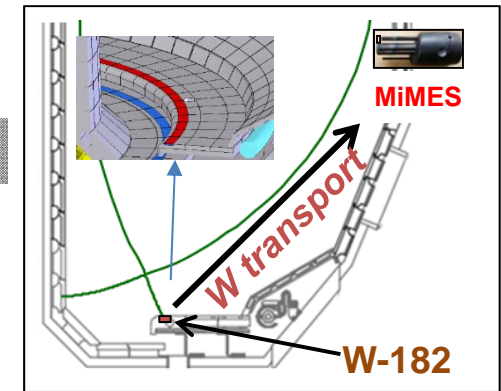


Reshaped upper divertor tiles – SAS divertor to increase closure



LTX – molten lithium pool

## Metal Ring Campaign on DIII-D



INL- STAR XPS



SRNL-  
Electrochemistry  
in Extreme  
Environments  
Characterization  
Facilities

- **Plasma-facing materials experiments:** enhanced and new research efforts, including an Early Career Award
- **Direct processing of tritium from liquid lithium:** new demonstration initiative in support of liquid metal plasma-facing components
- **Systems Studies Group:** New system-level study of liquid metal plasma-facing components

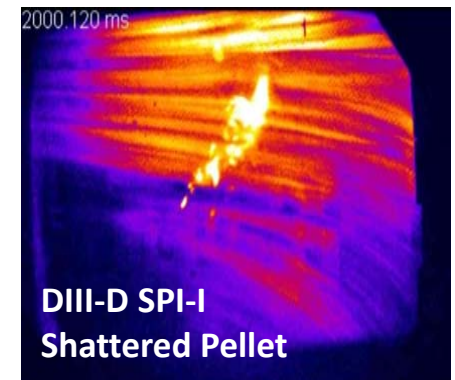




# Transients Research and Technology: Response to Community Workshops

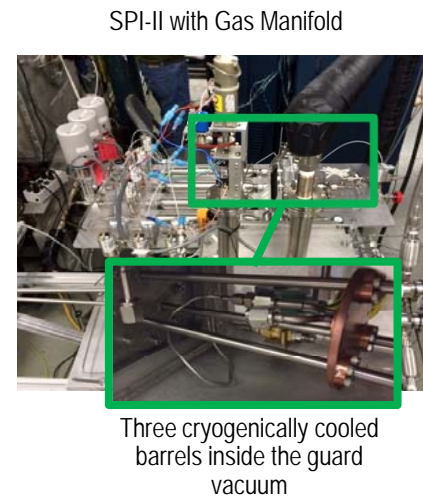
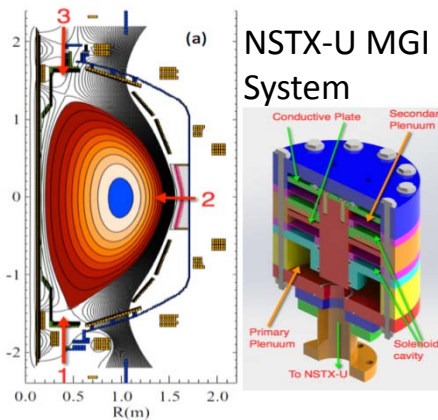
- **Increased priority to validate ITER disruption mitigation systems:**

- Coordinated closely with the JET program and supported the engineering and hardware fabrication required to manufacture a shattered pellet injector for JET.
- New ITER 3-barrel prototype shattered pellet injector (SPI-II) manufactured and tested – currently installed on DIII-D to conduct research on the effects of two injectors.

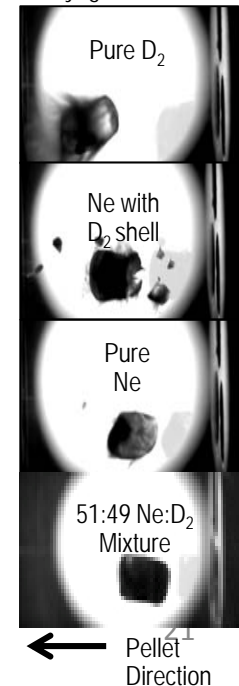


- **Enhanced research effort on real-time control techniques** including a new NSTX-U collaboration grant and an Early Career Award.
- **New international collaboration team** chosen for research on “*Disruption Prediction and Avoidance in High Beta Long Pulse KSTAR Plasmas*”

- **A three-valve massive gas injection (MGI) system** that uses a new double solenoid design based on the ORNL MGI design for ITER was built, installed, and tested on NSTX-U and is ready to support experiments



SPI-II 7 mm Diameter Cryogenic Pellets





# Frontiers of Plasma Science: Response to Community Workshops

The scientific opportunities and grand challenge questions articulated in the workshop report have played an active role in funding decisions for all three sub-programs (GPS, HEDLP, and EMP) for:

- 2016 NSF/DOE Partnership in Basic Plasma Science and Engineering applications
- 2016 SC-Early Career Award Applications

Additionally, input from the workshop report (in conjunction with other reports such as the 2010 Plasma Decadal Survey) informed the composition of two recent funding solicitations:

- FY 2017 Opportunities in Basic Plasma Science (LAB 16-1592); issued in FY 2016
- FY 2018 Plasma Science Facilities (DE-FOA-0001713; LAB 17-1713); issued January 19, 2017

**Frontiers of Plasma Science Workshops**

Sponsored by the U.S. Department of Energy  
Office of Fusion Energy Sciences  
Town Hall Meeting: June 30 - July 1, 2015  
Scientific Frontiers Workshop: August 20-21, 2015 [Panel Attendance Only]  
Research Needs Workshop: October 22-23, 2015 [Panel Attendance Only]

Home Background Organization White Papers Meeting Agendas Contacts Preliminary Draft FAQ Virtual Town Halls

The U.S. Department of Energy, Office of Science, Fusion Energy Sciences is sponsoring a series of community-led workshops to identify compelling scientific challenges at the frontiers of plasma physics, and research tools and capabilities that exist presently, as well as the general requirements necessary to address these challenges in the next decade.

Meeting Chairs:  
Prof. Fred Skiff (University of Iowa)  
Prof. Jonathan Wurtele (University of California, Berkeley)

The first event is a two-day community town hall meeting to be held in the Washington DC area – scheduled for June 30 and July 1, 2015. The goal of this activity is to provide a forum for the open discussion of known and emerging research opportunities and capabilities for discovery at the frontiers of plasma science.

In preparation for the town hall meeting the workshops chairs are requesting white papers on key research opportunities for discovery at the frontiers of plasma science covering the full scope of plasma physics.

The white papers, together with the town hall presentations, will form the community input that is used and discussed during two follow-on workshops. The first (to be held in August) will focus on compelling scientific challenges at the frontiers of plasma physics, while the second (to be held in October) will focus on Research tools and capabilities that exist presently, as well as the general requirements necessary to address these challenges in the next decade.

The report generated from these workshops will inform FES in planning and executing its strategic vision for the FES stewardship of the Plasma Science Frontiers activities.

Fundamental plasma physics has never had the benefit of a research needs workshop and we believe that the community of researchers would greatly benefit from a survey of the current state of the art, as well as from formulating a cohesive vision of the future horizons we can aim towards.

Our goal is that the Plasma Science Frontiers report will be of benefit to both the community and all funding agencies interested in plasma science, not just the Department of Energy. Furthermore, our report will serve as a starting point for the next NRC decadal survey of plasma science (Plasma 2020). We are taking pains to make sure that the process is as open and transparent as we can make it. If you have any questions or suggestions please feel free contact either of us. We look forward to broad participation in this process – to the benefit of the whole plasma science community.



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## New solicitation regarding intermediate scale facilities for discovery plasma science

- This solicitation was developed taking into account considerations expressed by the research community regarding the need for investment in this class of facilities
  - It is consistent with one of the recommendations in the report from the 2015 Plasma Science Frontiers Workshop: “There is a need for the creation and exploration of new regimes in the laboratory” (chapter 4)
  - It is also consistent with a recommendation in the 2010 Plasma Decadal Survey: “Several areas of basic plasma science would benefit from new intermediate-scale facilities.”
- The solicitation consists of a non-lab Funding Opportunity Announcement and also a Lab Call
- Proposals are sought for basic science facility research operation, enhancements, or construction requiring <\$25M over five years





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## Dialogue with University Fusion Association

- We are aware of concerns expressed through the UFA regarding on-campus research enterprises and the development of faculty.
- The outlook of university departments reported at the past UFA meeting, and recently to FES directly, is important to understand.
- DOE data indicates total university funding has not declined. However, we look forward to working with the university community to reconcile the understanding of funding levels, and other factors that may be fundamental to the concerns.





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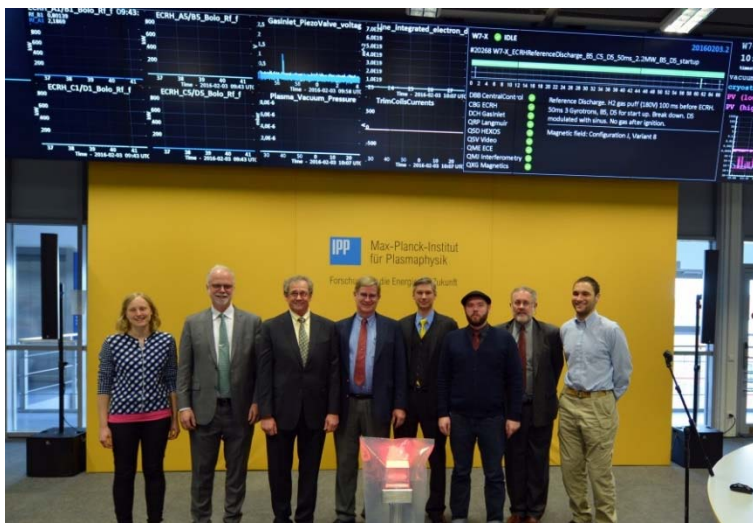
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## Recent progress in remote participation capabilities for overseas partnerships

Research conducted onsite and via fully remote research participation and facility operation leverages progress made in domestic devices and enables U.S. scientists to gain the knowledge needed to operate long-duration plasma discharges in ITER and future fusion devices.



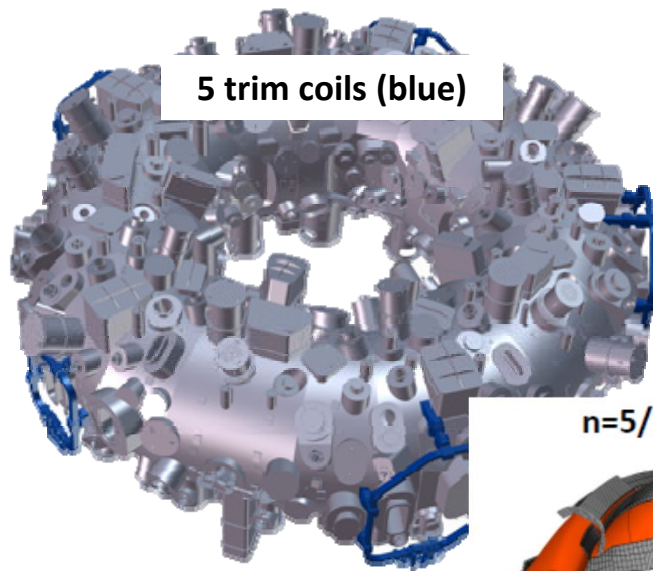
# The US is on the ground floor in these early days of W7-X operations



**Feb 3, 2016: Celebration of first hydrogen plasma operation**

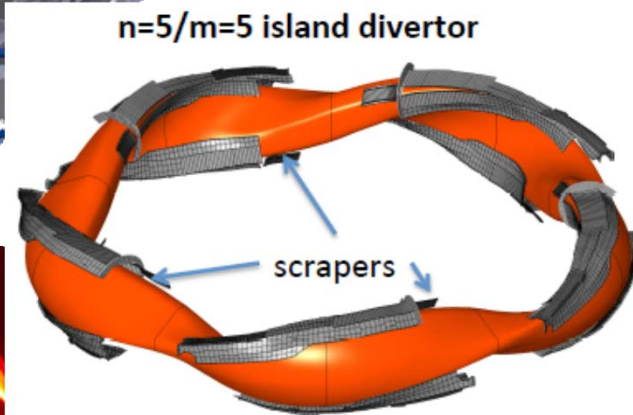


**Infra-red camera & visible imaging systems**



**5 trim coils (blue)**

**US hardware and scientific contributions**



**n=5/m=5 island divertor**

**scrapers**



**US scientists helped measure flux surfaces**



**Head-of-State interest in fusion**





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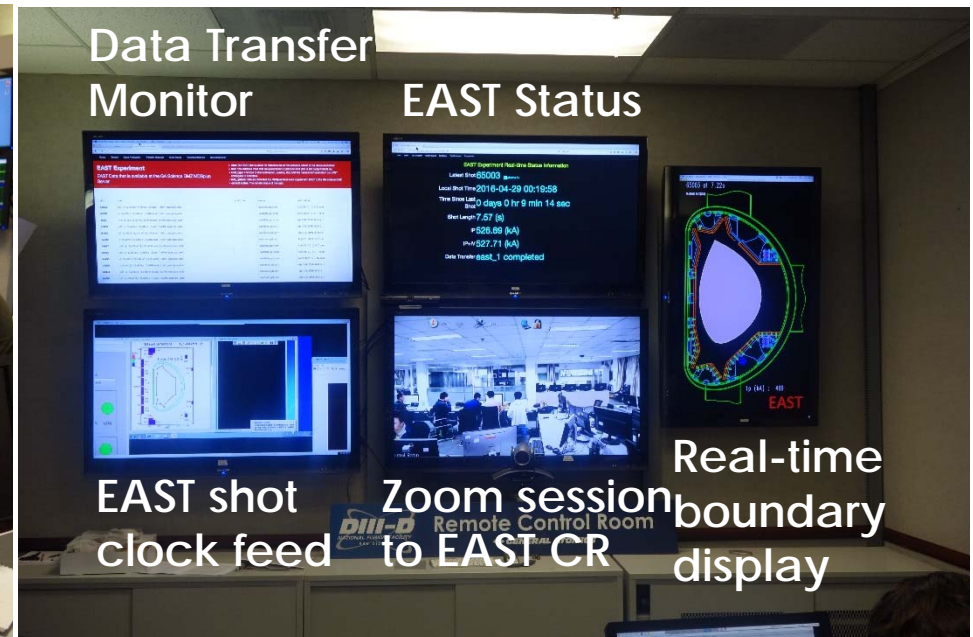
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# Remote participation approaches are being developed with national lab/universities team: US/Germany W7-X partnership



This team approach provides one model for university participation at world-leading fusion centers in the U.S. and overseas

## *First US-led 3<sup>rd</sup> Shift Experiment without U.S. Staff at ASIPP*

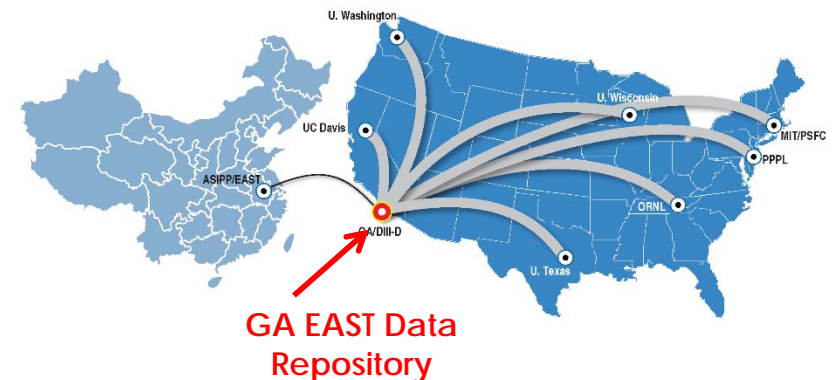


- **Experiment on Thursday, April 28, 2016, was very successful**
  - Six-hour session, 26 tokamak pulses, highest-priority experiments completed
  - Good GA-ASIPP staff communications and EAST data transfer to US
  - No significant impact to GA staff or added cost from EAST schedule changes
  - Experiment focused on empirical scalings of error field thresholds for ITER



# Remote communication and data access tools enhance scientific effectiveness

- **GA Remote Control Room:**
  - Display hardware and software to provide control room experience remotely
  - Accommodates 8 scientists and remote communication support staff
  - Audio/video connection to EAST control room, headphone links to key individuals
- **Operations and physics data display resources:**
  - Shot cycle, countdown clock display
  - Realtime in-vessel view video image from EAST
  - Pseudo-realtime signal traces and plasma boundary evolution displayed during shot (~100 ms delay)
- **GA Science Collaboration Zone:**
  - Utilizes 80% of a 1 GB/s network between GA and ASIPP through specialized tools
  - Maximum network utilization allows between-shot transfer of EAST data
  - Data mirror at GA serves all US collaborators
- **Pulse schedule prepared at GA Control Room:**
  - Secure remote access to EAST PCS at ASIPP
  - Pulse Schedule modified between shots by Physics Operator at GA
- **Pulse schedule validation at EAST**
  - Modified Pulse Schedule verified by Physics Operator at EAST
- **Execute pulse schedule at EAST**
  - Shot initiated by Machine Operator at EAST
  - Near real-time displays of selected signals and plasma boundary in Remote Control Room
- **Analyze expt'l data in Remote Control Room**
  - Post-shot mirroring of data at GA



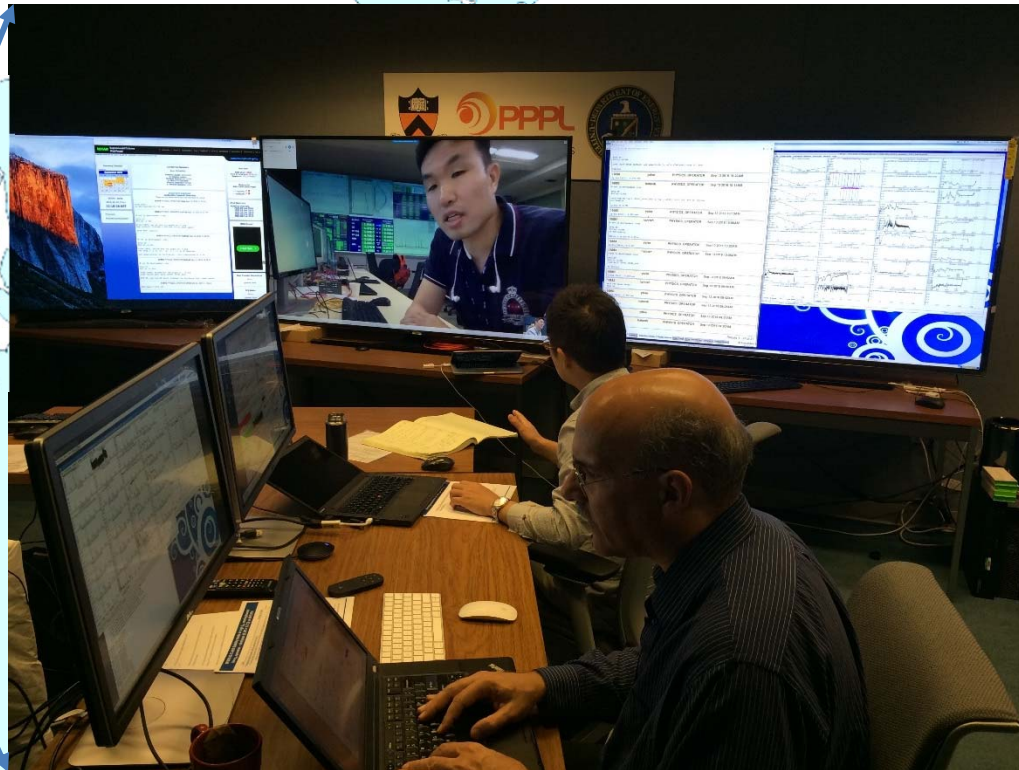




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# US/Korea partnership: US researchers on university/lab teams are leading experiments from the US on KSTAR



**US scientists sited at PPPL, led by Columbia University, head up experiments on the KSTAR long-pulse superconducting tokamak in Korea**

**Remote participation supplements the on-site U.S. presence at KSTAR**





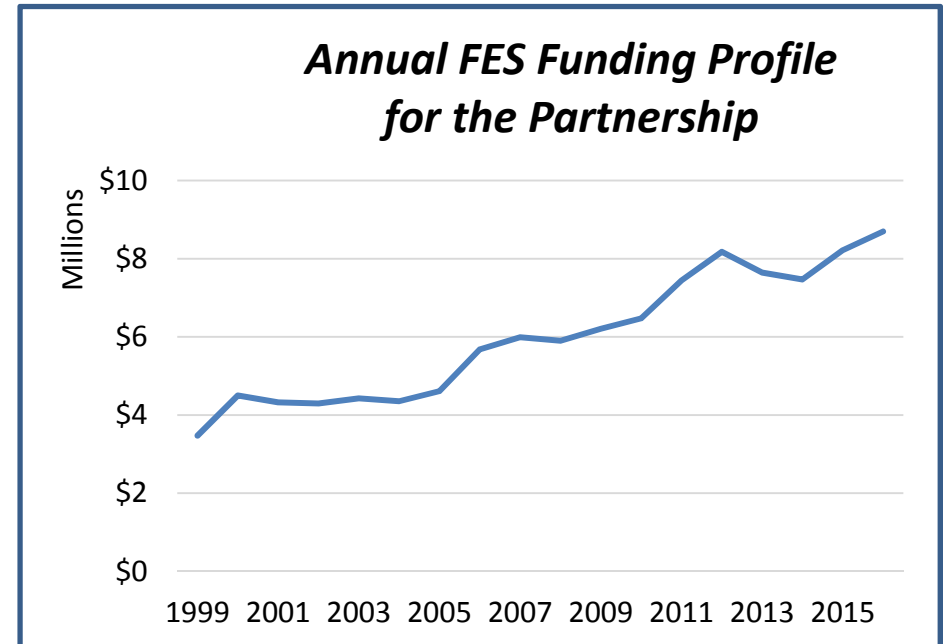
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## Recent workshop celebrated 20 years of NSF-DOE Partnership



***Attendees at Jan 9-11, 2017 workshop***



- The NSF/DOE Partnership is one of the longest-running interagency joint programs in the federal government.
- Main objective of original Memo of Understanding (1996) was to “provide enhanced opportunities for university-based research in fundamental processes in plasma science and engineering.”
- DOE funding increased from \$3.5M in 1999, to \$8.7M in 2016. DOE provided additional funding in 2016 of \$6.7M, which increased the award success rate to 28%.



- **Dr. Patricia Dehmer retired**
  - Deputy Director for Science (SC-2) for 9 years; also, Acting Director of the Office of Science (SC-1) for almost 3 years
  - Before that, Associate Director of Basic Energy Sciences program for 12 years
  - Before that, chemist at Argonne National Laboratory for 23 years
  - Retired November 10, 2016
- **New SC-2 is Dr. Stephen Binkley**
  - Formerly, SC Associate Director for Advanced Scientific Computing Research
  - As of January 16, 2017, also serving as Acting SC-1
  - New AD for ASCR is Barb Helland





## Thanks to Al Opdenaker, who retired January 3, 2017

- 43 years of dedicated service as Engineer at AEC → ERDA → USDOE
- Performed various responsibilities over many years, including:
  - Early work at Nuclear Energy (LMFBR) and Princeton Site Office (TFTR)
  - Executive Assistant to FES Associate Director and budget manager
  - Federal representative for FESAC (24 years)
  - FES program manager for ITER (CDA-EDA), ARIES reactor studies, technology, blankets, and tritium science
  - And more...



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## Other FES personnel news

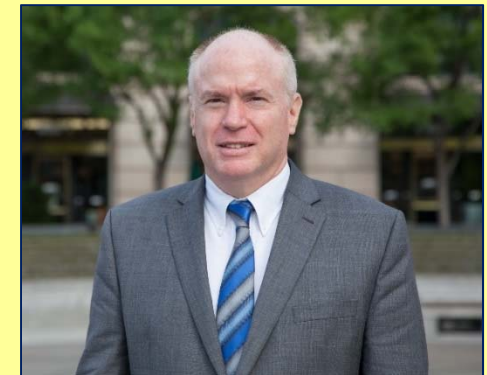
### New Program Managers



**Kramer Akli**  
High-energy-density  
laboratory plasmas



**Matthew Lanctot**  
International tokamak  
collaborations



**Bob Bartolo**  
AAAS Fellow  
(2<sup>nd</sup> year)



**Seth Aportadera**  
Summer Intern  
(from WVU)



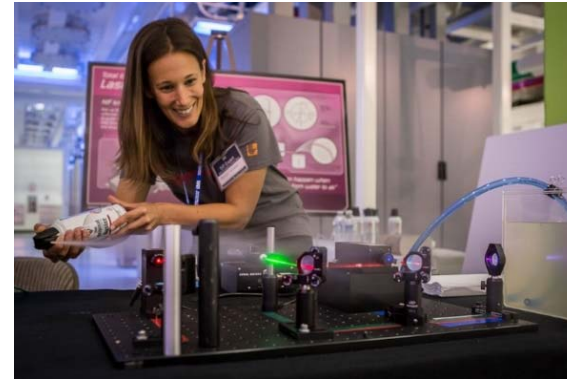


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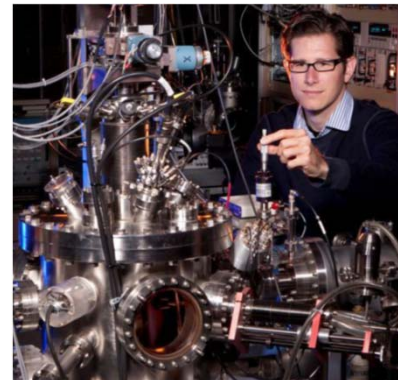
## 2016 Early Career Awards from FES

**Peter Bruggeman** (Minnesota)  
*Non-Equilibrium Plasma-  
Interactions with Biomaterials,  
Biological Solutions and Tissues*



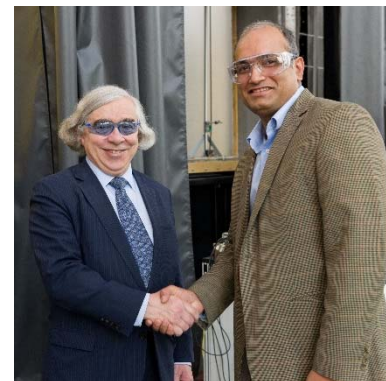
**Felicie Albert**  
(LLNL)  
*Laser-Driven X-  
Ray Sources for  
High Energy  
Density Science  
Experiments*

**Egemen Kolemen** (Princeton)  
*On the Physics-Based Real-  
time Analysis and Control to  
Achieve Transient Free  
Operations for the ITER Era*



**Robert Kolasinski** (SNL/CA)  
*Characterizing the  
Dynamic Response of  
Surfaces to Plasma  
Exposure*

**Scott Baalrud** (Iowa)  
*Transport Properties of  
Magnetized High-Energy-  
Density Plasma*



**Devesh Ranjan** (Georgia  
Tech)  
*Discoveries in Blast-Wave-  
Driven Turbulence of  
Astrophysical Relevance*



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## Two PECASE winners from FES in five years



***Daniel Sinars (SNL)***

Announced August 2012

2011 FES Early Career Awardee:  
"Fundamental instability measurements in  
magnetically-driven z-pinch liner implosions"



***Stephanie Hansen (SNL)***

Announced January 2017

2014 FES Early Career Awardee:  
"Non-equilibrium atomic physics in high  
energy density material"



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***Thank you***