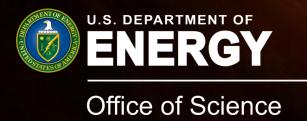
# FES Update on Strategic Planning

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Discuss the present strategic planning status, and outline the next steps for engaging the community in further planning



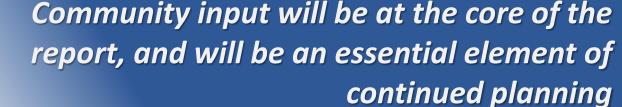
## We are advancing a high level strategic plan that embraces our science, emphasizes its potential, and describes plans for further community engagement

Likely title: "The Office of Science's Fusion Energy Sciences Program: A 10-Year Perspective"

At a high level, it argues for the necessity of a broad research portfolio, both topically and institutionally

It embraces both research towards the energy goal as well as plasma science for discovery

While maintaining breadth, increases focus on areas of high priority that the community has identified





The plan will reflect emphases that you have worked hard to identify and develop over the years

The report will represent a snapshot of an ongoing strategic planning effort that will continue to seek community input

It will build on U.S. strengths and will include policy considerations of overall directions in science and energy research



## The report will draw upon FESAC 2014, a history of community planning, and other broad considerations

- FESAC 2014 (from last year's planning activity) emphasized four primary thrusts: transients, plasma-materials interactions, computing, and a fusion nuclear science subprogram and facility. Their roots are several highly regarded studies performed with broad community input over the last decade, studies that in aggregate identified gaps in the world fusion program and provided well-articulated opportunities for U.S. leadership.
- The Office of Science supports the four primary research thrusts of FESAC
   2014, but with some qualifications
- Our approach: distill what has the strongest pedigree from the FESAC 2014
  report, consider community concerns, incorporate considerations including
  policy, and move forward through further targeted community planning
  activities. This includes a new series of Research Needs Workshops in most of
  the priority areas identified in FESAC 2014.



### FES activities through 2014 and since we last met in the fall

Through 2014, since the last FESAC meeting, activities and events include:

- Briefed Congressional staff on the status of the plans for planning and how we will receive the FESAC output and concerns. We described to them our plans to launch Research Needs Workshops to further inform our planning (October 17)
- Described at a UFA Town Hall meeting at APS-DPP the planning status and commented on community concerns and FES reaction to the FESAC report (October 27)
- Congress reflected our plan for these Workshops in the enacted budget (December 10)
- Hosted a dialogue with community leaders about these Workshops, to get their feedback and ideas (December 15)
- Spoke at the Fusion Power Associates meeting about our plans (December 17)



#### FES activities since the new year, 2015

- Invited chairs to lead Workshops in four areas and paired them with FES contacts in late December through mid January
- Held a video conference with chairs and co-chairs to exchange ideas (January 30)
- Held a Webinar about the FY 2016 Congressional Budget request. 100 connections; well over 100 participants (February 3)
- Announced community-wide the workshop outlines and logistics in a mass mailing (February 9)
- Second meeting with chairs, co-chairs, and FES to be held March 19

### The Workshops will update and inform FES in high priority areas

#### Topical areas

- Plasma transients
- Plasma-materials interactions
- Integrated Simulations for Magnetic Fusion Energy Sciences (with ASCR)
- Plasma Science Frontiers (2 workshops)

More discussion follows



#### Major considerations for the DOE plan

- First, massively parallel computing with the goal of validated whole-fusion-device modeling will enable a transformation in predictive power, which is required to minimize risk in future fusion energy development steps.
- Second, materials science as it relates to plasma and fusion sciences will provide the scientific foundations for greatly improved plasma confinement and heat exhaust for long pulse lengths.
- Third, research in the prediction and control of transient events that can be deleterious to toroidal fusion plasma confinement will provide greater confidence in machine designs with stable plasmas.
- Fourth, continued stewardship of discovery at the plasma science frontier that is not expressly driven by the energy goal will address frontier plasma science issues underpinning great mysteries of the visible universe.
- Fifth, FES facilities will be kept world-leading through robust operations and regular upgrades.



### Sharpening our understanding of research needs with community engagement workshops

- The document under review fulfills a requirement, but it is but one step in a more complete process that requires broad community participation
- FES is seeking further community engagement and input for planning through a series of technical workshops
  - Workshop on Integrated Simulations for Magnetic Fusion Energy Sciences
  - Workshop on Transients
  - Workshop on Plasma-Materials Interaction
  - Workshops (2) on Plasma Science Frontiers
- The deliverable from each workshop will be a report, written by the members
  of a community steering committee for the respective workshop, to discuss
  the scientific challenges and opportunities for addressing these challenges
- The workshops and deliverables will be discussed in more detail later today



### Achievements in energy research will be called out (1)

### Intention is to promote this in the Congressional report. Why? Because the audience will include many who do not know the field, or whose interest is just getting kindled. Examples:

- Fusion-grade plasmas in experiments such as DIII-D and NSTX-U are routinely created that match the extraordinary conditions of fuel temperature required in a fusion reactor. In experiments on the TFTR at PPPL the fusion power density achieved in the center of some DT plasmas exceeded reactor requirements, and plasma self-heating from energy released in the fusion process was observed.
- Fine details determining the heat confinement of the fusing plasma state, including temperatures of hundreds of millions of degrees Centigrade and fuel fluctuation levels smaller than 0.1% of the average fuel density, are routinely measured with precision. Experimentation takes advantage of rapid analysis of such measurements.
- Fusion scientists are leading contributors to the broad field of turbulence, complex dynamics, and selforganization. Advances regarding plasma turbulence have led to a revolution in the understanding of fusion system containment properties and the likely characteristics of future experiments, including ITER.
- Scientists are able to exert exquisite control of plasmas for fusion research as well as other applications.
   This control includes active feedback between real-time measurements and heating and magnetic field actuators that react within milliseconds to the early detection of potentially deleterious instabilities, allowing their targeted suppression before fusion plasma performance is degraded.



#### Examples for research towards energy (con't)

- Precise magnetic field control in real time enables the safe directing of enormous heat fluxes (many millions of watts per square meter) from fusion plasmas onto material structures that are designed to endure this harsh environment.
- Fusion researchers led the nation in developing the first supercomputing applications supported by DOE. Today, massively parallel computing is a signature feature of nearly every major scientific enterprise, including fusion. At DOE-sponsored national supercomputer centers, U.S. researchers carry out numerical simulations that continue to push the state of the computational art. Present-day codes capture the details of the extreme and complex fusion plasma state, and its interactions with the materials that surround it.
- Fusion scientists have been among leaders in materials science, identifying materials that can endure the many atomic displacements that will occur in an eventual fusion reactor, and understanding their properties with theoretical and computational analyses.

### Achievement in plasma frontiers research will be described (1)

#### **Examples**

- Laboratory experiments and computational research are establishing the understanding of some
  of the most extraordinary phenomena in the visible universe, including the generation of solar
  prominences and the formation of plasma jets that extend hundreds or even thousands of light
  years from a galactic core.
- Understanding the mystery of the surprisingly high temperature of the solar corona over 1,000,000 degrees K measured 10,000 km above the Sun's photosphere, while the Sun's photosurface resides at a comparatively cool 4500 degrees K has benefited from major discoveries in laboratory experiments. These confirm that the process of magnetic reconnection can efficiently convert the energy of the Sun's tangled magnetic field into thermal energy of solar corona ions.
- Plasma environments that simulate the conditions on the surfaces of white dwarf stars that
  eventually become Type IA supernova have been generated on the Z machine at Sandia National
  Laboratory, enabling detailed assessments of the intrinsic brightness of these stars. Astronomers
  use Type-IA supernova as "standard candles" to evaluate intergalactic distances. This research
  may improve the accuracy of our best "cosmic yardsticks," enabling more precise determination
  of the age of the universe than was previously possible.



### Achievement in plasma frontiers research will be described (2)

#### Examples (continued)

- Fundamental plasma physics principles have been applied to measurements obtained by Voyager 1 and 2 missions of the solar wind near Pluto to set the internationally accepted upper bound on the mass of the photon at less than 10<sup>-51</sup> grams, a dramatic improvement over previous such estimates.
- Computer codes used to understand fusion plasmas are being applied to the
  extraordinary conditions in the accretion disks of black holes, including research to
  understand the apparent deficit in luminosity of the accretion disk surrounding the
  massive black hole at the center of our Milky Way galaxy.

There are of course volumes more to call out.

Can you offer high level singular scientific achievements for us to consider?

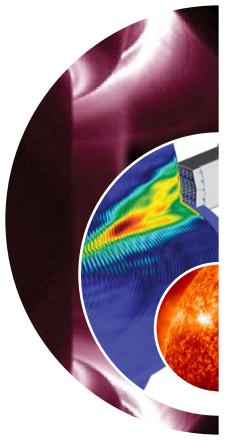


### Burning plasma science is a leading consideration framing the plan

Burning plasma science is the highest level goal of FES-sponsored research, and is best underpinned with a broad research portfolio

- Broadly supported; judged ready: In 2002, a large community summer study involving 80 scientists, held in Snowmass, CO, assessed three options for burning plasma facilities and indicated a preference the international ITER project.
- Following this, FESAC wrote A Burning Plasma Program Strategy to Advance Fusion Energy. It noted "an overwhelming consensus that...we are now ready scientifically, and have the full technical capability, to embark on this step" (viz., experimental study of a burning plasma).
- Important to all confinement concepts: A follow-up NRC study in 2008 provided A
   Review of the DOE Plan for U.S. Fusion Community Participation in the ITER Program.
   The DOE plan, itself a community report, emphasized the high value of the burning
   plasma knowledge to be learned on a tokamak for any magnetic confinement
   concept.

Office of Science



#### **Burning Plasma Science**

#### **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

Long Pulse

**Challenge**: Understand the fundamentals of transport, macrostability, wave-particle physics, plasma-wall interactions

Building on domestic capabilities and furthered by international partnership

**High Power** 

**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

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 Plasma Science

#### **Plasma Science Frontiers and Measurement Innovation**

General plasma science, non-tokamak and non-stellarator magnetic confinement, HEDLP, and diagnostics



#### Goal

 This research category advances the validated predictive understanding of plasma confinement, dynamics, and interactions with surrounding materials

#### Strategic implementation

- In all funding scenarios, emphasis will be on upgraded DIII-D and NSTX-U working as a complementary pair
- Research here will establish the scientific basis for research on superconducting longpulse overseas facilities already in operation or soon to operate
- Partnership opportunities with the Advanced Scientific Computing Research (ASCR)
  program in the Office of Science will be increasingly leveraged towards an integrated
  whole-device modeling endeavor
- Community workshops in 2015 will further inform and update research needs and opportunities in transients (experiment and computation) and in whole device modelling



### Foundations — high importance Computing and whole device modeling

#### Computing and whole device modeling needs to be an FES emphasis in the next decade

#### Community considerations include:

- The opportunity and strong sense of urgency were conveyed in FESAC's 2007 Priorities, Gaps and Opportunities report
- In 2007, FESAC issued an assessment: FESAC Fusion Simulation Project Panel Final Report. The same
  workshop output was also assessed by the Advanced Scientific Computing Advisory Committee (ASCAC).
  This and other community activities affirm the readiness for making whole-device modeling an FES
  priority
- Likely vehicle for strong ITER program impact

#### Additional considerations:

- A drive towards exascale is one of the leading scientific priorities of the Administration. Building on the FES/ASCR partnership, opportunities for FES are significant
- View of computation as a tool for discovery is widely held in the Administration, and is well suited for the Office of Science
- FES needs to be more deeply engaged in computing to reduce development path risks for fusion energy. Fusion researchers have been and need to be part of a transformation in computational science



### Foundations - high importance: Transients, including disruptions

#### FES proposes to increase emphasis in transients research, including disruptions

#### Community considerations include:

- In 2007, the FESAC report, *Priorities, Gaps, and Opportunities: Towards a Long Range Strategic Plan for Magnetic Fusion Energy,* gaps related to disruptions and large-scale Edge Localized Modes in tokamaks were judged to be among the most significant gaps for fusion energy development
- Widely voiced as a significant issue not only for ITER, but for any burning plasma concept based on a tokamak
- 3D physics of tokamaks and stellarators can inform each other in this area

#### Additional considerations:

 High leverage of resources: Disruptions and transients research captures a strong synergy between experiments of different type, advanced measurements, and massively parallel computing

#### Research Direction: Long Pulse

#### Goal

 This research category explores new and unique scientific regimes that can be achieved with longduration superconducting fusion confinement machines and addresses the development of advanced materials required to withstand the extreme conditions in a burning plasma environment

#### Strategic implementation

- Lever mature U.S. research knowledge established in the Foundations area into collaborative research activities carried out on overseas facilities that have long-pulse capability enabled by superconducting magnets
- Combine research on materials effects on plasma confinement, high heat flux effects on materials, and neutron irradiation effects. The overall motivation is to gain entry into a new class of fusion materials science wherein the combined effects of fusion-relevant heat, particle, and neutron fluxes can be studied for the first time anywhere.
- Community workshops in 2015 will further inform and update research needs and opportunities in fusion materials, and will promote a dialogue regarding PMI as it pertains to research on long pulse linear devices and on confinement facilities



### Long pulse – high importance: fusion materials

#### FES recognizes the importance of a robust program in materials science

#### Community considerations include:

- In 2007, the FESAC report, *Priorities, Gaps, and Opportunities: Towards a Long Range Strategic Plan for Magnetic Fusion Energy,* gaps related to materials science (nuclear, plasma materials interactions, and their synergy) were judged to be among the most significant gaps for fusion energy development
- FESAC 2014; also FESAC's "Opportunities for Fusion Materials Science and Technology Research Now and in the ITER Era" (February 2012)
- Widely understood and expressed to be essential for any realistic embodiment of a fusion reactor

#### Additional considerations:

- The upcoming community Workshop will help update and clarify the research needs and opportunities pertaining to possible approaches
- "Materials science for energy" and "Materials by design" are concepts frequently articulated and supported within DOE and elsewhere.
- Leverage opportunities for FES are significant, underscoring potential high value for a given



### Long pulse — increasing opportunities with international partnerships

- Many front-line research opportunities for U.S. researchers and students reside with our overseas fusion energy sciences partners. International partnerships in fusion science research go back decades
- Some overseas facilities are developing operational capabilities beyond those of any U.S. facility in some key respects. GA has recently demonstrated remote control of the superconducting EAST tokamak in China, applying advanced DIII-D operating scenarios
- → New paradigm: scenarios developed here enable U.S. scientists to have high impact overseas
- Stellarator research: unique, high impact possibilities. Highly relevant to one of the most important topics in tokamaks, 3D physics, and the science of transients
- Value of high leverage partnerships expressed in FESAC's report, "Opportunities and Modes of International Collaboration During the ITER Era" (February 2012)
- U.S. researchers could have significant impact in helping to set the research agendas for these emergent programs by means of vigorous engagement in level of program planning and through a combination of off-site participation and on-site engagement.
- Also, the experience gained from U.S. research teams that are based overseas will be invaluable for U.S. scientists who will be participants on future international ITER research operations teams.



### Research Direction: Plasma Science Frontiers

#### Goal

 This research area explores the fundamental properties and complex behavior of matter in the plasma state to improve the understanding required to control and manipulate plasmas for a broad range of applications.

#### Strategic implementation

- FES will continue to maintain a leadership role in the national stewardship of discovery plasma science
- Leverage with partnering agencies will continue to be promoted
- Community workshops will identify both the grand scientific challenges in the plasma science frontier area and also the research needs required to address them. These workshops will be of critical importance, as this area has not yet had the benefit of a research needs analysis. This portfolio shares many common intellectual threads with the potential for broadening connections between the fusion energy sciences program and other scientific fields.



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It will build on U.S. strengths and will include policy considerations of overall directions in science and energy research



### Thank you