FES Considerations for Strategic Planning

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U.S. DEPARTMENT OF ENERGY
Office of Science

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FESAC SP report is received as input to be considered for the DOE plan

- **After an enormous effort in a constrained schedule, the recent FESAC Strategic Planning Subcommittee produced a report that addressed the charge**
  - Sincere thanks to the members of the Subcommittee, its chair, and the group leaders
  - Report was subsequently approved by FESAC, although its approval was complicated by COI issues

- **The output has generated a great deal of interest and discussion**

- **Moving forward: Now DOE will consider the FESAC report, past FESAC advice, community input, and other considerations as we construct a report for Congress**

Charge for a ten-year strategic plan

- **FY 2014 Omnibus Appropriations Act required DOE to submit an FES program strategic plan**
  – "The ten-year plan should assume U.S. participation in ITER and assess priorities for the domestic fusion program based on three funding scenarios with the fiscal year 2014 enacted level as the funding baseline: (1) modest growth, (2) budget growth based only on a cost-of-living-adjusted fiscal year 2014 budget, and (3) flat funding."

- **Office of Science charged FESAC:**
  – To assess program priorities under these same three funding scenarios
  – And under a fourth scenario (budget growth based on COL-adjusted FY 2015 President's Request)

Summary of the recommendations of the 2014 FESAC SP report

Highest-priority initiatives	
Tier 1	
	Control of deleterious transient events: This Initiative combines experimental, theoretical, and simulation research to understand highly damaging transients and minimize their occurrence in ITER-scale systems.
	Taming the plasma-material interface: This Initiative combines experimental, theoretical, and simulation research to understand and address the plasma-materials interaction (PMI) challenges associated with long-pulse burning plasma operation.
Tier 2	
	Experimentally validated integrated predictive capabilities: This Initiative develops an integrated "whole-device" predictive capability, and will rely on data from existing and planned facilities for validation.
	A fusion nuclear science subprogram and facility: This Initiative will take an integrated approach to address the key scientific and technological issues for harnessing fusion power.

Moving forward with developing an Administration plan

- **In what follows:**
  - **Comments on process**
  - **Comments on recommendations**
  - **On being sponsored by the Office of Science, and what this means for our path forward**

Sincere appreciation for FESAC's efforts

- **FESAC deserves credit for having:**
  - Addressed the charge fully—making tough choices for priorities, within constrained budget scenarios
  - Invested enormous effort by the Subcommittee
  - Solicited community input
  - Succeeded in mapping priorities into the proposed new FES budget structure

Conflict of interest regulations were taken seriously

- **FESAC is governed by the Federal Advisory Committee Act (1972)**
  – FESAC members become "Special Government Employees" to give advice
  – COI regulations for SGEs differ from those for the NAS, as NAS is not a governmental organization and is not subject to the same regulations

- **Recusals had to be implemented for the FESAC SP Subcommittee and the full FESAC**
  – The inclusion of specific budget scenarios in the congressional charge towards specific recommendations on facilities.
  – The report's invocations of specific facilities triggered the COI actions
  – DOE relied on DOE legal counsel for recusal determinations

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Quick take on the Tier 1 & 2 recommendations

Recommendation	Comments
Control of deleterious transient events	Critical, show-stopper issue
Taming the plasma-material interface	Critical, show-stopper issue. Any new PMI facilities should serve the scientific needs.
Experimentally validated integrated predictive capabilities	Should be equally high priority, not Tier 2. It is critical for Transients and PMI, but more broadly as well
A fusion nuclear science subprogram and facility	Construction of an FNSF will not happen during the decade, due to budget pressures. Existing program of fusion nuclear science will be continued (not as a new subprogram), and should grow

Other comments on Tier 1 & 2 recommendations

- **In the DOE plan:**
  - Progress in all of the priorities can be made in all of the funding levels considered in the charge
    - Our own budgeting exercises point to the possibility of credible initiatives on all fronts, albeit delayed and/or more modest at the lower budgets under consideration
  - Validated predictive capability is a leading indicator of scientific progress, and so will be among the highest priorities
  - A broad palette of scientific research will still be embraced in the plan, even as these priorities are emphasized

Validated predictive capability is needed as much as progress in any single technical issue

In concert with our domestic facilities, validated computing is at the heart of our foundational scientific work

Predictive capability provides a metric for how well our science has been established. Fusion will not advance if predictive capability does not advance

FES relationship with ASCR is important and a great opportunity. Administration's efforts towards exascale should be captured by FES/ASCR partnership

On other high-level specific facility recommendations of the report

Item	Comment
C-Mod operations end	The plan will be consistent with the previously stated Administration position and recent House-Senate direction to operate Alcator C-Mod for FY 2015 and FY 2016.
Down-selection between DIII-D and NSTX in 5 years in some budget scenarios	DOE views this as premature in any case. In the Administration plan, any decision point will be later in the ten year period, regardless of budget scenario, and there will be more possible branching directions

We are hearing the critiques of the FESAC report

Expressed concern
Too technology oriented?
Too facility-centric?
Insufficiently scientific?
Short shrift to computation?
Short shrift to Discovery Plasma Science?
University role marginalized?
Peer review marginalized?
Too dependent on leverage?

Regarding the DOE plan

- **Science**:
  - It will articulate the highly scientific nature of the fusion/plasma enterprise
- **Structure**:
  - It will be expressed along the new programmatic lines (i.e., Foundations, Long Pulse, High Power, & Discovery)
- **Leverage**:
  - It will emphasize need for and benefits from sensible intra/inter-agency leveraging
- **Pedigree**:
  - It will embrace initiatives that are grounded in previous community studies

Past community studies informed the FESAC SP Report (and will inform the DOE plan)

- **Numerous examples (referenced in FESAC SP Report):**
  - Priorities, Gaps, and Opportunities: Towards a Long-Range Strategic Plan for Magnetic Fusion Energy (FESAC, 2007)
  - Fusion Simulation Project (DOE, 2007)
  - Low Temperature Plasma Science: Not Only the Fourth State of Matter but All of Them (DOE, 2008)
  - Plasma Science: Advancing Knowledge in the National Interest ("Plasma 2010") (NAS, 2007)
  - FESAC Fusion Simulation Project Panel Final Report (FESAC, 2007)
  - Report of the FESAC Toroidal Alternates Panel (FESAC, 2008)
  - Research Needs for Magnetic Fusion Energy Sciences (DOE, 2009)
  - Basic Research Needs for High Energy Density Laboratory Physics (DOE, 2009)
  - Scientific Grand Challenges: Fusion Energy Sciences and the Role of Computing at the Extreme Scale (DOE, 2009)
  - Advancing the Science of High Energy Density Laboratory Plasmas (FESAC, 2009)
  - Fusion Simulation Program Execution Plan (DOE, 2011)
  - Research Opportunities in Plasma Astrophysics (PPPL workshop, 2011)
  - Opportunities for Fusion Materials Science and Technology Research Now and in the ITER Era (FESAC, 2012)
  - Fusion Nuclear Science Pathways Assessment (DOE, 2012)
  - Opportunities for and Modes of International Collaboration in Fusion Energy Sciences Research during the ITER Era (FESAC, 2012)
  - Priorities of the Magnetic Fusion Energy Program (FESAC, 2013)
  - Prioritization of Proposed Scientific User Facilities for the Office of Science (FESAC, 2013)
  - Solar and Space Physics: A Science for a Technological Society (NAS, 2013)

Personal illustration of being informed by past community studies

- **UFA talk (Nov 2009)**
  - MFE ReNeW report (June 2009) had just finished building on the Greenwald Gaps report (2007)

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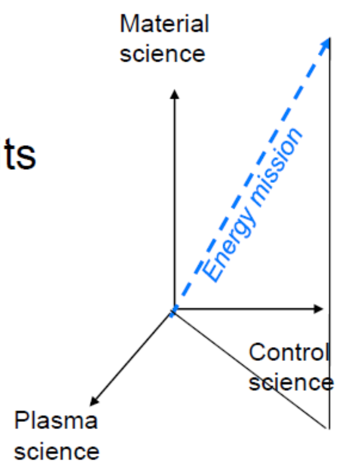
The science of fusion is rich and deep, and we can cast our research needs in the language of fusion science

Energy or science? Nearly moot right now: what we need to do to establish credibility towards an energy goal is deeply scientific in character.

The energy and basic science pursuits elevate each other



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  - Used 3D basis set to frame opportunities in fusion energy and discovery plasma science
  - Emphasized deeply scientific nature of program
  - Noted opportunities in validated predictive capability, long pulse research, PMI and FNS, and international collaborations

Recall the FES mission and objectives

Our enterprise is deeply scientific, and will continue to be so over the next decade

Mission

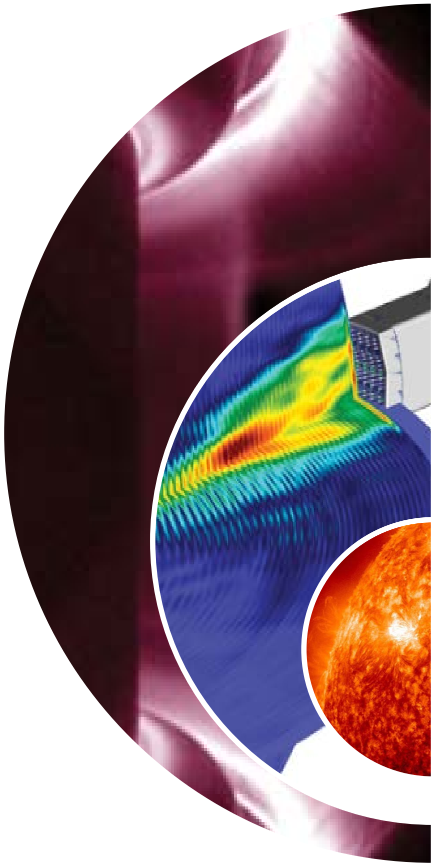
The mission of the Fusion Energy Sciences (FES) program is to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundations needed to develop a fusion energy source. This is accomplished by the study of the plasma state and its interactions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

Objectives

- Advance the fundamental science of magnetically confined plasmas for fusion energy
- Support the development of the scientific understanding required to design and deploy fusion materials
- Pursue scientific opportunities and grand challenges in high energy density plasma science
- Increase the fundamental understanding of plasma science beyond burning plasmas

The DOE plan will be structured along the following science themes

New proposed budget structure



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

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

Long Pulse

Building on domestic capabilities and furthered by international partnership

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

High Power

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

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

Discovery Science

Plasma Science Frontiers and Measurement Innovation

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

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Burning Plasma Science

Foundations

Advanced Tokamak & Spherical Tokamak

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

Theory and Simulation

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

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Burning Plasma Science

Long Pulse

Long-Pulse Tokamaks & Long-Pulse Stellarators

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

Materials and Fusion Nuclear Science

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

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Burning Plasma Science

High Power

US Contributions to the international ITER Project

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

NOTE: The mandate from Congress for a strategic plan said to assume that ITER is an ongoing project. Hence the charge to FESAC did not include this part of the program.

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Discovery Plasma Science

Plasma Science Frontiers

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

Measurement Innovation

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

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Role of facilities in the DOE plan

- **New/upgraded facilities:**
  - Will be promoted only insofar as they enable excellent science

- **Regarding a fusion nuclear science facility:**
  - The DOE plan will not be framed around a drive toward such a facility
  - The decadal budget outlook makes a start for new major facility construction appear unlikely
  - In the 2013 SC facilities prioritization, no program office was supported in advocating a multi-$B-class facility [cf. FESAC Facilities Report, 2013]
  - The DOE plan will embrace Foundations and Long Pulse science (including elements of fusion nuclear science research) that would be important to an FNSF and to ITER and are broadly important to any credible form for magnetic fusion energy science

Pedigree of facilities in the DOE plan

- **Any facilities promoted in the DOE plan will be grounded in previous community studies**
  – The roots for topical areas are found in the FESAC Greenwald report (2007)
  – Particular concepts were highlighted in ReNeW (2009)

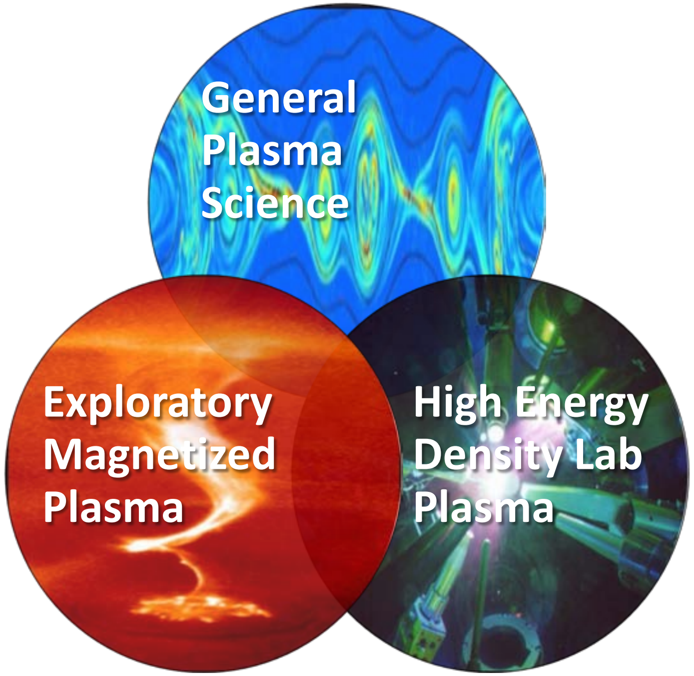
- **The facilities recommended in the FESAC SP Report rely on this pedigree**

Will the DOE plan have a late-decade decision point?

- **Likely, yes. But it will be multi-faceted. Such a decision point would be informed by the science, community input, and funding environment at that time**

- **What might the science tell us by that time? Examples:**
  - We may decide that the science and political support allow for a move forward even more vigorously in fusion nuclear science (but we don't know that yet)
  - We may learn that it is too risky to assume mastery of disruption prediction/avoidance/mitigation. If our international and university-scale stellarator research is successful, we might conclude that invigorated investment in this area is warranted
  - In PMI, we might learn that liquid metal divertor research results warrant moving further with this approach

Discovery plasma science has a highly valued place in DOE planning



Plasma Science Frontiers

General Plasma Science

Addresses outstanding questions related to fundamental plasma properties and processes through discovery-based investigations in basic, astrophysical, and low-temperature plasma science

***Challenge*:** Understand the fundamental properties and complex behavior of matter in the plasma state to improve the understanding required to control and manipulate plasmas

High Energy Density Lab Plasma

High Energy Density (HED) physics is the study of ionized matter at extremely high density and temperature, approximately 100 billion Joules per cubic meter

Challenge: Understand the fundamental character of matter in extreme conditions and the phase transition from weakly coupled to strongly coupled degenerate plasma.

Exploratory Magnetized Plasmas

The study of plasma systems which exhibit properties known as "self-organization" where the plasma spontaneously alters externally applied fields in a way that reduces the degrees of freedom

Challenge: Understanding the nature by which plasma rearrange and spontaneously generate global magnetic structure.

Measurement Innovation

Research on the development of new plasma diagnostic techniques, critical for prediction and control of fusion plasma behavior and for V&V.

Challenge: Create novel measurement methods for use in high-power, long-pulse, and burning plasmas.

Rising to the challenge through community engagement & participation

Inter– and intra-agency partnering

- Strong active partnerships currently with:
  - The National Science Foundation (NSF)
  - National Nuclear Security Administration (NNSA)
  - Advanced Scientific Computing Research (ASCR)
- Immediate opportunities for enhanced engagement
  - Basic Energy Sciences (BES)
  - High Energy Physics (HEP)
  - National Aeronautics and Space Administration (NASA)

Intermediate–scale facilities

- Best science available!
- Peer review is critical and necessary

Reviewing the breadth of the portfolio

- Opportunity to engage the National Academies Plasma Science Committee
- We are prepared to sponsor a series of community-led workshops in CY 2015

Lab-university partnerships

- **We should develop ways of working together in which the labs and universities are partners, not rivals**

- **It's about the science**
  – Labs have infrastructure required by important scientific frontiers. Universities have talent required to take advantage of this infrastructure. This is a fundamental Administration view.

- **Our major confinement facilities are under-utilized**
  – The FESAC SP Report correctly points to their potential as user facilities in a broader sense than they are now. The DOE plan will reflect this value.

- **Frontiers in Discovery Science requires intermediate-scale facilities to provide access to plasma regimes of interest and to allow complete measurements**
  – The labs can be a great resource for everyone in this area

The FESAC SP Report will be used in constructing the DOE plan

- **Many of the scientific priorities indicated in the FESAC SP Report will be included in the DOE plan because:**
  - They demand great science
  - They have a strong, vetted pedigree
  - They take advantage of U.S. strengths
  - They represent potential show-stoppers for fusion
  - They are broadly important, for burning plasma science and for discovery plasma science

Possibilities for going forward

- **Discovery Plasma Science**
  - Community workshops (e.g., intermediate-scale DPS facilities)
  - Review the breadth of the portfolio
- **Fusion materials**
  - Basic Research Needs workshop(s)
  - Workshop on possible implementations (linear, toroidal, short/long pulse, etc.)

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Major elements of the DOE plan (to reiterate)

- The FES program will remain deeply scientific and well suited to the Office of Science
- For MFE, high-priority scientific opportunities include transient events, integrated predictive computing, and fusion materials/nuclear science
- Discovery Plasma Science is valued
- A major new confinement facility start is not likely given likely budgets and FES priorities
- Down-selection near the 5 year point between DIII-D and NSTX-U is premature.
- Any late-decade decision point will be multi-faceted and will include considerations of fusion nuclear science but will be broader
- Partnerships and leveraging are essential
- Further community engagement and input will be sought

Our essential task is establishing scientific credibility

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Establishing credibility is our challenge

- There are at least three major scientific needs for establishing credibility for fusion energy:

  (1) We must generate, study, optimize, and learn to predict the properties of the burning plasma state

  (2) We must develop the scientific basis for robust control strategies for the burning plasma state: in MFE, this includes developing the scientific understanding to enable long plasma pulses.

  (3) We must develop the understanding of the material/plasma interface, and the fusion nuclear science needed to endure the fusion environment and to harness fusion power

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FES shares the value set that establishing fusion's credibility is a deeply scientific enterprise, fully consistent with the Office of Science's mission space

UFA talk, APS-DPP 2009

Thank you