FESAC Strategic Planning (SP) Report

Initiatives and Primary/Supporting Recommendations from Priorities Assessment and Budget Scenario Formulation

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FESAC Strategic Planning Panel Chair

FESAC Meeting
Monday 22 September 2014
Marriott Washingtonian Hotel, Gaithersburg, MD

Outline of Presentation

- Discussion of charge letter and approach taken by panel
- Report structure
- Introduction – Forward Look
- SP Panel process
- Initiatives and primary/supporting recommendations
- Budgetary considerations
- Burning Plasma Science: **Foundations**
- Burning Plasma Science: **Long Pulse**
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- **Partnerships** with Other-Federal and International Research Programs
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- Communication: Community workshops and presentations
- Detailed narrative of Leverage and Partner opportunities with DOE, other-federal, and international
- Summary and Discussion

FESAC Strategic Planning (SP) Report

Initiatives and Primary/Supporting Recommendations from Priorities Assessment and Budget Scenario Formulation

Strategic planning is the acceptable process for making investment decisions to realize the mission and goals of a program's vision. A good strategy should extend a little bit outside the comfort zone.

True strategy is about placing bets, making hard choices, and maximizing the odds for success, rather than minimizing risk. Good strategic development involves deciding the goals that are worth achieving, what it would take to achieve them, and whether or not they are realistic.

The ranking of strategic priorities comprises the charge to the FESAC Strategic Planning Panel where the priority assessment and budget scenarios were to address the next 10 years (2015 through 2024) with a 2025 vision.

FESAC Strategic Planning (SP) Panel gathered options for initiatives and recommendations

FESAC is charged to assess the priorities among continuing and potential new scientific, engineering, and technical research program investments within and among each of the three subprograms in FES's newly structured program:

- the science of *prediction and control of burning plasmas* ranging from the strongly-driven state to the self-heated state (FOUNDATIONS),
- the science of *fusion plasmas* , *plasma-material interactions*, *engineering and materials physics modeling and experimental validation,* and *fusion nuclear science* approaching and beyond ITER-relevant heat fluxes neutron fluences, and pulse lengths (LONG PULSE), and
- the study of laboratory plasmas and the high-energy-density state relevant to *astrophysical phenomena*, the development of *advanced measurement validation*, and the science of *plasma control important to industrial applications* (DISCOVERY PLASMA SCIENCE).
- A 4th subprogram (HIGH POWER), establishing the scientific basis for robust control of the self-heated, burning plasma state, uses ITER as the keystone, is not so focused on domestic capabilities, and is not emphasized in this charge.

FESAC Strategic Planning (SP) Panel assessed priorities and prioritized initiatives

So that FES can formulate the FES strategic plan required by the Fiscal Year 2014 Omnibus Appropriations Act by mid-January 2013, the DOE Office of Science (DOE-SC) asks FESAC

- to prioritize between the FES Program's subprogram elements,
- to include views on new facilities, new research initiatives, and facility closures,
- to establish a scientific basis for advancing fusion nuclear science,
- to assess potential for strengthened or new partnerships with other federal agencies and international research programs that foster opportunities otherwise unavailable to FES-supported scientists, and
- to make use of prior studies and reports.

FESAC SP Panel had the responsibility and intent to deliver a serious, careful, and precise response to the charge

This is an extremely important charge in the eyes of the Office of Science and for the fusion community, with high visibility to policymakers and to our own universities and national laboratories.

Built into the process was the commitment to having the panel **gather information openly** and **deliberate in an unencumbered, unbiased, and independent manner** that minimizes conflict of interest issues while providing the best technical advice for the charge.

The priorities and the initiatives that were ranked came from the research community. The Panel did not cook up anything new. To satisfy the budget scenarios, a strategic spectrum of subprogram elements were able to be accelerated ahead of other elements while balancing facility closure with new facility planning and expanded collaborations.

Community Communication

https://www.burningplasma.org/activities/?article=2014%20FESAC%20Strategic%20Planning%20Panel

This website supports the 2014 FESAC Strategic Planning Panel.
Led by Prof. Mark Koepke (WVU, Chair) and Prof. Steve Zinkle (UT - K, Vice Chair).
Fusion Energy Sciences contact at DOE: Sam Barish
Members of the subcommittee are listed here.

Panel Documents
Charge, by Patricia Dehmer, Acting Director, Office of Science, April 8, 2014
Presentation at FESAC, by E. Synakowski, Assoc Director, FES. April 10, 2014
Motivation and Process, by Prof. Mark Koepke, FESAC SP Panel Chair

Request for Input
Submitted white papers received by the FESAC subcommittee are available here.
Information on Public Meetings, June 3-5 and July 8-10.
Click here to see the detailed meeting schedule for 3-5 June.
Click here for instructions to remotely connect to the meeting, using Adobe Connect.

Burning Plasma Science: Long Pulse, June 3, Tuesday, (12 talks).
Discovery Science, June 4, Wednesday, (12 talks).
Burning Plasma Science: Foundations, June 5, Thursday, (12 talks).

Burning Plasma Science: Foundations, July 8-10, (12 talks/day):
AT and ST Experiments, Theory and Simulation, Plasma-on-Surface Interaction

Reference Documents and Format Guidance for White Papers and Presentations

FESAC Strategic Planning (SP) Panel Member List

Mark Koepke: **Panel Chair**: West Virginia Univ.
Discovery, Partnerships, **APS-DPP Chair, FESAC Chair**

Steve Zinkle: **Panel Vice Chair**: Univ. Tennessee
Long Pulse, **FESAC Vice Chair**

Kevin J. Bowers: LANL (guest scientist)
Foundations

Troy Carter: University of California – Los Angeles
Foundations, Discovery

Don Correll: Lawrence Livermore National Lab
Discovery, Partnerships

Arati Dasgupta: Naval Research Laboratory
Discovery, Partnerships

Chris Hegna: University of Wisconsin – Madison
Foundations, Long Pulse

William "Bill" Heidbrink: Univ. California – Irvine
Foundations

Stephen Knowlton: Auburn University (retired)
Foundations, Long Pulse

Douglas Kothe: Oak Ridge National Laboratory
Foundations, Partnerships

Stan Milora: Oak Ridge National Lab (retired)
Long Pulse, Partnerships, High Power

David E. Newman: University of Alaska
Foundations, Discovery

Gert Patello: Pacific Northwest National Laboratory
Long Pulse, Partnerships

Don Rej: Los Alamos National Laboratory
Long Pulse, Partnerships

Susana Reyes: Lawrence Livermore National Lab
High Power, Long Pulse

John Steadman: University of South Alabama
FESAC ex-officio member representing IEEE
Partnerships

Karl A. Van Bibber: Univ. California – Berkeley
Long Pulse, Partnerships

Alan Wootton: University of Texas-Austin (retired)
Foundations, Discovery, Partnerships

Minami Yoda: Georgia Institute of Technology
FESAC ex-officio member representing ANS-FED
Long Pulse, Partnerships

The Panel worked in four subpanels

Burning Plasma: Foundations
Burning Plasma: Long Pulse
Discovery Plasma Science
Partnerships with other-federal and international programs.

The eighteen science and technology Thrusts from the 2009 MFE-ReNeW Report were considered, along with valuable community input to the Panel in 2014 through presentations, Question & Answer sessions, and white papers.

Closely related Thrusts that addressed an overarching topic were combined as an Initiative. Prioritization of the Thrusts in terms of metrics that included their importance to Vision 2025 directly led to formulation of four overarching initiatives. These four highest priority Initiatives are categorized into two tiers.

SP Panel thanks the research community

The Panel members are indebted to the research community for its thoughtful previous studies and its broad input into this report. The Panel considered this input, leaving not option off the table and resolved conflicts when they occurred, to reach a consensus that is the basis for the recommended 10-year vision.

The U.S. fusion community looks forward to this transformative era in fusion research that will lay the foundations for a world-leading U.S. subprogram and facility in fusion nuclear science.

To our national and international colleagues, the Panel conveys a heartfelt thank you. We appreciate your understanding of the tight schedule and the magnitude of the charge.

Report Structure

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Introduction – Forward Look

Fusion Science: Preface

Fusion, the energy source that powers the sun and stars, promises a nearly limitless high-density energy source that does not emit greenhouse gases. Fusion energy could fulfill one of the basic needs of a modern civilization: abundant energy with excellent safety features and modest environmental impact that is available to all nations.

The quest for controlled fusion energy— replicating on earth the energy of the Sun— is a scientific grand challenge. After six decades of research, magnetic fusion science has successfully progressed to the threshold of the magnetic fusion energy era. This is an era characterized by burning plasma, steady-state operation, advanced materials that can withstand the harsh environment inside a fusion reactor, and safe regeneration of the fusion fuel from within the reactor.

Vision 2025: U.S. will continue as a world leader in fusion

Priorities resolve ranked scientific/technical gaps

Scientific opportunities on the path to fusion energy development, including international partnering, are pursued.

U.S. program transitions to a fusion energy research program to

(1) enable successful operation of ITER with a significant leading participation by the U.S.;

(2) provide the scientific basis for a U.S. Fusion Nuclear Science Facility (FNSF); and

(3) create a U.S. "Generation ITER-FNSF" workforce that is leading scientific discoveries and technological innovation.

Fusion Science: Preface (cont'd)

At the same time ITER is being constructed, international colleagues are building other large-scale facilities with capabilities that complement those in the U.S.. These new international facilities provide two opportunities for U.S. fusion science.

(1) for the U.S. to initiate and grow a new subprogram in fusion nuclear science, including the design of a facility to conduct research in an area not currently being addressed internationally.

(2) for the U.S. to selectively engage in international collaborations to access new parameter regimes in preparation for the design of the new facility.

The priorities presented have been formulated to enhance and direct areas of U.S. scientific and engineering leadership in coordination with rapidly expanding international expertise and capabilities to realize the prospect of a global fusion energy future at the earliest realistic date. This report provides the basis of that plan with a 10-year vision with priority research recommendations to allow the U.S. to make decisive contributions in fusion science in this new era.

SP Panel Process

Strategic Planning (SP) panel activities

Charge issued: **8 April**; Koepke requests 2-month deadline extension **11 April**; Request denied **14 April**; Subcommittee finalized: **2 May**; Report deadline: 1 **Oct**
https://www.burningplasma.org/activities/?article=2014 FESAC Strategic Planning Panel

FESAC *Strategic Planning* (SP) panel Meeting-Agenda Timeline

Week 3 (30 April): **1st SP Teleconference: Plans for Process and Gathering Input**
Week 6 (20 May): **2nd SP Teleconference: Gathered Input – relevant reports**
Week 8 (2-6 June): **1st SP Meeting – 3-days of talks (Tuesday, Wed, Thursday)**
Week 13 (7-11 July): **2nd SP Meeting – 3-days of talks (Tuesday, Wed, Thursday)**
Week 19 (20 August): **3rd SP Telecon: Priority Assessment**
Week 20 (28 August): **4th SP Telecon: Budget Scenarios**
Week 21 (2-5 September): **3rd SP Meeting – no talks, panel only**
Week 24 (22-23 September): **FESAC Meeting for SP Panel Report Approval**

Initiatives and primary/supporting recommendations

Vision 2025: Primary Recommendation **1**

Control of Burning Plasmas:

The FES experimental program needs an integrated and prioritized approach to achieve a significant leading participation by the U.S. on ITER. Specifically, new proposed solutions will be applied to two long-standing and ubiquitous show-stopping issues, relevant for tokamak-based burning fusion plasma. The issues are:

(1) dealing with unwanted transients, and

(2) dealing the interaction between the plasma boundary and material walls.

Vision 2025: Primary Recommendation **2**

Fusion Predictive Modeling:

FES theory and simulation subprogram should develop the modeling capability to understand, predict, and control

(a) burning, long-pulse, fusion plasmas and

(b) plasma-facing components.

Such a capability, when combined with experimental operational experience, will maximize ITER operation and ITER-results interpretation for burning, long-pulse, fusion plasmas, and decide the necessary requirements for future fusion facilities. This endeavor must encompass the regions from plasma core through to the edge and into the surrounding materials, and requires coupling the nonlinear, multi-disciplinary, multi-scale, phenomena, in experimentally validated, theory-based models

Vision 2025: Primary Recommendation **3**

Fusion Nuclear Science:

A fusion nuclear science subprogram should be created to provide the science and technology understanding for informing decisions on the preferred plasma confinement, materials, and tritium fuel-cycle concepts for a Fusion Nuclear Science Facility (FNSF), a proposed U.S.-based international centerpiece beyond 2025. FNSF's mission is to utilize an experimental plasma platform having a long-duration pulse (up to one million seconds) for the complex integration and for the convergence of fusion plasma science and fusion nuclear science.

Partnering with other-federal and international programs

The experiments available to implement these four primary recommendations are located both in the U.S. and at major international research facilities.

The international experiments provide both access to unique magnetic geometries and long-pulse operating regimes that are unavailable in the U.S. at that scale.

These experiments should provide information required to design FNSF and, ultimately, a fusion demonstration power plant.

Vision 2025: Primary Recommendation **4**

Discovery Plasma Science:

FES stewardship of basic plasma research should be accomplished through strengthening of peer-reviewed university, national laboratory, and industry collaborations. In order to realize the broadest range of plasma science discoveries, the research should be enhanced through federal-agency partnerships that include cost-sharing of intermediate-scale, collaborative facilities

Four Initiatives

Tier 1:

- Control of deleterious transient events (**Transients**)
- Taming the plasma-material interface (**Interface**)

Tier 2:

- Experimentally validated integrated predictive capabilities (**Predictive**)
- A fusion nuclear science subprogram and facility (**FNS**)

Tier 1 Initiatives are higher priority than Tier 2 Initiatives.

Within a tier, the priority is equal.

Control deleterious transient events in burning plasmas: Transients Initiative (Tier 1)

Undesirable transients in tokamak plasmas are ubiquitous but tolerable occurrences in most present-day experiments, but some events could prove too limiting to regular operation of an experiment without frequeny shutdown for repairs. To reduce the threat of disruptions, both passive and active control techniques, as well as preemptive plasma shutdown measures, will be employed.

Taming the plasma-material interface: Interface Initiative (Tier 1)

Understanding the boundary that extends from the high-temperature plasma core to the surrounding material is a priority.

This boundary region establishes the heat and particle fluxes incident on material surfaces and the response of the material surfaces influences the boundary.

Understanding, accommodating, and controlling this complex interaction, while maintaining high confinement, is a prerequisite for ITER success and for designing FNSF.

A self-consistent solution to the plasma-materials interface challenge requires the construction of a prototypic high-power and high-fluence linear divertor simulator. Results from this facility will be iterated with experimental results on suitably equipped domestic and international tokamaks and stellarators, as well as in numerical simulations.

Experimentally Validated Integrated Predictive Capabilities: Predictive Initiative (Tier 2)

Next decade provides an opportunity to break ground in integrated predictive understanding.

Traditionally, theory and simulation model isolated phenomena based on mathematical formulations that have restricted validity regimes. However, there are crucial situations where the coupling between the validity regime and the phenomena is required, which implies that new phenomena can appear.

Expanded computing capabilities, enhancements in analytic theory, and the use of applied mathematics is required.

This effort must be connected to a laboratory experiments and diagnostics to provide crucial tests of theory and allow for validation.

Fusion Nuclear Science: FNS Initiative (Tier 2)

The selection of the plasma magnetic configuration and plasma operational regimes needs to be established based on collaborative long-pulse, high-power research (domestic, international).

Identification is needed of a viable approach to a robust plasma-materials interface that provides acceptably high heat flux capability and low net erosion rates without impairing plasma performance or resulting in excessive tritium entrapment.

Materials research needs to be expanded to comprehend and mitigate neutron-irradiation effects and fuel-cycle research is needed to identify a feasible tritium generation and power-conversion concept. A fusion materials neutron-irradiation facility that leverages an existing megawatt-level neutron spallation source is envisioned as a highly cost-effective option.

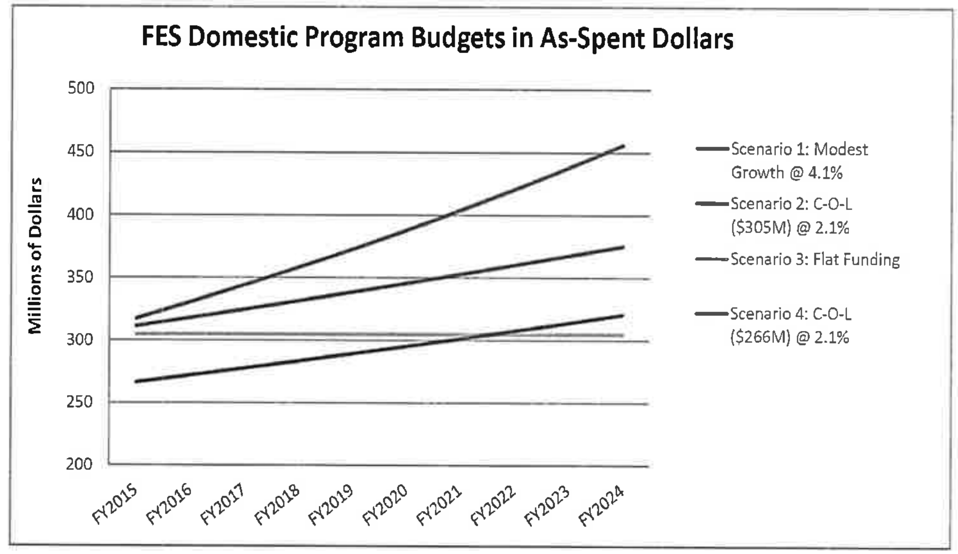
Discovery Plasma Science

In concert with the initiatives, DPS provides transformational ideas. DPS research seeks to address the wide range of fundamental science, including fusion, outlined by the NRC Plasma 2010 report. DPS activities are synergistic with the research mission of other federal agencies and opportunities exist to develop and expand strategic partnerships between FES and other agencies.

Addressing fundamental science questions at the frontier of plasma science requires a spectrum of laboratory experimental facilities from small-scale facilities with a single principal investigator to intermediate-scale, highly collaborative facilities.

Interactions between larger facilities found at national laboratories and small and intermediate facilities can advance DPS frontiers, and enrich the training the next generation of plasma scientists and engineers.

Implementation of the Initiatives are tied to the four Budget Scenario assumptions



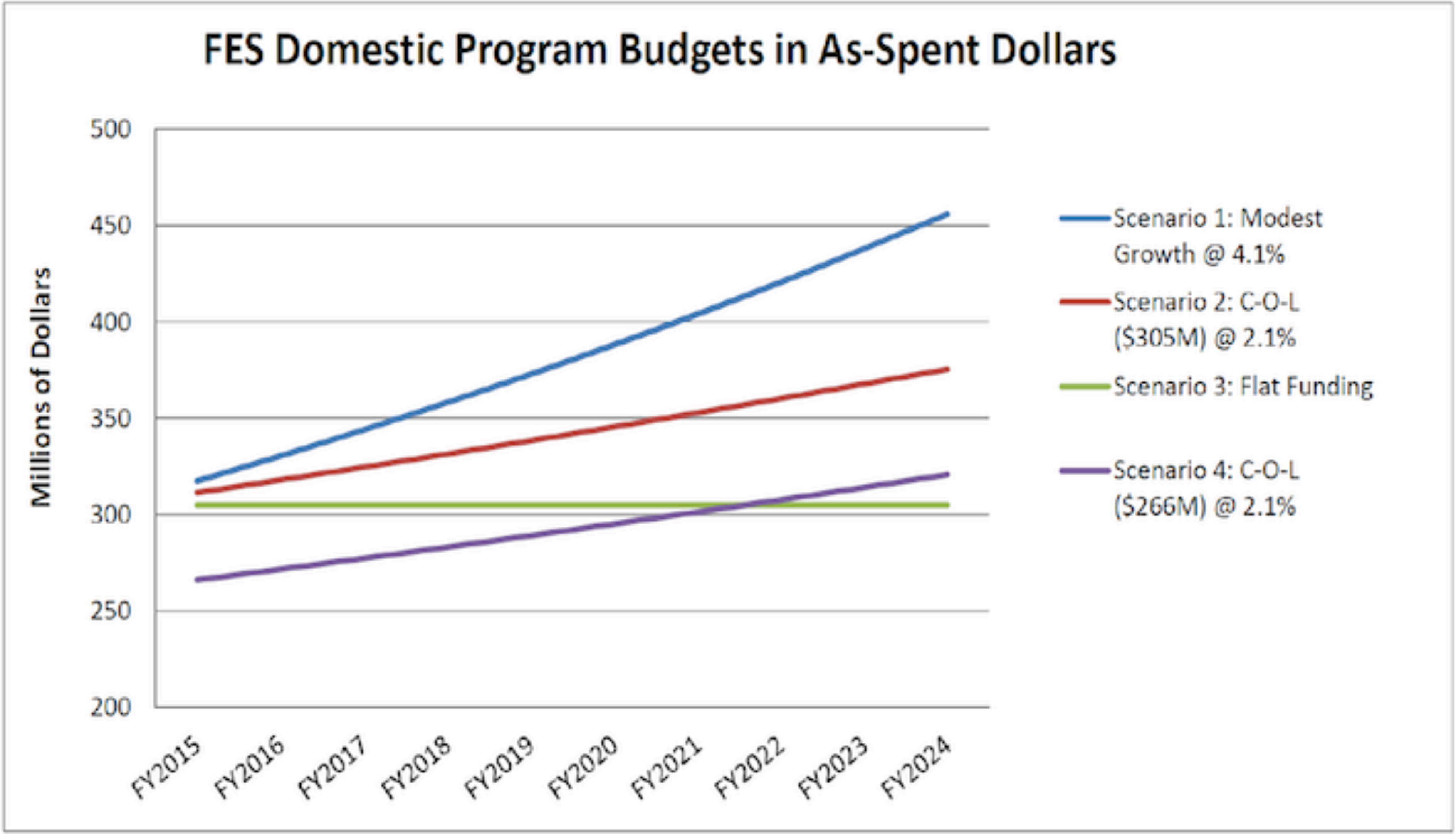
Budgetary Considerations

Implementation

0, -$400M, -$780M, -$900M in the integrated funds are the decrements between Scenarios 1, 2, 3, and 4.

For all scenarios, it was assumed that the scientific workforce was retained in the event of a facility closure. In reallocating funds to the Initiatives, there were obvious problems with time histories. Closures provide a sudden reduction, whereas what is often required for a new Initiative is a ramp.

For the first ~5 years (~2015 to ~2020) the number of run weeks of the two operating facilities (NSTX-U and DIII-D) should be kept significantly higher than in the recent past. Between ~2020 and ~2025, the number of facilities should be at least one, with the date of any shut down (or cold storage) being dependent on budget beyond the smooth scenario. If two facilities were maintained (perhaps a possibility in only the highest budget, Budget Scenario 1), the operational availability of one but not both could be reduced.



FES Domestic Program Budgets in As-Spent Dollars
Millions of Dollars
500
450
400
350
300
250
200
FY2015
FY2016
FY2017
FY2018
FY2019
FY2020
FY2021
FY2022
FY2023
FY2024
Scenario 1: Modest Growth @ 4.1%
Scenario 2: C-O-L ($305M) @ 2.1%
Scenario 3: Flat Funding
Scenario 4: C-O-L ($266M) @ 2.1%

Vision 2025, recommendations, and initiatives will require redirection of resources over the decade

Construction a prototypic **high-power and high-fluence linear divertor simulator** and an **intense, neutron-irradiation source** leveraging an existing MW-level neutron spallation source, are recommended.

Resources for investments in **plasma technology and materials**, **fusion nuclear science**, **modeling and simulation**; **and DIII-D and/or NSTX-U upgrades** should come from major facility or facilities being closed, mothballed, and/or reduced in run weeks, and reconsideration of DPS funding allocations. For all budget scenarios, the Panel recommends:

- increased international collaborations, where scientifically justified,
- the operation of at least one major domestic plasma machine,
- the simultaneous operation of DIII-D and NSTX-U for of order 5 years, and
- the cessation of C-Mod operations.

The five-year operation of NSTX-U enables consideration of a spherical torus magnetic geometry for FNSF. The number and level of facilities operating between years 5 and 10 is budget dependent.

It is crucial that scientists and engineers from the MIT Plasma Science and Fusion Center participate in the proposed Initiatives including taking leadership roles.

Panel explored various funding scenarios to derive credible funding profiles for the highest priority research activities.

- 2014 Modest Growth –Vision 2025 has an acceptable probability of being achieved. Both Tier 1 and Tier 2 Initiatives go forward, informing the design of FNSF. The U.S. features prominently in four areas: Transients, Interfaces, Predictions, and, importantly, FNS.
- 2014 Cost of Living – Vision 2025 can be met, but with lower probability, with probable consequence for one of the two remaining major facilities or for DPS funding. Both Tier 1 and Tier 2 initiatives go forward, with three (Transients, Interface, Predictions) being emphasized. If necessary the Tier 2 Initiative FNS is slowed down. The U.S. features prominently in at least three Initiative areas (Transients, Interfaces, Predictions), with the possibility of featuring prominently in the FNS Initiative.

Focused effort on 4 highest-priority initiatives, with U.S. strengths in diagnostics, experiment, theory, simulation, and computation, promulgates a vibrant program and sets stage for world leadership in emerging key fusion nuclear science research.

Panel explored various funding scenarios to derive credible funding profiles for the highest priority research activities.

- 2014 Flat – Vision 2025 will be only partially met, with consequence for one of the two remaining major facilities, and for DPS. The two Tier 1 Initiatives (Transients, Interfaces) and one Tier 2 Initiative (Predictions) go forward, but the Tier 2 Initiative FNS is slowed. The U.S. Fusion Program features prominently in two, possibly three Initiative areas (Transients, Interfaces, Predictions). .
- 2015 Cost of Living – Vision 2025 will be partially met, but a second Initiative is lost. However, the U.S. will maintain leadership encompassed by the two Tier-1 Initiatives, specifically Transients and Interfaces. The necessary delay to the Initiatives FNS and Predictive could allow international partners to take the leading role in these areas. The U.S. could feature prominently in two Initiative areas (Transients and Interfaces).

New facilities are required for Vision 2025 Initiatives

During Phase 1, both NSTX -U and DIII-D should be available for ITER-related research, for assessing FNSF magnetic geometry, and for Transients Initiative. New international partnership arise.

During Phase 2, at least one of NSTX-U/DIII-D is required for ITER-related research and for Interface and Predictive Initiatives. New international partnerships on superconducting tokamaks and stellarators flourish.

After ~2025, 1 facility is required both for programmatic research and, operating as a User Facility, for DPS. The best facility for beyond ~2025 is not necessarily the same as the best facility for the ~5 years prior to ~2025. If this is the case, then cold storage, i.e., mothballing, should be considered.

Between 2015 and 2025, the DPS program is strengthened by peer-reviewed univ., national lab, and industry collaborations. These collaborations will be enhanced by partnering with federal agencies and by cost-sharing collaborative, intermediate-scale facilities in order to realize the broadest range of plasma science discoveries.

With cost-effective high-impact research enabled by collaborations and partnerships, the DPS program will train a U.S. "Generation ITER-FNSF" workforce that is leading scientific discoveries and technological innovation.

Timeline for Facilities and Initiatives

2015: Initiate cessation of C-Mod operations

2025: Either DIII-D or NSTX-U operating as a national user facility for discovery science as well as for programmatic objectives.

Phase I:

- DIII-D is operating and information on transient mitigation, boundary physics, plasma control, and other ITER-related research is being provided
- NSTX-U is operating and information on potential path to a FNSF-ST, boundary physics, and on ITER-related research is being provided
- Linear divertor simulator is under construction
- Predictive Initiative is launched and grown
- FNS subprogram is initiated
- Scientifically justified international partnerships are increased on leading international superconducting advanced tokamaks and stellarators
- Expanded integration of DPS elements are facilitated for effective stewardship of plasma science

Phase II:

- International partnerships centered on leading international superconducting advanced tokamaks and stellarators
- Minimum of one domestic facility (DIII-D, NSTX-U) operating and providing information for taming the Interface Initiative
- Linear divertor simulator operating and providing information for Interface Initiative
- Predictive Initiative is fully functional and providing information for the Interface Initiative
- FNS subprogram on science and technology for fusion materials thriving, including a new neutron-irradiation capability that levers an existing high-power spallation source
- Priority increasing for fusion power extraction, and tritium sustainability
- DPS collaborations and partnerships are advancing the frontiers of DPS knowledge through highly levered collaborative facilities.

Burning Plasma Science: Foundations

Foundations: Definition

The subprogram Foundations encompasses fundamental and applied research pertaining to the magnetic confinement of plasmas with emphasis on ITER and future burning plasmas. Both experimental and theoretical contributions are included in Foundations with the key objectives being to establish the scientific basis for the optimization of approaches to magnetic confinement fusion based on the tokamak (including the spherical torus), develop a predictive understanding of burning plasma behavior, and develop technologies that will enhance the performance of both existing and next-step machines.

Foundations subprogram elements

- The research and operations of three major U.S. machines, the DIII-D tokamak, the National Spherical Torus Experiment Upgrade (NSTX-U), and the C-MOD tokamak. Infrastructure improvements to these facilities are included, but activities pertaining to steady-state operation and fusion nuclear science are part of the Long Pulse category.
- Theory and Scientific Discovery Through Advanced Computing (SciDAC) activities.
- Smaller tokamak projects.
- Heating, fueling and transient mitigation research.

Foundations Supporting Recommendations for Vision 2025

- Focus research efforts on studies crucial to viability of the ST for FNSF.
- Resolve the major impediment to the success of ITER and to the realization of a tokamak design for FNSF and DEMO, the elimination and/or amelioration of debilitating transient events.
- Technically assess which upgrades to existing facilities or new facilities will most effectively address crucial boundary physics issues.
- Leverage activities with the broader applied mathematics and computer science communities and maintain and strengthen existing base theory and SCIDAC subprograms to maintain world leadership.
- Ensure excellence in the Experimentally Validated Integrated Predictive Capabilities program with a peer-reviewed, competitive proposal process. A community-wide process is needed to precisely define the scope and implementation strategy for ultimately realizing a whole-device predictive model.

Supporting Recommendations for Foundations

Recommendation: *Maintain the strong experimental U.S. focus on eliminating and/or mitigating destructive transient events to enable the high-performance operation of ITER. Develop improved predictive modeling of plasma behavior during controlled transient events to explore the basis for the disruption-free sustained tokamak scenario for FNSF and DEMO.*

Recommendation: *Undertake a technical assessment with community experts to ascertain which existing facility could most effectively address the key boundary physics issues.*

Recommendation: *Maintain and strengthen existing base theory and SCIDAC subprograms to maintain world leadership and leverage activities with the broader applied mathematics and computer science communities.*

Recommendation: *Ensure excellence in the experimentally validated integrated Predictive Initiative with a peer-reviewed, competitive proposal process. A community-wide process is needed to define the scope and implementation strategy for realizing a whole-device predictive model.*

Recommendation: *Focus research efforts on studies crucial to deciding the viability of the ST for FNSF.*

The Foundations subprogram in 2025

ITER research is benefiting from the Transients and Interfaces initiatives.

Accurate predictions of average heat loads to the divertor and pedestal height are being made.

ITER discharge behavior can be modeled sufficiently to predict future alpha-heated burning ITER plasmas.

Looking beyond 2025, the advanced control and sustainment techniques developed on DIII-D and extended to tests on the Asian superconducting tokamaks directly contribute to the ITER mission's long-pulse discharges.

Burning Plasma Science: Long Pulse

Graphical Visualization of Short and Long Pulse-Duration Discharges in terms of Plasma-Confinement Performance

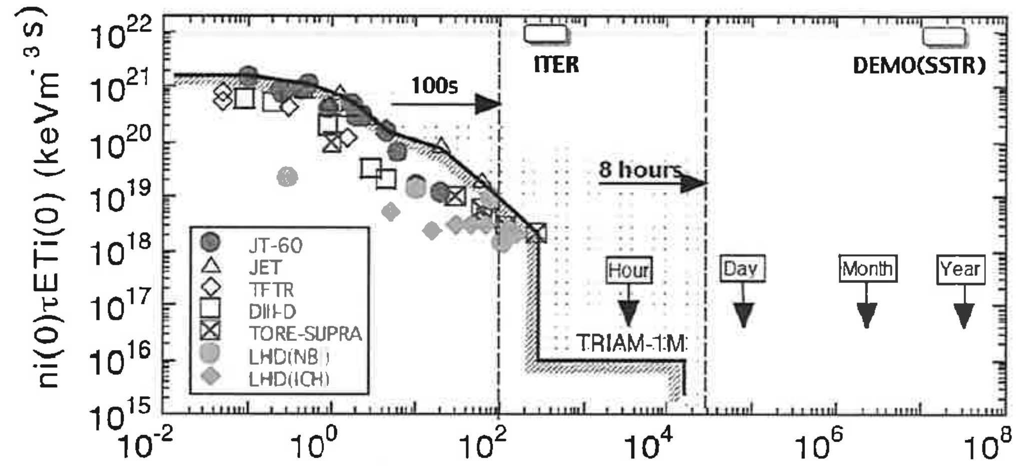


Fig. 4.1 in FESAC's 2012 report on Opportunities in International Collaboration

Long Pulse: Definition

The plasma performance achievable in current or recent tokamak and stellarator experiments, characterized by the fusion figure-of-merit $n\tau_E T$ incorporating the plasma density n, plasma temperature T, and overall energy containment time τ_E, generally decreases as the duration of the plasma increases. The category of Long Pulse research encompasses the extension of high-performance plasmas to discharge durations that progressively satisfy the goals of ITER and FNSF, and project to DEMO and ultimately steady-state fusion power plants.

Long Pulse subprogram elements

- The research and operations of DIII-D, National Spherical Torus Experiment Upgrade (NSTX-U), and C-Mod,
- Long-pulse plasma physics research using stellarators and international superconducting tokamaks,
- Activities in the theory and simulation and the Scientific Discovery Through Advanced Computing (SciDAC) subprograms related to long-pulse plasma operations, plasma material interactions, and fusion nuclear science issues,
- Plasma-material interactions (PMI) and high heat flux (HHF) research for plasma-facing components during long pulse operation,
- Materials science research to understand and mitigate property degradation phenomena associated with intense D-T fusion neutron-irradiation and to design new high-performance materials to enable practical fusion energy,
- Blanket engineering and science to devise solutions for creating and reprocessing the tritium fuel and efficiently utilizing the deposited heat for electricity production, and
- Development of integrated designs and models for attractive fusion power concepts.

Supporting Recommendations for Long Pulse

- Design and build the advanced multi-effects linear divertor simulator described above to support the Interfaces Initiative.

- Design and build a new fusion materials neutron-irradiation facility that leverages an existing MW-level neutron spallation source to support the Fusion Nuclear Sciences Initiative.

- Invest in a research subprogram element on blanket technologies and tritium sustainability that will advance studies from single to multiple effects and interactions.

The Long Pulse subprogram in 2025

- The Interfaces and FNS Initiatives have identified scientifically robust solutions for long pulse DT burning plasma machines.
- The advanced linear divertor simulator is a world-leading user facility.
- Using a fusion materials neutron-irradiation test stand, the preliminary science basis for materials for FNSF and DEMO has been established.
- FNSF configuration is decided; design is underway based on new scientific knowledge of highly stable long pulse plasma configurations, high performance materials systems, innovative fusion blanket systems, and proven tritium extraction techniques.
- Stellarator plasmas suitable for long-pulse operation have been demonstrated in integrated tests.
- Principles of long-pulse advanced tokamak operation are established.

Discovery Plasma Science

DPS: Definition

The subprogram Foundations encompasses fundamental and applied research pertaining to the magnetic confinement of plasmas with emphasis on ITER and future burning plasmas. Both experimental and theoretical contributions are included in Foundations with the key objectives being to establish the scientific basis for the optimization of approaches to magnetic confinement fusion based on the tokamak (including the spherical torus), develop a predictive understanding of burning plasma behavior, and develop technologies that will enhance the performance of both existing and next-step machines.

Supporting Recommendations for DPS

- General Plasma Science (GPS): *FES should take the lead in exploring multi-agency partnering for GPS activities. This effort should include funding for intermediate-scale facilities (as discussed in the NRC Plasma 2010 report) with funding for construction, operations, facility-staff research, and the corresponding user research program.*

- High Energy Density Laboratory Plasmas (HEDLP): *FES should avail itself of SC and NNSA high-energy-density-physics user facilities, within the context of the NNSA-SC Joint Program in HEDLP. This is especially true for the FES HEDLP community researchers who have been awarded experimental shot time, much as FES avails itself of the highly successful SciDAC partnership between ASCR and FES.*

- Self-Organized Systems: *Elements of SO-Systems should adopt subprogram-wide metrics and 3-5-year peer reviews to cultivate a suite of capabilities that explore an intellectually broad set of scientific questions related to self-organized systems.*

- Diagnostic Measurement Innovations: *FES should manage diagnostic development and measurement innovation to have a coordinated cross-cutting set of predictive model validation activities across all DPS subprogram elements.*

The DPS subprogram in 2025

The major FES facilities should have a DPS User Community role per the SC description of User Facilities and User Programs.

Partnerships with Other-Federal and International Research Programs

Partnerships and collaborations in 2025

Supporting Recommendation:
Develop a mutually beneficial partnership agreement with JT60-SA , similar to those already established on EAST and KSTAR, that will allow U.S. Fusion researchers access to this larger-scale, long-pulse device in support of the report initiatives.

Supporting Recommendation
Develop a mutually beneficial partnership with BES that would enable fusion materials scientists access to the Spallation Neutron Source for irradiation studies. Such a partnership will require frequent and effective FES-BES communication, strong FES project management that adheres to Office of Science Project Management best practices, and acceptable mitigation of operational risks.

There are potential opportunities for U.S. fusion researchers to collaboratively access unique foreign facilities, such as: (1) large scale corrosion and thermo-mechanical test loop facilities; (2) high heat flux and plasma material interaction facilities, tokamak diverter exposure facilities (WEST, EAST, ASDEX, etc; (3) future possible fusion neutron irradiation facilities such as IFMIF: (4) tritium facilities;and (5) collaborations with operational, safety and regulatory experts on how to best develop a performance-based regulatory basis for fusion power (Canada, IAEA, JET, ITER).

Federal Programs within DOE Office of Science

Federal Program	FES Themes Benefitting	Current Partnership Status	New or Expanded Opportunity Level	Comments
DOE OFFICE OF SCIENCE				
Advanced Scientific Computing Research (ASCR)	F, LP, DPS	Moderate-Strong	High	Exemplary relationship resulting in U.S. leadership in fusion theory, simulation, and computation. Future SciDAC opportunities for DPS are also evident (cf. Ch. 4)
Basic Energy Sciences (BES)	LP	Moderate	Medium to High	Joint operations of the LCLS MEC Station and longstanding fusion materials irradiation programs using BES reactor neutron sources. Materials Science PI-to-PI interactions evident in core FES programs and BES Energy Frontier Research Centers. Mutual benefits of spallation-neutron-sources use for fusion materials irradiation studies need to be evaluated.
High Energy Physics (HEP)	LP DPS	Minimal	Medium	Modest overlap in plasma science (advanced accelerator and HEDLP) and fusion technology (high-temperature superconducting magnets).
Nuclear Physics (NP)	LP	None	Medium	New Nuclear Physics Program identifies Nuclear Engineering and Applications as a primary client for nuclear data.

Low opportunity corresponds to meeting one or fewer of the four Panel prioritization criteria; **medium** meets two or three criteria; **high** meets all four criteria.

Other Federal Programs

OTHER FEDERAL PROGRAMS				
Dept. Of Defense (DOD)	DPS	Minimal	Low	DOE supports individual HEDLP and ICF projects on DOD facilities. Otherwise, missions are non-overlapping.
Nat. Aeronautics & Space Administration (NASA)	DPS	None	Low	Non-overlapping missions but shared interest in high-heat flux technologies and high-temperature structural materials.
Nat. Inst. of Standards & Technology (NIST)	DPS	None	Low	Complementary materials R&D spanning nanoscience materials to advanced manufacturing.
Nat. Science Foundation (NSF)	DPS	Strong	High	Exemplary relationship, with further opportunities for new Joint programs for research and intermediate-scale facilities.

Low opportunity corresponds to meeting one or fewer of the four Panel prioritization criteria; **medium** meets two or three criteria; **high** meets all four criteria.

Other DOE Federal Programs

OTHER DOE PROGRAMS				
Advanced Research Projects Agency – Energy (ARPA-E)	DPS	Minimal	Unknown at this time	New program announced in Aug. 2014.
Energy Efficiency and Renewable Energy (EERE)	LP	None	Medium	Supports fundamental investigations of additive manufacturing for producing high-performance components that would be difficult or impossible to fabricate using conventional means.
Fossil Energy (FE)	LP	Minimal	Medium	Supports leading approach for developing new steels in both fossil and fusion energy systems based on computational thermodynamics and thermomechanical treatments.
Nuclear Energy (NE)	LP	Moderate	High	Provides infrastructure, materials programs, and nuclear regulatory expertise that should be of significant value to FES as it moves toward an FNS Program.
Nat. Nuclear Security Administration (NNSA)	DPS	Moderate	Medium to High	NNSA-ASCR partnership to develop the next generation computing platforms enables fusion scientists to maintain world-leading capability. Significant HEDLP discovery science opportunities exist on world leading NNSA-operated laser and pulsed-power facilities.

Low opportunity corresponds to meeting one or fewer of the four Panel prioritization criteria; **medium** meets two or three criteria; **high** meets all four criteria.

Major Foreign Facilities	First Plasma or Beam on Target	First Plasma after last major upgrade	Current Partnership Status	Initiative Contribution	Capability
ASDEX Upgrade Tokamak (Germany)	1991		Minimal	Integrated Prediction	Excellent diagnostics
EAST Tokamak (China)	2007	2014	Strong	Interface, Transients	Superconducting long pulse tokamak: hot W divertor
JET Tokamak (UK)	1983	2012 (ITER-like Wall)	Minimal	Fusion Nuclear Science	D-T experiments with Be/W wall
JT60 Tokamak (Japan)	1985	2019 JT60-SA	None	Integrated Prediction	Advanced superconducting tokamak, size scaling
KSTAR Tokamak (S.Korea)	2008		Moderate	Interface, Transients	Superconducting long pulse tokamak
LHD Stellarator	1998	2013 Helical divertor	Moderate	Interface	Superconducting long pulse stellarator with helical divertor
MAST Spherical Torus (UK)	1999	2015	Moderate	Interface	Super-X divertor
Tore Supra Tokamak (France)	1988	2015 (WEST)	None	Interface	Superconducting long pulse tokamak
W7-X Stellarator (Germany)	2015		Strong	Interface, Integrated Prediction	Superconducting long pulse stellarator with island divertor

Minimal partnership corresponds to fewer than two scientist and engineer FTEs; **moderate** between two and five FTEs; **strong** greater than five FTEs.

Community Communication

Community Communication

https://www.burningplasma.org/activities/?article=2014%20FESAC%20Strategic%20Planning%20Panel

This website supports the 2014 FESAC Strategic Planning Panel.
Led by Prof. Mark Koepke (WVU, Chair) and Prof. Steve Zinkle (UT - K, Vice Chair).
Fusion Energy Sciences contact at DOE: Sam Barish
Members of the subcommittee are listed here.

Panel Documents

- Charge, by Patricia Dehmer, Acting Director, Office of Science, April 8, 2014
- Presentation at FESAC, by E. Synakowski, Assoc Director, FES. April 10, 2014
- Motivation and Process, by Prof. Mark Koepke, FESAC SP Panel Chair

Request for Input

Submitted white papers received by the FESAC subcommittee are available here.
Information on Public Meetings, June 3-5 and July 8-10.

- Click here to see the detailed meeting schedule for 3-5 June.
- Click here for instructions to remotely connect to the meeting, using Adobe Connect.

Burning Plasma Science: Long Pulse, June 3, Tuesday, (12 talks).
Discovery Science, June 4, Wednesday, (12 talks).
Burning Plasma Science: Foundations, June 5, Thursday, (12 talks).

Burning Plasma Science: Foundations, July 8-10, (12 talks/day):

- AT and ST Experiments, Theory and Simulation, Plasma-on-Surface Interaction
- Reference Documents and Format Guidance for White Papers and Presentations

Information and guidance in submitting input was provided to the research community

Information on the charge is detailed on the FIRE website (http://fire.pppl.gov) under "Fusion Program News".

To access reference documents and
to receive white-paper guidance, please see the
following website kindly arranged and hosted
by the U.S. Burning Plasma Organization:

https://www.burningplasma.org/activities/?article=2014 FESAC Strategic Planning Panel

Community White Papers
SP Panel received 95 White Papers

Community White Papers

Author(s) Title or Subject

Mohamed Abdou, Alice Ying, Sergey Smolentsev, and Neil B. Morley of UCLA
Scientific Framework for Advancing Blanket/FW/Tritium Fuel Cycle Systems towards FNSF & DEMO Readiness – Input to FESAC Strategic Plan Panel on Blanket/FW Research Initiatives

Ed Barnat, Sandia National Laboratories, Albuquerque N.M.
Dynamic exploratory clusters: Facilitating inter-disciplinary discovery driven research

L.R. Baylor, G.L. Bell, T. S. Bigelow, J. B. Caughman, R. H. Goulding, G.R. Hanson, and D.A. Rasmussen, ORNL, J. C. Hosea, G. Taylor, and R. Perkins, PPPL, J. M. Lohr, P. B. Parks, and R. I. Pinsker, GA, G. Nusinovich, U. of Maryland, M. A. Shapiro and R. J. Temkin, MIT
Plasma Controlling and Actuation Technologies that Enable Long Pulse Burning Plasma Science – Status and Priorities

R. Boivin (GA), M. Austin (UT), T. Biewer (ORNL), D. Brower (UCLA), E. Doyle (UCLA), G. McKee (UW), P. Snyder (GA)
Enhanced Validation of Performance-Defining Physics through Measurement Innovation

Community White Papers

Author(s) Title or Subject

Dylan Brennan, President, UFA, Phil Ferguson, ORNL, Raymond Fonck, UWISC, Miklos Porkolab, MIT, Stewart Prager, PPPL, Ned Sauthoff US ITER, Tony Taylor, GA
Perspectives on Ten-Year Planning for the Fusion Energy Sciences Program

USBPO Diagnostics Topical Group: David L. Brower, Leader. Theodore M. Biewer, Deputy, with R. Boivin, R. Moyer, C. Skinner, D. Thomas, K. Tritz, and K. Young
A Burning Plasma Diagnostic Initiative for the US Magnetic Fusion Energy Science Program

M. R. Brown, representing P. M. Bellan, S. A. Cohen, D. Hwang, E. V. Belova. Swarthmore College
The role of compact torus research in fusion energy science

Tom Brown, PPPL, A Personal View
U.S. Next Step Strategy for Magnetic Fusion

C. Denise Caldwell, NSF MPS-PHY
NSF'S Plasma Physics Program

R.W. Callis, A. Garofalo, V. Chan, H. Guo, GA
Applied Scientific Research to Prepare the Technology for Blanket and Nuclear Components to Enable Design of the Next-Step Burning Plasma Device (Status)

Community White Papers

Author(s) Title or Subject

R.W. Callis, A. Garofalo, V. Chan, H. Guo, GA
Applied Scientific Research to Prepare the Technology for Blanket and Nuclear Components to Enable Design of the Next-Step Burning Plasma Device (Initiative)

C.S. Chang, Princeton Plasma Physics Laboratory
First-Principles Simulation of the Whole Fusion Physics on Leadership Class Computers, in collaboration with ASCR scientists

B. Coppi, MIT Physics
The High Field Compact Line of Experiment: From Alcator to Ignitor and Beyond

R Paul Drake, University of Michigan
Opportunities and Challenges in High-Energy-Density Laboratory Plasmas

R Paul Drake, University of Michigan
Initiatives in High-Energy-Density Laboratory Plasmas

Philip C. Efthimion, PPPL
OFES Stewardship of Plasma Science and its Partnering and Leveraging Discovery Science

Community White Papers

Author(s) Title or Subject

R. Fonck, UWISC, G. McKee, GA, D. Smith, PPPL
Revitalizing university and national facility integration in Fusion Energy Science

W. Fox, A. Bhattacharjee, H. Ji, K. Hill, I. Kaganovich, and R. Davidson, PPPL, A. Spitkovsky, Princeton U., D.D. Meyerhofer, R. Betti, D. Froula, and P. Nilson, U. Rochester, D. Uzdensky and C. Kuranz, UMICH, R. Petrasso and C.K. Li, MIT PSFC, S. Glenzer, SLAC
Laboratory astrophysics and basic plasma physics with high-energy-density, laser-produced plasmas

E. Fredrickson, PPPL
Some Recent Advances in Understanding of Energetic Particle Driven Instabilities and Fast-ion Confinement.

Andrea M. Garofalo and Tony S. Taylor, GA
Leveraging International Collaborations to Accelerate Development of the Fusion Nuclear Science Facility (FNSF)

S. H. Glenzer, SLAC National Accelerator Laboratory
US leadership in Discovery Plasma & Fusion Science

Community White Papers

Author(s) Title or Subject

R. Goldston, PPPL, B. LaBombard, D. Whyte, M. Zarnstorff, MIT PSFC
A Strategy for Resolving the Problems of Plasma-Material Interaction for FNSF

C.M. Greenfield for the U.S. Burning Plasma Organization
Positioning the U.S. to Play a Leading Role in and Benefit from a Successful ITER Research Program

Martin Greenwald, a personal view
Implications and Lessons from 2007 Strategic Planning Activity and Subsequent Events

H.Y. Guo, E.A. Unterberg, S.L. Allen, D.N. Hill, A.W. Leonard, P.C. Stangeby, D.M. Thomas and DIII-D BPMIC Team
Developing Heat Flux and Advanced Material Solutions for Next-Step Fusion Devices

W. Guttenfelder, E. Belova, N.N. Gorelenkov, S.M. Kaye, J.E. Menard, M. Podesta, Y. Ren, and W.X. Wang, PPPL, D.L. Brower, N. Crocker, W.A. Peebles, T.L. Rhodes, and L. Schmitz, UCLA, J. Candy, G.M. Staebler, and R.E. Waltz, GA, J. Hillesheim, CCFE, C. Holland, UCSD, J.H. Irby and A.E. White, MIT, J.E. Kinsey, CompX, F.M. Levinton and H. Yuh, Nova Photonics, M.J. Pueschel, UWisc
Validating electromagnetic turbulence and transport effects for burning plasmas

G.W. Hammett, PPPL, with input from C.S. Chang, S. Kaye, and A. H. Hakim, PPPL, A. Pletzer and J. Cary, Tech-X
An Advanced Computing Initiative To Study Methods of Improving Fusion

Community White Papers

Author(s) Title or Subject

P. W. Humrickhouse, M. Shimada, B. J. Merrill, L. C. Cadwallader, and C. N. Taylor, Idaho National Laboratory
Tritium research needs in support of long-pulse burning plasmas: new initiatives

T. R. Jarboe, C. J. Hansen, A. C. Hossack, G. J. Marklin, K. D. Morgan, B. A. Nelson, D. A. Sutherland, and B. S. Victor
Helicity Injected Torus (HIT) Current Drive Program

Thomas R. Jarboe PI, Richard Milroy Co-PI, Brian Nelson Co-PI, and Uri Shumlak Co-PI, University of Washington, Carl Sovinec PI, University of Wisconsin, Eric Held, Utah State, Vyacheslav Lukin, NRL
Plasma Science and Innovation Center (PSI-Center) at Washington, Wisconsin, Utah State, and NRL

T. R. Jarboe, C. J. Hansen, A. C. Hossack, G. J. Marklin, K. D. Morgan, B. A. Nelson, R. Raman, D. A. Sutherland, B. S. Victor, and S. You
An Imposed Dynamo Current Drive experiment: studying and developing efficient current drive with sufficient confinement at high temperature

For SCIDAC: S. Jardin, PPPL, N. Ferraro, GA, A. Glasser, UWash, V. Izzo, UCSD, S. Kruger TechX, C. Sovinec, HRS Fusion, H. Strauss, UWISC
Increased Understanding and Predictive Modeling of Tokamak Disruptions

Community White Papers

Author(s) Title or Subject

R. J. Hawryluk PPPL, H. Berk UTEXAS, B. Breizman, UTEXAS, D. Darrow, PPPL, R. Granetz, MIT, D. Hillis, ORNL, A. Kritz, LEHIGH, G. Navrati, COLUMBIA U., T. Rafiq, LEHIGH, S. Sabbagh, COLUMBIA U, G. Wurden, LANL, and M. C. Zarnstorff, PPPL
US Collaboration on JET D-T Experiments

David N. Hill, LLNL
Develop the basis for PMI solutions for FNSF and DEMO

Matthew M. Hopkins, Sandia National Laboratories
Overcoming Cultural Challenges to Increasing Reliance on Predictive Simulation

W. Horton, H. L. Berk, C. Michoski, and D. Meyerson, UTEXAS Austin, I. Alvarado and L. Wenzel, National Instruments, Austin, Texas, A. Molvik, D. Ryutov, T. Simonen, and B. Hooper, LLNL, J. F. Santarius, UWISC
A Fusion Science Facility to Evaluate Materials for Fusion Reactors

P. W. Humrickhouse, M. Shimada, B. J. Merrill, L. C. Cadwallader, and C. N. Taylor, Idaho National Laboratory
Tritium research needs in support of long-pulse burning plasmas: gaps, status, and priorities

Community White Papers

Author(s) Title or Subject

H. Ji for the WOPA Team
Initiative for Major Opportunities in Plasma Astrophysics in Discovery Plasma Science in Fusion Energy Sciences

H. Ji, PPPL, C. Forest, UWISC, M. Mauel, Columbia U., S. Prager, PPPL, J. Sarff, PPPL, and E. Thomas, Auburn U.
Initiative for a New Program Component for Intermediate--scale Experiments in Discovery Plasma Science in Fusion Energy Sciences

C. E. Kessel, P. W. Humrickhouse, N. Morley, S. Smolentsev, M. E. Rensink, T. D. Rognlien
Critical Fusion Nuclear Material Science Activities Required Over the Next Decade to Establish the Scientific Basis for a Fusion Nuclear Science Facility

C. E. Kessel, J. P. Blanchard, A. Davis, L. El-Guebaly, N. Ghoniem, P. W. Humrickhouse, A. Khodak, S. Malang, B. Merrill, N. Morley, G. H. Neilson, F. M. Poli, M. E. Rensink, T. D. Rognlien, A. Rowcliffe, S. Smolentsev, L. Snead, M. S. Tillack, P. Titus, L. Waganer, A. Ying, K. Young, Y. Zhai
Critical Fusion Nuclear Material Science Activities Required Over the Next Decade to Establish the Scientific Basis for a Fusion Nuclear Science Facility

Community White Papers

Author(s) Title or Subject

Mike Kotschenreuther, Swadesh Mahajan, Prashant Valanju, Brent Covele, and Francois Waelbroeck, IFS, University of Texas; Steve Cowley UKAEA, John Canik ORNL, Brian LaBombard MIT, Houyang Guo, GA
Taming the Heat Flux Problem, Advanced Divertors towards Fusion Power

Predrag Krstić, Institute for Advanced Computational Science, SBU, Igor Kaganovich, Daren Stotler, Bruce Koel, PPPL
Priorities: Integrated Multi-Scale Divertor Simulation Project

Predrag Krstić, Institute for Advanced Computational Science, SBU, Igor Kaganovich, Daren Stotler, Bruce Koel PPPL
Initiatives: Integrated Multi-Scale Divertor Simulation Project

Mark J. Kushner, UMICH, EECS, Co-submitted by 28 other scientists, at 22 other locations
A Low Temperature Plasma Science Program: Discovery Science for Societal Benefit

Brian LaBombard, MIT PSFC
High priority divertor and PMI research on the pathway to FNSF/DEMO.

Community White Papers

Author(s) Title or Subject

N.C. Luhmann, Jr., A.V. Pham (UC Davis), T. Munsat (U. Colorado)
Advanced Electronics Development for Fusion Diagnostics

R. Maingi, M.A. Jaworski, R. Kaita, R. Majeski, C.H. Skinner, and D.P. Stotler, PPPL, J.P. Allain, D. Andruczyk, D. Currelli, and D.N. Ruzic, Princeton University, B.E. Koel, UIUC
A Liquid Metal PFC Initiative

E. S. Marmar, on behalf of the MIT Alcator Team
Priorities and Opportunities, White Paper for MIT/PSFC 10 Year Research Plan

E. S. Marmar, on behalf of the MIT Alcator Team
Initiatives led by the MIT Plasma Science and Fusion Center: Successful Completion of Alcator C-Mod and Transition to a New, Advanced Divertor High-Field Tokamak Facility

M. Mauel, D. Garnier, J. Kesner, P. Michael, M. Porkolab, T. Roberts, P. Woskov, Dept of Applied Physics and Applied Math, Columbia U., MIT PSFC
Multi-University Research to Advance Discovery Fusion Energy Science using a Superconducting Laboratory Magnetosphere

Community White Papers

Author(s) Title or Subject

B. LaBombard, E. Marmar, J. Irby, J. Terry, R. Vieira, D.G. Whyte, S. Wolfe, S. Wukitch, N. Asakura, W. Beck, P. Bonoli, D. Brower, J. Doody, L. Delgado-Aparicio, R. Ellis, D. Ernst, C. Fiore, R. Granetz, M. Greenwald, Z.S. Hartwig, A. Hubbard, J.W. Hughes, I.H. Hutchinson, C. Kessel, M. Kotschenreuther, S. Krasheninnikiov, R. Leccacorvi, Y. Lin, B. Lipschultz, S. Mahajan, J. Minervini, R. Nygren, R. Parker, F. Poli, M. Porkolab, M.L. Reinke, J. Rice, T. Rognlien, W. Rowan, D. Ryutov, S. Scott, S. Shiraiwa, D. Terry, C. Theiler, P. Titus, G. Tynan, M. Umansky, P. Valanju, F. Waelbroeck, G. Wallace, A. White, J.R. Wilson, S.J. Zweben
ADX: a high field, high power density advanced divertor tokamak experiment.

Mission: Develop and demonstrate plasma exhaust and PMI physics solutions that scale to long pulse at FNSF/DEMO divertor parameters.

T.C. Luce, R.J. Buttery, C.C. Petty, M.R. Wade, GA
Preparing the Foundations for Burning Plasmas and Steady-state Tokamak Operation

T.C. Luce, GA
Missions and Priorities for the US Fusion Program—the Role of Burning Plasma and Steady-State Tokamak Physics

Community White Papers

Author(s) Title or Subject

J. Menard, R. Fonck, R. Majeski for the NSTX-U, Pegasus, and LTX research teams
U.S. Spherical Tokamak Program Initiatives for the Next Decade

T. Munsat (U. Colorado), N.C. Luhmann, Jr. (UC Davis), B. Tobias (PPPL)
Center for Imaging and Visualization in Tokamak Plasmas

R. R. Parker, G-S. Baek, P. T. Bonoli, B. LaBombard, Y. Lin, M. Porkolab, S. Shiraiwa, G. M. Wallace, S. J. Wukitch, D. Whyte, MIT PSFC
RF Actuators for Steady-State Tokamak Development

C. K. Phillips PPPL and P. T. Bonoli MIT, L. A. Berry, XCEL, N. Bertelli, PPPL, D. D'Ippolito, Lodestar, D. L. Green, ORNL, R.W. Harvey, CompX, E. F. Jaeger, XCEL, J. Myra, Lodestar, Y. Petrov, CompX, M. Porkolab, S. Shiraiwa, MIT, D.N. Smithe, TechX, E. J. Valeo, PPPL, and J. C. Wright, MIT
International Collaborative Initiative for RF Simulation Models in support of ITER and the ITER Integrated Modeling Program: Status and Priorities

C. K. Phillips PPPL and P. T. Bonoli MIT, L. A. Berry, XCEL, N. Bertelli, PPPL, D. D'Ippolito, Lodestar, D. L. Green, ORNL, R.W. Harvey, CompX, E. F. Jaeger, XCEL, J. Myra, Lodestar, Y. Petrov, CompX, M. Porkolab, S. Shiraiwa, MIT, D.N. Smithe, TechX, E. J. Valeo, PPPL, and J. C. Wright, MIT
International Collaborative Initiative for RF Simulation Models in support of ITER and the ITER Integrated Modeling Program: Proposed Initiative

Community White Papers

Author(s) Title or Subject

Leanne Pitchford, LAPLACE, CNRS and University of Toulouse III, France
The Plasma Data Exchange Project and the LXCat Platform

Leanne Pitchford, LAPLACE, CNRS and University of Toulouse, France
Resource request for the Plasma Data Exchange Project and the LXCat platform

M. Podesta, D. Darrow, E. Fredrickson, G.-Y. Fu1, N. Gorelenkov, J. Menard, and R. White, PPPL, J. K. Anderson, UWisc, W. Boeglin, FIU, B. Breizman, UTexas, D. Brennan, Princeton U., A. Fasoli, CRPP/EPFL, Z. Lin, UCLA Irvine, S. D. Pinches and J. Snipes, ITER, S. Tripathi, UCLA LA, M. Van Zeeland, GA
Development of tools for understanding, predicting and controlling fast ion driven instabilities in fusion plasmas

S. Prager, Princeton Plasma Physics Laboratory
The PPPL Perspective on Ten Year Planning in Magnetic Fusion

R. Prater, R.I. Pinsker, V. Chan, A. Garofalo, C. Petty, M. Wade, GA
Optimize Current Drive Techniques Enabling Steady-State Operation of Burning Plasma Tokamaks

R. Raman, UWash, T.R. Jarboe, UWash, J.E. Menard, S.P. Gerhardt and M. Ono, PPPL
Development of a Fast Time Response Electromagnetic Disruption Mitigation System

R. Raman, UWash, T.R. Jarboe, and B.A. Nelson, UWash, T. Brown, J.E. Menard, D. Mueller, and M. Ono, PPPL
Simplifying the ST and AT Concepts

Community White Papers

Author(s) Title or Subject

T. Schenkel, P. Seidl, W. Waldron, A. Persaud, LBNL, John Barnard and Alex Friedman, LLNL, E. Gilson, I. Kaganovich, and R. Davidson, PPPL, A. Minor and P. Hosemann, University of California, Berkeley
Discovery Science with Intense, Pulsed Ion Beams

Peter Seidl, Thomas Schenkel, Arun Persaud, and W.L. Waldron, LBNL, John Barnard and Alex Friedman, LLNL, Erik Gilson, Igor Kaganovich, and Ronald Davidson, PPPL
Heavy-Ion-Driven Inertial Fusion Energy

David R. Smith, UWISC
Data science and data accessibility at national fusion facilities

E.J. Strait, GA
Establishing the Basis for Sustained Tokamak Fusion through Stability Control and Disruption Avoidance: (I) Present Status

E.J. Strait, GA
Establishing the Basis for Sustained Tokamak Fusion through Stability Control and Disruption Avoidance: (II) Proposed Research

William Tang, PPPL
Validated Integrated Fusion Simulations Enabled by Extreme Scale Computing

Community White Papers

Author(s) Title or Subject

J. Rapp, D.L. Hillis, J.P. Allain, J.N. Brooks, H.Y. Guo, A. Hassanein, D. Hill, R. Maingi, D. Ruzic, O Schmitz, E. Scime, G. Tynan
Material Facilities Initiative: MPEX and FMITS

S.A. Sabbagh and J.M. Hanson, Columbia U., N. Commaux, ORNL, N. Eidietis, R. La Haye, and M. Walker, GAVE, S.P. Gerhardt, E. Kolemen. J.E. Menard, PPPL, B. Granetz, MIT, V. Izzo, UCSD, R. Raman, U. WASHINGTON, S. Woodruff, Woodruff Scientific
Critical Need for Disruption Prediction, Avoidance, and Mitigation in Tokamaks

Alla Safronova, Physics Department, University of Nevada
Significance of Atomic Physics for Magnetically Confined Fusion and High-Energy-Density Laboratory Plasmas, Status, priorities, and initiatives white paper

J.S. Sarff, A.F. Almagri, J.K. Anderson, D.L. Brower, B.E. Chapman, D. Craig, D.R. Demers, D.J. Den Hartog, W. Ding, C.B. Forest, J.A. Goetz, K.J. McCollam, M.D. Nornberg, C.R. Sovinec, P.W. Terry, and Collaborators
Opportunities and Context for Reversed Field Pinch Research

Ann Satsangi, OFES DOE
Discovery Plasma Science: A question on Facilities

Community White Papers

Author(s) Title or Subject

P.W. Terry UWISC, Peter Catto MIT, Nikolai Gorelenkov PPPL, Jim Myra LODESTAR, Dmitri Ryutov LLNL, Phil Snyder GA, and F. Waelbroeck UTEXAS
Role of Analytic Theory in the US Magnetic Fusion Program

The University Fusion Association
The Role of Universities in Discovery Science

Mickey R. Wade, GA, for the DIII-D Team
Developing the Scientific Basis for the Burning Plasma Era and Fusion Energy Development, (A 10-Year Vision for DIII-D)

Anne White, Paul Bonoli, Bob Granetz, Martin Greenwald, Zach Hartwig, Jerry Hughes, Jim Irby, Brian LaBombard, Earl Marmar, Miklos Porkolab, Syun'ichi Shiraiwa, Rui Vieira, Greg Wallace, and Graham Wright, MIT, David Brower, Neal Crocker, and Terry Rhodes, UCLA, Walter Guttenfelder, PPPL, Chris Holland, UCSD, Nathan Howard, ORISE, George McKee, UWISC
A new research initiative for "Validation Teams"

G. Wurden, S. Hsu, T. Intrator, C. Grabowski, J. Degnan, M. Domonkos, P. Turchi, M. Herrmann, D. Sinars, M. Campbell , R. Betti , D. Ryutov, B. Bauer, I. Lindemuth, R. Siemon, R. Miller, M. Laberge, M. Delage
Magneto-Inertial Fusion

Community White Papers

Author(s) Title or Subject

D. Whyte, MIT Plasma Science and Fusion Center
Exploiting high magnetic fields from new superconductors will provide a faster and more attractive fusion development path

X. Q. Xu, LLNL
International collaboration on theory, validation, and integrated simulation

J. Freidberg, E. Marmar, MIT, H. Neilson , M. Zarnstorff, PPPL
The Case for QUASAR (NCSX)

Thomas Klinger, Hans-Stephan Bosch, Per Helander, Thomas Sunn Pedersen, Robert Wolf Max-Planck Institute for Plasma Physics
A Perspective on QUASAR

Thomas Klinger, Hans-Stephan Bosch, Per Helander, Thomas Sunn Pedersen, Robert Wolf Max-Planck Institute For Plasma Physics
Status And Prospects Of The U.S. Collaboration With The Max-Planck Institute For Plasma Physics On Stellarator Research On The Wendelstein 7-X Device

H. Neilson, D. Gates, M. Zarnstorff, S. Prager, PPPL
Management Strategy for QUASAR

Members of the National Stellarator Coordinating Committee
Control of High-Performance Steady-State Plasmas: Status of Gaps and Stellarator Solutions

Community Workshops and Presentations

Community White Papers

Author(s) Title or Subject

Members of the National Stellarator Coordinating Committee
Solutions for Steady-State High Performance MFE: A U.S. Stellarator Program for the Next Ten Years

Oliver Schmitz, UWISC, on behalf of U.S. stellarator collaborators
Development of 3-D divertor solutions for stellarators through coordinated domestic and international research

Matt Landreman, University of Maryland, on behalf of the US Stellarator Coordinating Committee
3D theory and computation: A cost-effective means to address "long-pulse" and "control" gaps

Tues (12 talks) 3 June:
"Heat Fluxes, Neutron Fluences, Long Pulse Length" [i.e., Burning Plasma: Long Pulse]

0830 **Fonck**, *Perspectives on 10-Year Planning for the Fusion Energy Sciences Program*
0900 **Kessel**, *Critical Fusion Nuclear Material Science Activities Required Over the Next Decade to Establish the Scientific Basis for a Fusion Nuclear Science Facility*
0930 **Abdou**, *Scientific Framework for Advancing Blanket/FW/Tritium Fuel Cycle Systems towards FNSF & DEMO Readiness*
1000 **Wirth** *An Integrated, Component-level Approach to Fusion Materials Development*
1030 Break
1045 **Hill**, *Develop the Basis for PMI Solutions for FNSF*
1115 **Callis**, *Applied Scientific Research for Blanket and Nuclear Components to Enable Design of the Next-Step BP Device*
1145 Lunch
1345 **Zarnstorff,** *U.S. strategies for an innovative stellarator-based FNSF*
1415 **Buttery**, *Establishing the Physics Basis for Sustaining a High* b *BP in Steady-State*
1445 **Prater**, *Optimize Current Drive Techniques Enabling S-S Operation of BP Tokamaks*
1515 Break
1535 **Garofalo**, *Leveraging International Collaborations to Accelerate FNSF Development*
1605 **Harris**, *Alternatives and prospects for development of the U.S. stellarator program*
1635 **Landreman**, *3D theory & computation as a major driver for advances in stellarators*

Wednesday (12 talks) 4 June:
""Astrophysical Phenomena, Plasma Control Important for Industrial Applications"
[i.e., *Discovery Science*]

0840 **Glenzer**, *High-Energy Density science at 4th generation Light Sources*
0910 **Seidl**, *Heavy-Ion-Driven Inertial Fusion Energy*
0940 **Schenkel**, *Discovery Science with Intense, Pulsed Ion Beams*
1010 Break
1030 **Jarboe**, *A pre-Proof-of-Principle experiment of a spheromak formed and sustained by Imposed Dynamo Current-Drive (IDCD)*
1100 **Ji**, *Major Opportunities in Plasma Astrophysics*
1130 Lunch
1315 **Petrasso**, *Oppositely directed laser beams at OMEGA-EP for advancing HED Physics: A Finding & Recommendation of the Omega Laser Users Group*
1345 **Fox**, *Lab astrophysics & basic plasma physics with HED, laser-produced plasmas*
1415 **Drake**, R. P, *Challenges and Opportunities in High-Energy-Density Lab Plasmas*
1445 Break
1505 **Kushner**, *Science Issues in Low Temperature Plasmas: Overview, Progress, Needs*
1535 **Raitses**, *Plasma Science Associated with Modern Nanotechnology*
1605 **Donnelly**, *Ignition Delays in Pulsed Tandem Inductively Coupled Plasmas System*
1635 **Kaganovich**, *DoD's Multi-Institution Collaborations for Discovery Science*

Thurs (12 talks) 5 June:
"Discovery Science, Advanced Measurement for Validation," [i.e., *Discovery Science*]

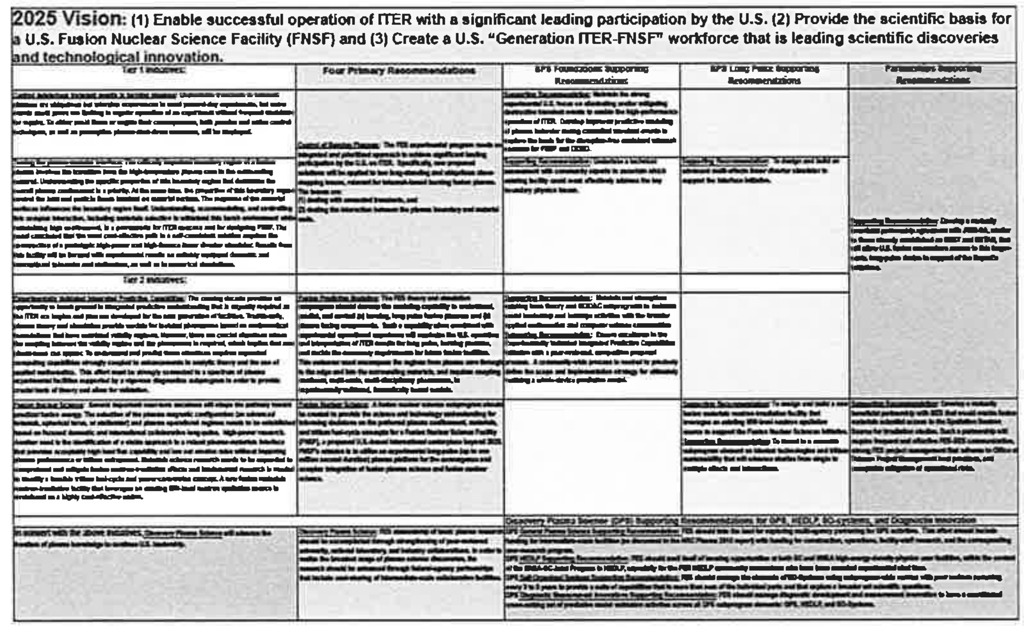
0840 **Wurden**, *Long-pulse physics via international stellarator collaboration*
0910 **Schmitz**, *Development of 3-D divertor solutions for stellarators through coordinated domestic and international research*
0940 **Krstic**, *Multiscale, integrated divertor plasma-material simulation*
1010 Break
1030 **Sarff**, *Opportunities and Context for Reversed Field Pinch Research*
1100 **Mauel**, *Multi-University Research to Advance Discovery Fusion Energy Science using a Superconducting Laboratory Magnetosphere*
1130 Lunch
1315 **Ji**, *Importance of Intermediate-scale Experiments in Discovery Plasma Science*
1345 **Efthimion**, *Office of Science Partnerships and Leveraging of Discovery Science*
1415 **Brennan**, *The Role of Universities in Discovery Science in the FES Program*
1445 Break
1505 **Whyte**, *Exploiting high magnetic fields from new superconductors will provide a faster and more attractive fusion development path*
1535 **Minervini**, *Superconducting Magnets Research for a Viable U.S. Fusion Program*
1605 **Parker**, *RF Actuators for Steady-State Tokamak Development*
1635 **LaBombard**, *A nationally organized, advanced divertor tokamak test facility is needed to demonstrate plasma exhaust and PMI solutions for FNSF/DEMO*

Tuesday July 8 Meeting (16 talks):
0830 **Zohm**, *ASDEX-Upgrade*
0905 **Horton**, *JET*
0940 **Guo**, *EAST*
1015 Break
1045 **Kwak**, *KSTAR*
1120 **Kamada**, The *JT-60SA research regimes for ITER and DEMO*
1155 **Litaudon**, *EUROfusion Roadmap*
1225 **Litaudon**, *WEST facility*
1300 Lunch
1415 **Menard**, *NSTX-U: ST research to accelerate fusion development*
1445 **Majeski**, *LTX: Exploring the advantages of liquid lithium walls*
1515 **Fonck**, *Initiatives in non-solenoidal startup and edge stability dynamics at near-unity aspect ratio in the PEGASUS experiment*
1545 Break
1600 **Marmar,** *Successful completion of Alcator C-Mod, and transition to a new, advanced divertor facility (ADX) to solve key challenges in PMI and development of the steady-state tokamak: Maintaining world-leadership on the high magnetic field path to fusion*
1630 **Wade**, *DIII-D 10-year vision: Develop the scientific basis for burning plasma experiments and fusion energy development*
1700 **Raman**, *Simplifying the ST and AT concepts*
1730 **Guo**, *Developing plasma-based divertor solutions for next step devices*
1800 **Coppi**, *The high-field compact line of experiments: From Alcator to Ignitor & beyond*
1830 **Freidberg,** *MIT-PSFC makes the case for QUASAR*

Wednesday July 9 Meeting (15 talks):
0830 **Greenwald**, *Implications and lessons from 2007 strategic planning activity and subsequent events: A personal view*
0900 **Meade**, *U.S. road map activity*
0930 **Taylor**, *A U.S. domestic program in the ITER era*
1000 **Greenfield**, *USBPO high priority research in support of ITER*
1030 Break
1100 **Boivin**, *Enhanced Validation of Performance-Defining Physics through Measurement Innovation*
1130 **White**, *Advanced diagnostics for validation in high-performance toroidal confinement experiments*
1200 **Crocker**, *Validating electromagnetic turbulence and transport effects for burning plasmas*
1230 **Brower**, *A burning plasma diagnostic technology initiative for the U.S. magnetic fusion energy science program*
1300 Lunch
1445 **Petty**, *Preparing for burning plasma operation and exploitation in ITER*
1515 **Sabbagh**, *Critical need for disruption prediction, avoidance, and mitigation in tokamaks*
1545 **Strait**, *Stability control, disruption avoidance, and mitigation*
1615 **Jardin**, *Increased understanding and predictive modeling of tokamak disrupttions*
1645 Break
1700 **Podesta**, *Development of tools for understanding, predicting and controlling fast-ion-driven instabilities in burning plasmas*
1730 **Fu**, *Integrated simulation of performance-limiting MHD and energetic particle instabilities with micro-turbulence*
1800 **Goldston**, *A strategy for resolving problems of plasma-material interaction for FNSF*

Thursday July 10 Meeting (16 talks)

0830 **Tang**, *Validated integrated fusion simulations enabled by extreme scale computing*
0900 **Snyder**, *Crossing the threshold to prediction-driven research and device design*
0930 **Hammett**, *Integrated computing initiative to predict fusion device performance and study possible improvements*
1000 **Chang**, *First-principles simulation of whole fusion device on leadership class high-performance computers in collaboration with ASCR scientists*
1030 Break
1100 **Xu**, *International collaboration on theory, validation, and integrated simulation*
1130 **Phillips**, *International collaborative initiative for RF simulation models in support of ITER and the ITER integrated modeling program*
1200 **Catto**, *Unique opportunities to advance theory and simulations of RF heating & current drive and core & pedestal physics at reactor relevant regimes in the Advanced Divertor Experiment*
1230 **Terry**, *Role of analytic theory in the U.S. magnetic fusion program*
1300 Lunch
1415 **Hillis**, *Materials facilities initiative*
1445 **Unterberg**, *Advanced Materials Validation in Toroidal Systems for Next-Step Devices*
1515 **Maingi**, *A liquid-metal plasma-facing-component initiative*
1545 **Jaworski**, *Liquid metal plasma-material interaction science and component development toward integrated demonstration*
1615 **Allain**, *Establishing the surface science and engineering of liquid-metal plasma-facing components*
1645 Break
1700 **Baylor**, *Plasma controlling and sustainment technologies that enable long-pulse burning plasma science*
1730 **Gekelman**, *The Basic Plasma Science Facility – Upgrade for the next decade & beyond*
1800 **Prager**, *The PPPL perspective on the charge to the FESAC strategic planning panel*



Conclusion and Summary

End

2025 Vision: (1) Enable successful operation of ITER with a significant leading participation by the U.S. (2) Provide the scientific basis for a U.S. Fusion Nuclear Science Facility (FNSF) and (3) Create a U.S. "Generation ITER-FNSF" workforce that is leading scientific discoveries and technological innovation.

Tier 1 Initiatives:	Four Primary Recommendations	BPS Foundations Supporting Recommendations	BPS Long Pulse Supporting Recommendations	Partnerships Supporting Recommendations
Control deleterious transient events in burning plasmas: Undesirable transients in tokamak plasmas are ubiquitous but tolerable occurrences in most present-day experiments, but some events could prove too limiting to regular operation of an experiment without frequent shutdown for repairs. To either avoid these or negate their consequences, both passive and active control techniques, as well as preemptive plasma-shut-down measures, will be employed.	Control of Burning Plasmas: The FES experimental program needs an integrated and prioritized approach to achieve significant leading participation by the U.S. on ITER. Specifically, new proposed solutions will be applied to two long-standing and ubiquitous show-stopping issues, relevant for tokamak-based burning fusion plasma. The issues are: (1) dealing with unwanted transients, and (2) dealing the interaction between the plasma boundary and material walls.	Supporting Recommendation: Maintain the strong experimental U.S. focus on eliminating and/or mitigating destructive transient events to enable the high-performance operation of ITER. Develop improved predictive modeling of plasma behavior during controlled transient events to explore the basis for the disruption-free sustained tokamak scenario for FNSF and DEMO.		Supporting Recommendation: Develop a mutually beneficial partnership agreement with JT60-SA, similar to those already established on EAST and KSTAR, that will allow U.S. fusion researchers access to this larger-scale, long-pulse device in support of the Report's Initiatives.
Taming the plasma-material interface: The critically important boundary region of a fusion plasma involves the transition from the high-temperature plasma core to the surrounding material. Understanding the specific properties of this boundary region that determine the overall plasma confinement is a priority. At the same time, the properties of this boundary region control the heat and particle fluxes incident on material surface. The response of the material surfaces influences the boundary region itself. Understanding, accommodating, and controlling this complex interaction, including materials selection to withstand this harsh environment while maintaining high confinement, is a prerequisite for ITER success and for designing FNSF. The panel concluded that the most cost-effective path to a self-consistent solution requires the construction of a prototypic high-power and high-fluence linear divertor simulator. Results from this facility will be iterated with experimental results on suitably equipped domestic and international tokamaks and stellarators, as well as in numerical simulations.		Supporting Recommendation: Undertake a technical assessment with community experts to ascertain which existing facility could most effectively address the key boundary physics issues.	Supporting Recommendation: To design and build an advanced multi-effects linear divertor simulator to support the interface initiative.	
Tier 2 Initiatives:				
Experimentally Validated Integrated Predictive Capabilities: The coming decade provides an opportunity to break ground in integrated predictive understanding that is urgently required as the ITER era begins and plan are developed for the next generation of facilities. Traditionally, plasma theory and simulation provide models for isolated phenomena based on mathematical formulations that have restricted validity regimes. However, there are crucial situations where the coupling between the validity regime and the phenomena is required, which implies that new phenomena can appear. To understand and predict these situations requires expanded computing capabilities strongly coupled to enhancements in analytic theory and the use of applied mathematics. This effort must be strongly connected to a spectrum of plasma experimental facilities supported by a vigorous diagnostics subprogram in order to provide crucial tests of theory and allow for validation.	Fusion Predictive Modeling: The FES theory and simulation subprogram should develop the modeling capability to understand, predict, and control (a) burning, long pulse fusion plasmas and (b) plasma facing components. Such a capability when combined with experimental operational experience will maximize the U.S. operation and interpretation of ITER results for long pulse, burning plasmas, and decide the necessary requirements for future fusion facilities. This endeavor must encompass the regions from plasma core through to the edge and into the surrounding materials, and requires coupling nonlinear, multi-scale, multi-disciplinary phenomena, in experimentally validated, theoretically based models.	Supporting Recommendation: Maintain and strengthen existing base theory and SCIDAC subprograms to maintain world leadership and leverage activities with the broader applied mathematics and computer science communities Supporting Recommendation: Ensure excellence in the Experimentally Validated Integrated Predictive Capabilities Initiative with a peer-reviewed, competitive proposal process. A community-wide process is needed to precisely define the scope and implementation strategy for ultimately realizing a whole-device predictive model.		
Fusion Nuclear Science: Several importantl near-term decisions will shape the pathway toward practical fusion energy. The selection of the plasma magnetic configuration (an advanced tokamak, spherical torus, or stellarator) and plasma operational regimes needs to be established based on focused domestic and international collaborative long-pulse, high-power research. Another need is the identification of a viable approach to a robust plasma-materials interface that provides acceptably high heat flux capability and low net erosion rates without impairing plasma performance or tritium entrapment. Materials science research needs to be expanded to comprehend and mitigate fusion neutron-irradiation effects and fundamental research is needed to identify a feasible tritium fuel-cycle and power-conversion concept. A new fusion materials neutron-irradiation facility that leverages an existing MW-level neutron spallation source is envisioned as a highly cost-effective option.	Fusion Nuclear Science: A fusion nuclear science subprogram should be created to provide the science and technology understanding for informing decisions on the preferred plasma confinement, materials, and tritium fuel-cycle concepts for a Fusion Nuclear Science Facility (FNSF), a proposed U.S.-based international centerpiece beyond 2025. FNSF's mission is to utilize an experimental long-pulse (up to one million second duration) plasma platform for the convergence and complex integration of fusion plasma science and fusion nuclear science.		Supporting Recommendation: To design and build a new fusion materials neutron-irradiation facility that leverages an existing MW-level neutron spallation source to support the Fusion Nuclear Sciences Initiative. Supporting Recommendation: To invest in a research subprogram element on blanket technologies and tritium sustainability that will advance studies from single to multiple effects and interactions.	Supporting Recommendation: Develop a mutually beneficial partnership with BES that would enable fusion materials scientist access to the Spallation Neutron Source for irradiation studies. Such a partnership will require frequent and effective FES-BES communication, strong FES project management that adheres to Office of Science Project Management best practices, and acceptable mitigation of operational risks.
		Discovery Plasma Science (DPS) Supporting Recommendations for GPS, HEDLP, SO-systems, and Diagnostic Innovation		
In concert with the above initiatives, Discovery Plasma Science will advance the frontiers of plasma knowledge to continue U.S. leadership.	Discovery Plasma Science: FES stewardship of basic plasma research should be accomplished through strengthening of peer-reviewed university, national laboratory, and industry collaborations. In order to realize the broadest range of plasma science discoveries, the research should be enhanced through federal-agency partnerships that include cost-sharing of intermediate-scale collaborative facilities.	DPS General Plasma Science Supporting Recommendation: FES should take the lead for exploring multi-agency partnering for GPS activities. This effort should include funding for intermediate-scale facilities (as discussed in the NRC Plasma 2010 report) with funding for construction, operations, facility-staff research, and the corresponding user-research program. DPS HEDLP Supporting Recommendation: FES should avail itself of levering opportunities at both SC and NNSA high-energy-density-physics user facilities, within the context of the NNSA-SC Joint Program in HEDLP, especially for the FES HEDLP community researchers who have been awarded experimental shot time. DPS Self-Organized Systems Supporting Recommendation: FES should manage the elements of SO-Systems using subprogram-wide metrics with peer reviews occurring every 3 to 5 years to provide a suite of capabilities that is more than sum of the individual parts and that explore a broader set scientific questions. DPS Diagnostic Measurement Innovations Supporting Recommendation: FES should manage diagnostic development and measurement innovation to have a coordinated cross-cutting set of predictive model validation activities across all DPS subprogram elements: GPS, HEDLP, and SO-Systems.		