2014 Activities of the Fusion Energy Sciences Advisory Committee (FESAC)

Mark Koepke, *West Virginia University*

FESAC Chair

www.science.energy.gov/fes/fesac
www.burningplasma.org
http://fire.pppl.gov

APS-DPP Meeting
Monday 27 October 2014
New Orleans Marriott, New Orleans, LA

FESAC's departing members June 2014:

Ray Fonck, U. Wisconsin
Amanda Hubbard, MIT
Hantao Ji, Princeton University and PPPL
Ray Leeper, Los Alamos National Laboratory

FESAC's new members June 2014:

Troy Carter, UCLA
Arati Dasgupta, NRL
Chris Hegna, U. Wisconsin
Valerie Izzo, UCSD
Gert Patello, Pacific Northwest National Lab
Don Rej, Los Alamos National Laboratory

FESAC's continuing members for 2014:

Amitava Bhattacharjee, PPPL, U. Princeton
Bruce Cohen, LLNL
John Foster, U. Michigan
Chuck Greenfield, General Atomics
Richard Groebner, General Atomics
Chris Keane, Washington State U.
Jin-Soo Kim, FAR-TECH, Inc.
Fred Skiff, U. Iowa, *APS-DPP* →
Minami Yoda, Georgia Tech, *ANS-FED* →
Mark Koepke, W. Virginia U., **Chair**
Hutch Neilson, PPPL
Juergen Rapp, ORNL
Linda Sugiyama, MIT
Steven Zinkle, U. Tennessee, **Vice Chair**
Ellen Zweibel, U. Wisconsin-Madison
John Steadman, U. South Alabama, *IEEE*
Riccardo Betti, U. Rochester, *APS-DPP*
Susana Reyes, LLNL, *ANS-FED*

FESAC processes involve **a charge** issued by DOE Office of Science (SC), appointment of a subcommittee/panel, input gathering, deliberations, draft report, FESAC presentation, FESAC revision, FESAC approval, report submission to DOE-SC

Each FESAC meeting includes a Public Comment Session. *Speakers wishing to present should contact Dr. Sam Barish* (sam.barish@science.doe.gov) *to be put on the session schedule.*

FESAC Charges issued in 2014:

Assessment of Workforce Development Needs (AWDN) in the Office of Science research disciplines (Hantao Ji, *Chair*, and Ed Thomas, *Vice Chair*)

Committee of Visitors (COV) (Amitava Bhattacharjee, *Chair*)

Priorities Assessment and Budget Scenarios for Strategic Planning (SP) for 2015-2024 (Mark Koepke, *Chair*, and Steve Zinkle, *Vice Chair*)

Assessment of Workforce Development Needs (AWDN) *in the Office of Science research disciplines*

Charge issued**: February**; Subcommittee formed**: March**; Report deadline: 30 **June**
https://www.burningplasma.org/activities/?article=FESAC Subcommittee on Workforce Development

Jean Paul Allain	University of Illinois at Urbana-Champaign
Lee Berry	Oak Ridge National Laboratory
Rich Groebner	General Atomics
Amanda Hubbard	Massachusetts Institute of Technology
Hantao Ji (Chair)	Princeton University and PPPL
Ray Leeper	Los Alamos National Laboratory
Ed Thomas (Vice Chair)	Auburn University

Names highlighted in blue are FESAC members

Assessment of Workforce Development Needs (AWDN) *in the Office of Science research disciplines*

Findings to identify **disciplines not well represented in academic curricula**:

F1. Curricula in MFE core disciplines are reasonably represented in academia.

F2. The university HEDLP/IFE research groups are small in number but stable in size.

F3. Discovery Plasma Science is stable and healthy at a large number of universities. Curricula in Discovery Plasma Science are strong.

F4. All emerging disciplines in fusion engineering sciences are poorly represented in curricula.

Findings to identify **disciplines in high demand**:

F5. The demand in workforce in the core disciplines is strong and is well matched by the strong curricula, with the exception of diagnostics for MFE, which is least represented in curricula.

F6. Fusion engineering sciences are in high demand, as a whole, and are poorly represented in curricula.

Finding to identify **disciplines for which the DOE labs may play a role in workforce needs**:

F7. There is general recognition that national labs can play a role in workforce development for the emerging disciplines, especially in fusion engineering sciences.

Finding for grad **student/postdoc programs that address discipline-specific workforce needs**:

F8. It is critical to support faculty who develop and deliver curricula of sufficient depth and breadth and who provide research training needed for workforce development.

Assessment of Workforce Development Needs (AWDN) *in the Office of Science research disciplines*

Recommendations for **Curriculum development and classroom education**:

***1**. Establish summer schools for grad students and postdocs in fusion engineering sciences*.

***2.** Establish a consortium among national labs and academic institutions to enhance grad student training & develop curricula for advanced diagnostics & fusion engineering sciences.*

Recommendations for **Workforce development needs in research training**:

***3**. Encourage grad students/postdocs to pursue fusion engineering sciences*.

***4a.** Enhance the participation of universities in large FES projects and FES international collaborations – particularly in the areas of advanced diagnostic and materials development.*

***4b**. Establish a program at national labs to support grad students and postdocs in advanced diagnostics and in targeted emerging engineering science areas, including nuclear materials.*

Committee of Visitors

Charge issued: **8 April**; COV formed: **30 July**; Report deadline: **30 January**

What—A panel to assess the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document funding actions and to assess the quality of the resulting portfolio The national and international standings of the programs' sub-elements are part of the evaluation of the breadth and depth of the portfolio

Who—Each COV panel is composed of a group of recognized scientists and research program leaders with broad expertise in the designated program areas

When—Each program element must be reviewed once every 3 years

Why—To ensure quality and fairness and to help foster improvements

Where—A 2.5-day visit to DOE Germantown area to review documents and meet with DOE program managers

Committee of Visitors

Theory and Computation **Amitava Bhattarcharjee** PPPL, Chair;
Alice Koniges LLNL

Toroidal Experiment **David Gates** PPPL;
Jerry Hughes MIT

Enabling Technology **Richard Temkin** MIT;
Richard Kurtz Pacific Northwest National Laboratory;
Russ Doerner Univ. Calif. San Diego

Experimental Plasma Research **Mark Nornberg** U. Wisconsin;
Brian Nelson U. Washington

General Plasma Science **Bill Amatucci** NRL;
Steve Vincena UCLA

High-Energy-Density **Bob Rosner** Univ. Chicago

Project Management (ITER) **Joe Arango** DOE-TJSO;
Mark Reichanadter SLAC;
John Tapia LANL

Names highlighted in blue are FESAC members

Strategic Planning (SP) panel activities

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

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

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 comprised the charge to the FESAC SP 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 was 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 [stellarators and long-pulse tokamaks] (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, separate budget is assumed), 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 2015, the DOE Office of Science (DOE-SC) asked FESAC

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

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

This was 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 initiatives that were ranked came from the research community. 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.

The response to the charge was careful and precise.

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: Univ. 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

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 Lab
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: Univ. of Texas-Austin (retired)
Foundations, Discovery, Partnerships

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

Names highlighted in blue are FESAC members

Panel unanimously signed the submitted draft report

Mark E. Koepke: Chair
West Virginia University

Steve J. Zinkle: Vice Chair
University of Tennessee – Knoxville

Kevin Bowers
LANL (guest scientist)

Troy Carter
University of California – Los Angeles

Don Correll
Lawrence Livermore National Laboratory

Arati Dasgupta
Naval Research Laboratory

Chris Hegna
University of Wisconsin – Madison

Bill Heidbrink
University of California – Irvine

Stephen Knowlton
Auburn University (retired)

Douglas Kothe
Oak Ridge National Laboratory

Stan Milora
Oak Ridge National Laboratory (retired)

University of Alaska

Gert Patello
Pacific Northwest National Laboratory

Don J. Rej
Los Alamos National Laboratory

Susana Reyes
Lawrence Livermore National Laboratory

John Steadman
University of South Alabama

Karl A. Van Bibber
University of California – Berkeley

Alan Wootton
University of Texas - Austin (retired)

Minami Yoda
Georgia Institute of Technology

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 primary recommendations and four overarching initiatives. These four highest priority Initiatives are categorized into two tiers.

SP Panel Process

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**

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 no 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 can look forward to this transformative era in fusion research that will lay the foundations for a world-leading U.S. subprogram and, hopefully, a 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.

The quality, imagination, comprehensive coverage of fusion science (discovery, plasma, and nuclear sciences) input was impressive and spoke to the priorities, gaps, and opportunities described in 2007.

Report Structure

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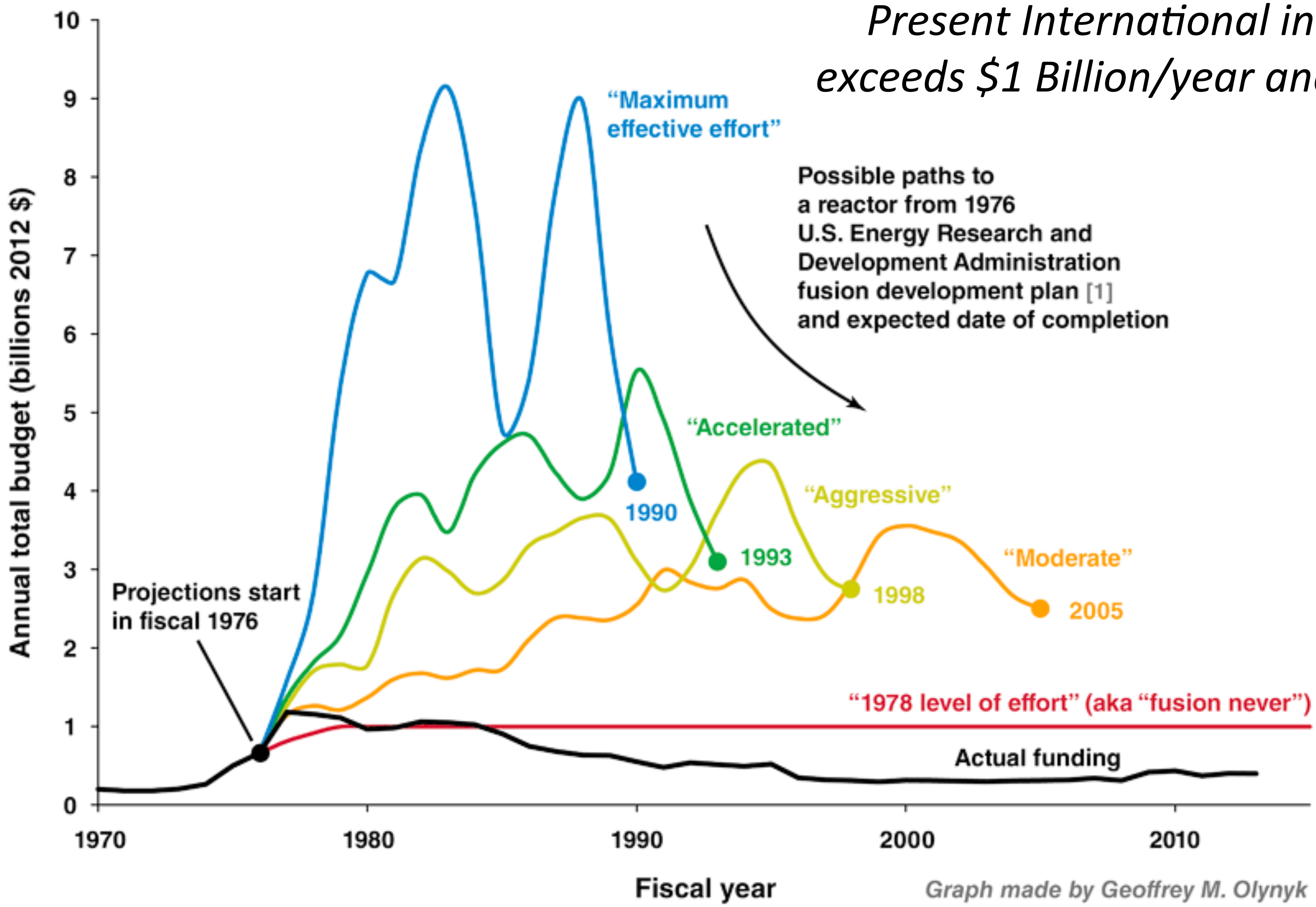
Recent international investments compensate the shortfall of the historical U.S. fusion budget profile toward fusion development

Present International investment exceeds $1 Billion/year and will rise



[1] U.S. Energy Research and Development Administration, 1976. "Fusion power by magnetic confinement: Program plan" ERDA report ERDA-76/110. Also published as S.O. Dean (1998), *J. Fus. Energy* **17**(4), 263–287, doi:10.1023/A:1021815909065

http://commons.wikimedia.org/wiki/File:U.S._historical_fusion_budget_vs._1976_ERDA_plan.png

Vision
Primary recommendations
Initiatives

Vision 2025: Priorities resolve the ranked scientific/technical gaps

Enable U.S. leadership in burning plasma science and fusion power production research, including programs planned for ITER – the world's premier upcoming fusion facility.

Provide the scientific and technological basis for a U.S. Fusion Nuclear Science Facility (FNSF) – a critical next step towards commercial fusion power.

Continue U.S. leadership in discovery plasma science, fusion-related technology, and other areas needed to realize the promise of fusion energy and develop the future fusion workforce.

As scientific opportunities on the path to fusion energy development, including international partnering, are pursued, the U.S. can:

- participate significantly in the successful operation of ITER;
- initiate a broad fusion nuclear science subprogram with the intent to construct, operate, and host researchers at a U.S. Fusion Nuclear Science Facility (FNSF); &
- create a pioneering research atmosphere for a U.S. "Generation ITER-FNSF" workforce that is leading global scientific discoveries and technological innovation.

Vision 2025: Primary Recommendation 1

Control of Burning Plasmas:

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

(1) dealing with unwanted transients, and

(2) dealing with 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 optimize ITER operation and maximize ITER-results interpretation for burning, long-pulse, fusion plasmas, and will 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-scale, multi-disciplinary, phenomena, in experimentally validated, theory-based models

Vision 2025: Primary Recommendation **3**

Fusion Nuclear Science:

A fusion nuclear science subprogram should be created to, besides push the fusion nuclear science frontier and exert a long-term leadership role in this area, 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 fusion plasma science's and fusion nuclear science's complex integration and convergence.

Vision 2025: Primary Recommendation **4**

Discovery Plasma Science:

FES stewardship of basic plasma research should be accomplished through 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 with which grand scientific challenges in select physics-discovery frontiers can be resolved.

Vision 2025: 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 sites.

The international experiments provide access both to unique magnetic geometries and to extended operating regimes unavailable in the U.S..

These experiments should provide information required to design FNSF beyond 2025 and, ultimately, a fusion demonstration power plant.

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 Initiative)

Undesirable transients in tokamak plasmas are ubiquitous, but tolerable, occurrences in most present-day experiments, but could prevent regular operation of a burning plasma experiment on the scale of ITER without frequent shutdown for repairs. To reduce the threat of disruptions to tolerable levels in upcoming nuclear experiments, 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 Initiative)

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, in turn, 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 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 Initiative)

The coming 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. An increasing number of situations are found where the validity regime and the phenomena need to be coupled to account for all relevant phenomena.

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 Initiative)

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

A viable approach to a robust plasma-materials interface needs to be identified 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 expand to comprehend/mitigate neutron-irradiation effects, and fuel-cycle research is needed to identify a feasible tritium generation and power-conversion blanket/first-wall concept. A materials neutron-irradiation facility that leverages an existing megawatt-level neutron spallation source is envisioned as a cost-effective option.

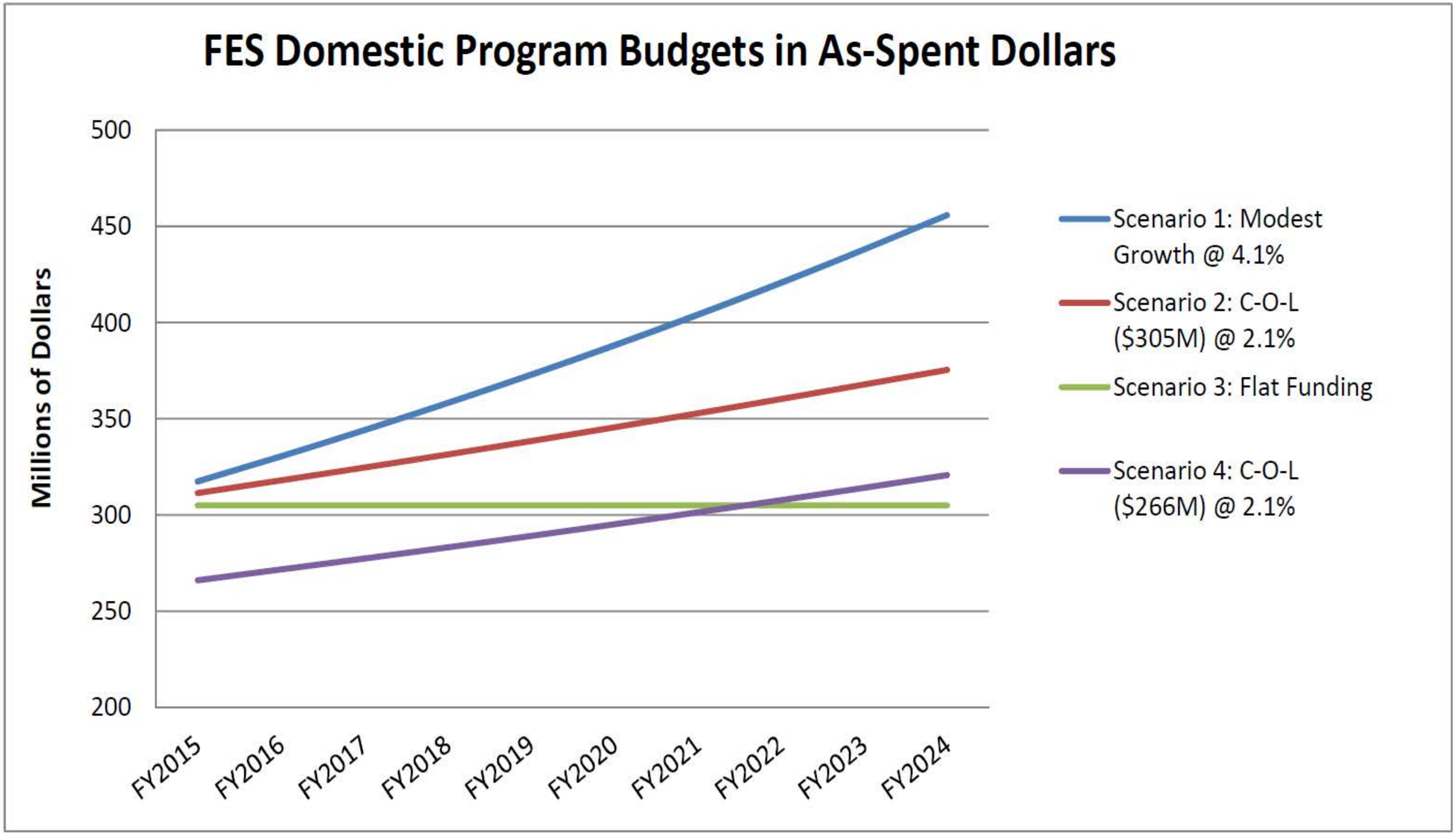
Discovery Plasma Science

In concert with the initiatives, DPS provides transformational ideas. DPS research seeks to address the wide, but select, range of basic science, including magnetic-fusion science, 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 plasma science frontier 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.

Budgetary Considerations for Vision 2025



Implementation

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

For all scenarios, it was assumed that the scientific workforce was retained in the event of a facility closure.

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 for 10 years (a possibility, but perhaps in only the highest budget, Budget Scenario 1), the operational availability of one but not both could be reduced.

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 facility** leveraging an existing MW-level neutron spallation source, are recommended.

Resources for investments in **plasma technology and materials science**, **fusion nuclear science**, **theory and simulation**; **and DIII-D and/or NSTX-U upgrades** should come from major-facility closure(s) and, in the lower budget scenarios, reduction of run weeks and reconsideration of DPS funding allocations. For all budget scenarios, the Panel recommends:

- increased international collaborations in targeted areas of importance,
- 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
- C-Mod operations end.

The five-year operation of NSTX-U enables consideration of a spherical torus magnetic geometry for FNSF. The five-year operation of DIII-D provides optimal investigation of transient mitigation and plasma control for ITER.

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

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, Interface, Predictive, 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, Predictive) being emphasized. If necessary the Tier 2 Initiative FNS is slowed down. The U.S. features prominently in at least three Initiative areas (Transients, Interface, Predictive), with the possibility of featuring prominently in the FNS Initiative. U.S. prospects for FNS-frontier leadership diminish.

Focused effort on 4 highest-priority initiatives, with U.S. strengths in diagnostics, experiment, theory, simulation, and computation, can support 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 lowest priority research activities.

- 2014 Flat – Vision 2025 only partially met, earlier next-closure of a major facility, and reduction to DPS. Neutron-irradiation facility may not be possible, but linear divertor simulator and the upgraded tokamak-divertor are operating. The two Tier 1 Initiatives (Transients, Interface) and one Tier 2 Initiative (Predictive) go forward, but the Tier 2 Initiative FNS is slowed further. The U.S. fusion program features prominently in two (Transients, Interface), possibly also in the Predictive Initiative.

- 2015 C.O.L – Vision 2025 only partially met, and the second Tier 2 (Predictive) Initiative is lost. DPS funds get reduced slightly and linear divertor simulator and/or the upgraded tokamak divertor may not be possible in spite of a 2020 next-closure of a major facility. It is expected that the U.S. will be influential in the research fields encompassed by the two Tier-1 Initiatives (Transients and Interface). The necessary delay to the Initiatives FNS and Predictive will leave significant obstacles in the path to fusion power precisely where the U.S. is best situated to lead the way, ceding the leading role in these areas to the international programs. The U.S. would be in a weak position to proceed as an innovative center of fusion science beyond 2025.

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 collab-orative, intermediate-scale facilities in order to realize the broadest range of plasma science discoveries.

With such collaborations in place, DPS will able to train the next generation of plasma scientists to ensure continuing U.S. leadership in plasma science.

Timeline for Facilities and Initiatives

Phase I:

- Alcator C-Mod operation ends
- DIII-D operating and providing info on transient mitigation, boundary physics, plasma control, and other ITER-related research
- NSTX-U operating and providing information on potential path to a FNSF-ST, boundary physics, and on ITER-related research
- Linear divertor simulator is under construction
- Predictive Initiative is launched and grown
- FNS subprogram is initiated
- Partnerships on leading international superconducting tokamaks and stellarators are increased with intentions of supporting long-term engagements
- Expanded integration of DPS elements facilitate the effective stewardship of plasma science

Phase II:

- Partnerships are centered on leading international superconducting tokamaks and stellarators
- Minimum of one domestic facility (DIII-D, NSTX-U) operating and providing information for the Interface Initiative
- Linear divertor simulator operating and providing information for the Interface Initiative
- Predictive Initiative is fully underway and providing information in support of all Initiatives
- FNS Initiative underway and expanding science and technology for fusion materials, including a new neutron-irradiation capability
- Priority increasing for fusion power extraction, and tritium sustainability
- DPS partnerships advancing the frontiers of DPS knowledge enhanced by cost-sharing on intermediate-scale collaborative facilities.

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

End