EPAct Draft Report Discussion…

U.S. BURNING PLASMA ORGANIZATION

- Purpose
- Structure
- Content
- Remaining…

R. J. Fonck

for the

USBPO EPAct Task Group

presented to

FESAC

Gaithersburg, MD

June 1, 2006

Why are We Here? Help Address BP/ITER Research Plan

U.S. BURNING PLASMA ORGANIZATION

- Energy Policy Act of July, 2005 calls for a Plan for US Participation in ITER
- DoE/OFES asked USBPO to help develop this Plan
- Consultation with FESAC required and desired
- Relatively short time allowed
    - DOE/OFES needs document by ~ June 9
    - Task Group has produced a Draft Report for discussion with FESAC
    - Clean-up and integration ongoing

Charge Letter from A. Davies, AD, OFES

U.S. BURNING PLASMA ORGANIZATION

…The EPAct requires the Secretary of Energy to develop a Plan, in consultation with the Fusion Energy Sciences Advisory Committee (FESAC), for the participation of United States scientists in ITER that include:

(i) The U.S. research agenda for ITER;
(ii) Methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power; and
(iii) Description of how work at ITER will relate to other elements of US fusion program.

The EPA also requires that the Secretary shall request a review of the plan by the National Academy of Sciences.

I would like the U.S. Burning Plasma Organization (USBPO) to develop this Plan in close cooperation with the U.S. fusion community. …

…The Plan, including consultation with FESAC … must be completed by June 30, 2006. …

…Your status report on BPO to FESAC on March 1 should include your approach to prepare this Plan. …

Please let me know any obstacles you see in completing this task by June 2006.

USBPO

Customers and Scope

U.S. BURNING PLASMA ORGANIZATION

- Customers
  - Immediate = OFES and DOE as raw material for part of its EPAct response
  - Ultimate = Congress and Staff (via DOE/OFES incorporation into overall EPAct response)
  - While NOT explicitly for the community, technical details in back to support future work
- Scope = First draft at devising a plan for ITER participation
  - ITER participation a given; no need to justify
  - BUT need to demonstrate organization of community and development of plans to respond to major new direction of the fusion program
  - Summary answers to 3 charges
  - Provide a White Paper for seeding a more in-depth planning process
    - NOT the final word in this; rather, the beginning…

EPAct Task Group Members

U.S. BURNING PLASMA ORGANIZATION

Chair = R. Fonck (UW; USBPO)   vice-Chair = E. Synakowski (LLNL)

Topic 1 - US Research Agenda for ITER

R. Stambaugh (GA)*
R. Hawryluk (PPPL)
C. Baker (SNL/UCSD)
R. Parker (MIT)
W. Nevins (LLNL)
H. Berk (UT)

Topic 2 - Methods to evaluate whether ITER is promoting progress towards making fusion a reliable and affordable source of power

D. Meade (PPPL)*
M. Greenwald (MIT)
F. Najmabadi (UCSD)
C. Baker (SNL/UCSD)

Topic 3 - Description of how work at ITER will relate to other elements of the US fusion program

G. H. Neilson (PPPL)*
T. Strait (GA)
M. Mauel (Columbia)
D. Batchelor (ORNL)

OFES Participants: E. Oktay, S. Eckstrand, G. Nardella, S. Stevens

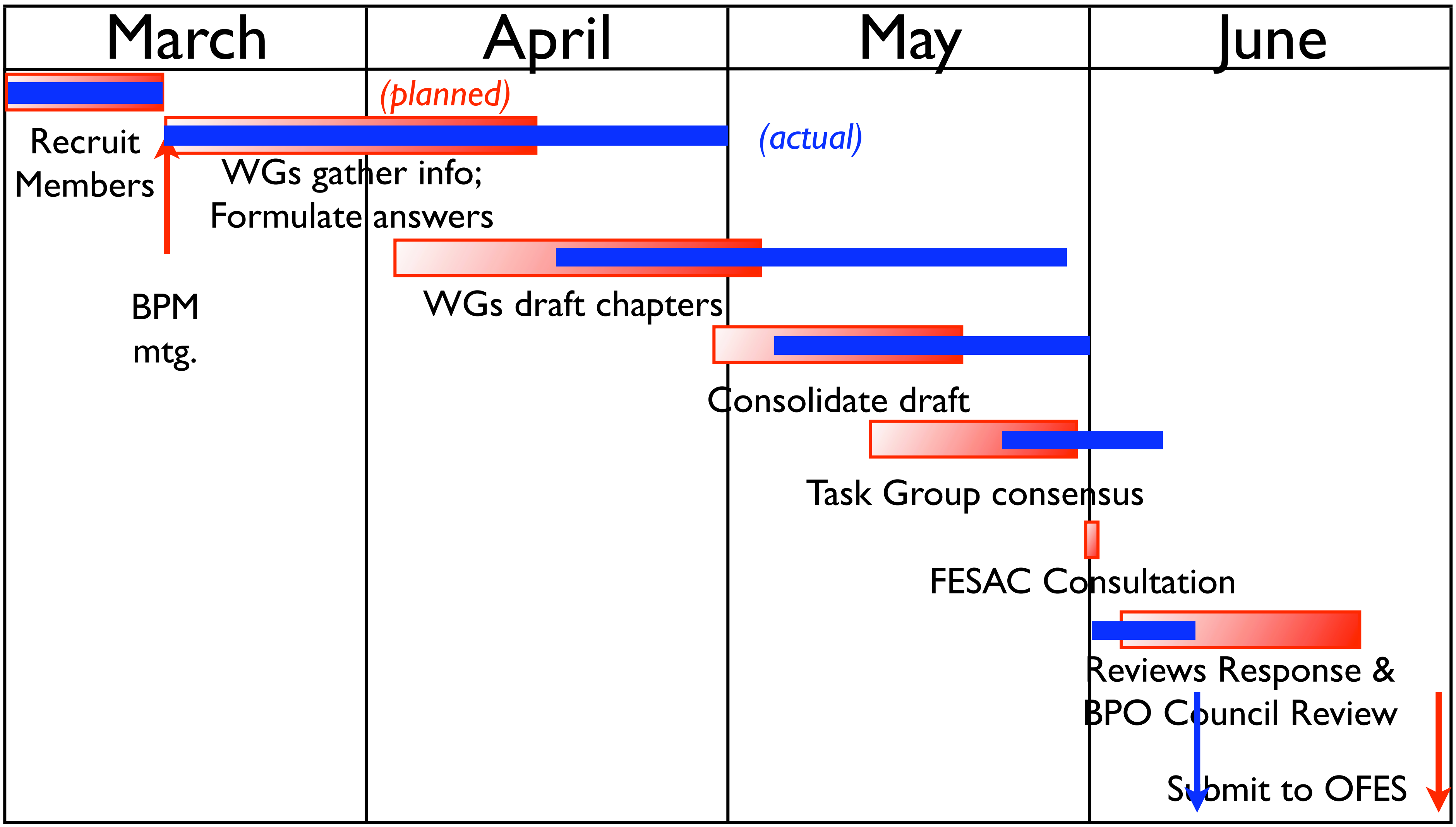
Approach to Addressing Charge

U.S. BURNING PLASMA ORGANIZATION

- Task Group worked via teleconference and e-mail
  - No opportunity for general meeting; ~quorum at BPM lunch mtg.
  - Sub-panels worked mainly separately
  - Consolidation by sub-panel leaders, chair, and vice-chair
  - Panel as a whole is still working on this
- Used, as much as possible, wealth of relevant community studies
  - BP workshop, Facilities Report, Priorities Report, Snowmass, ITPA, BPAC, FESAC BP, PAC reports, etc.
  - However, specific info for questions needed some new development

Schedule for EPAct Report

U.S. BURNING PLASMA ORGANIZATION



General Report Structure

U.S. BURNING PLASMA ORGANIZATION

- Low(er)-jargon Overview
  - Executive Summary (2-page; in progress)
  - Chap I: Overview and timing and scope of issues
- 3 more-detailed Chapters to support Overview
  - Chap II: The U.S. research agenda for ITER
  - Chap III: Metrics for evaluating whether ITER is promoting progress towards fusion energy
  - Chap IV: Relation to other elements of the U.S. Program

Summary Findings - I

U.S. BURNING PLASMA ORGANIZATION

- **General Thesis**
  - Creating and controlling the first sustained "star on earth" in ITER for future energy production is a grand scientific, technological, and organizational challenge.
- **Research Community Structure**
  - The burning plasma research program in the U.S. is being organized to maximize the scientific benefits of participation in the international ITER experiment.
  - Past investments in fusion research have positioned the U.S. Fusion Energy Sciences program to contribute to and benefit from participation in the ITER experiment.
- **(i) The U.S. Research Agenda for ITER**
  - ITER will make major contributions to the U.S. research agenda for burning plasma studies in six major scientific themes, or campaigns.
  - Achieving the long-term scientific goals in ITER requires well-defined, long-term R&D activities in each of the priority science areas. These efforts span from the present design support stage to the final high-power, long-pulse technology test stage of ITER operation.

Summary Findings - II

U.S. BURNING PLASMA ORGANIZATION

- **(ii) Methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power**
  - Progress on critical scientific and technology issues needed to design future fusion energy power plants will be evaluated with metrics based on increased scientific understanding and on performance in the burning plasma regime.
  - The research plan toward the fusion goal should be periodically assessed and modified by internal and external reviews.
- **(iii) Description of how work at ITER will relate to other elements of US fusion program.**
  - A program of configuration optimization, enabling technology, and predictive simulation, supplementing ITER, ensures that the U.S. will have an adequate knowledge base for developing an attractive fusion power source beyond ITER.

Overview

U.S. BURNING PLASMA ORGANIZATION

- Introduction
  - Uniqueness = *burning plasma integration*
  - Focus of U.S. program = *predictive understanding* of the fusion plasma system
  - Tightly coupled to international community planning
- Research community structure is evolving to adapt to anticipated modes of participation
  - Participation in USIPO
  - Members of international ITER Organization
  - Visiting participant scientists
  - ITPA
  - USBPO
  - Multilateral IEA and U.S. bilateral agreements

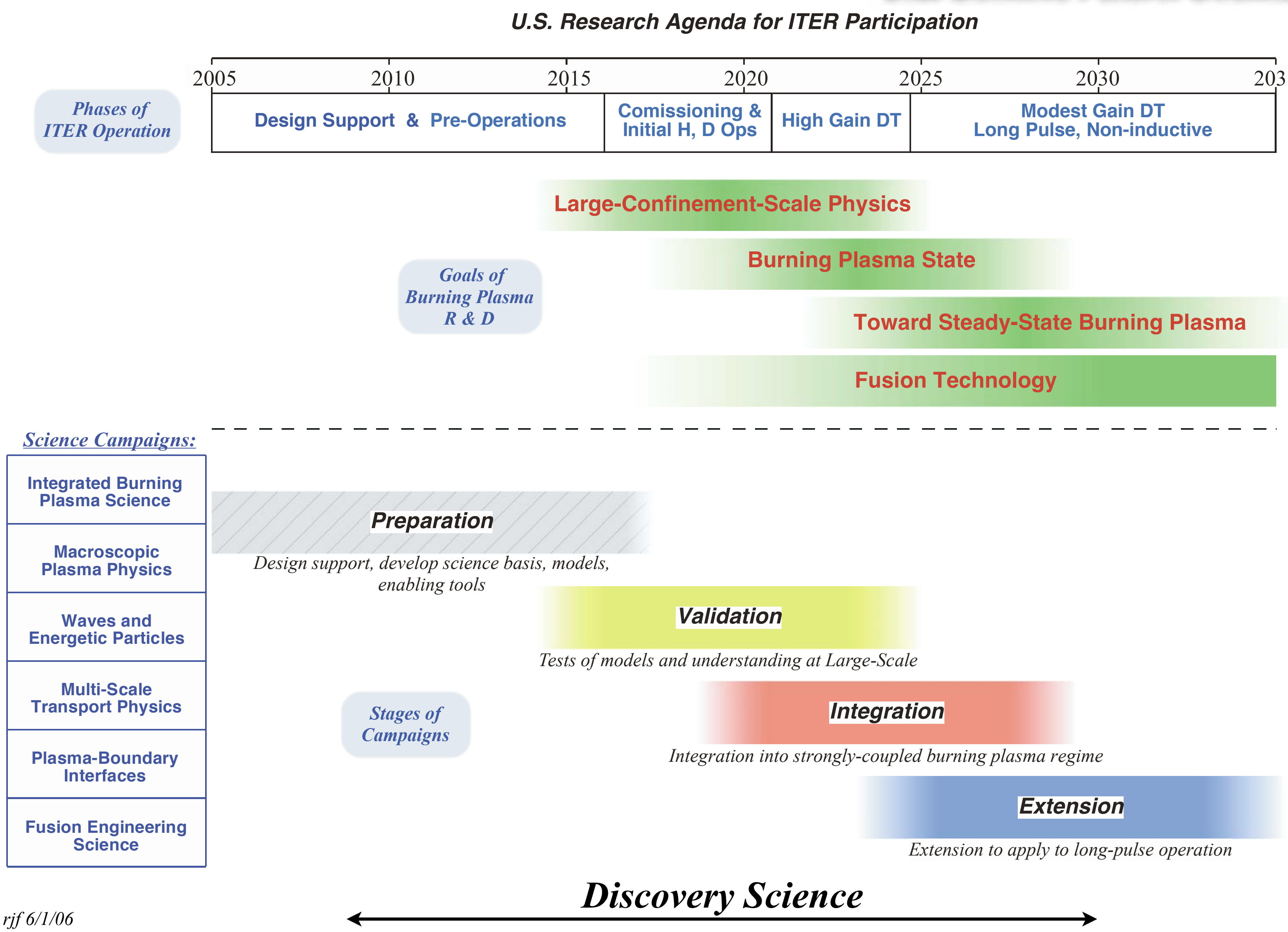
(i) The U.S. research agenda for ITER: Goals: Posed as 4 Questions to Answer

U.S. BURNING PLASMA ORGANIZATION

- Large-Confinement-Scale Physics:
  - *How does the large size required for a fusion power plant affect its confinement, stability, and energy dissipation properties?*
- The Burning Plasma State:
  - *Can a self-heated fusion plasma be created, controlled, and sustained?*
- Toward Steady-state Burning Plasma Operation:
  - *Can the tokamak confinement concept be extended to the continuous, self-sustaining regime required for future power plants?*
- Fusion Technology:
  - *What materials and components are compatible with the nuclear and plasma environment of a fusion power plant?*

(i) The U.S. research agenda for ITER: General Conceptual Timeline

U.S. BURNING PLASMA ORGANIZATION



(i) The U.S. research agenda for ITER: Aligned with Science Campaigns

U.S. Burning Plasma Organization

- Specific long-term goals require near-term preparatory research
  - Determines the near-term agenda for U.S. program over next decade or so
  - A range of topics identified
  - Plan backwards from goals…
- Examples:
  - Macroscopic Plasma Physics:

Goal on ITER:	***Stabilize pressure-limiting instabilities***
ITER Time Frame:	***Modest gain Non-inductive Phase***
Preparatory Research:	***Define suitable control coil systems for ITER***

  - Waves and Energetic Particles:

Goal on ITER:	***Understand instabilities driven by alpha-particles***
ITER Time Frame:	***High gain DT Phase***
	Modest gain Non-inductive Phase
Preparatory Research:	***Investigate energetic particle instabilities***
	Develop alpha particle diagnostics

(i) The U.S. research agenda for ITER: Specific Tasks for Each Campaign

U.S. BURNING PLASMA ORGANIZATION

Research Agenda for ITER

Phases of ITER Development	2005–2010	2010–2015	2015–2020	2020–2025	2025–2030	2030–2035
Fusion Science Campaigns	DESIGN SUPPORT	PRE-OPERATIONS	COMMISSIONING First Plasma ←H→ ←D→	HIGH GAIN DT	MODEST GAIN DT LONG PULSE, NON-INDUCTIVE	FUSION TECHNOLOGY TESTS

(DT: 2021–2033)

Campaign	Tasks (before ITER operation)	Tasks in ITER
The Integrated Burning Plasma System	High energy gain long pulse inductive scenarios for ITER; High energy gain steady-state scenarios for ITER; Develop integrated plasma model; Develop integrated plasma control	Achieve high gain long pulses in ITER; Achieve modest gain steady-state capability; Optimize gain in non-inductive plasmas; High duty cycle operation in burning plasma; Study alpha heating effects; Establish integrated model on ITER; Control complex, burning plasmas in ITER
Macroscopic Plasma Physics	Design suppression coils for pressure limiting instabilities; Develop disruption avoidance and mitigation methods; Specify RF systems to stabilize confinement limiting instabilities	Mitigate disruptions in ITER; Stabilize pressure limiting instabilities in ITER; Suppress confinement limiting instabilities in ITER
Waves and Energetic Particles	Resolve RF and microwave issues; Specify Upgrade of H&CD systems for ITER; Investigate energetic particle instabilities; Develop alpha particle diagnostics	Achieve 100% non-inductive current drive in ITER; Understand instabilities driven by alpha particles
Multi-Scale Transport Physics	Understand electron heat transport; Develop turbulence diagnostics for ITER; Decide how to spin the ITER plasma; Understand transport barriers	Understand transport in the burning plasma regime; Control how the ITER plasma spins; Use transport barrier physics to achieve high gain, in ITER
Plasma-Boundary Interface	Understand edge pedestal physics; Identify approaches to minimize the impact of edge instabilities; Understand role of density in divertor physics	Achieve a sufficient edge pedestal for high gain; Implement edge instability suppression in ITER; Understand how to project edge physics
Fusion Engineering Science	Study first wall material options; Participate in a test blanket module program; Develop advanced fueling for ITER; Support superconducting magnet construction; Develop RF sources and wave launchers; Develop applicable technique	Handle unprecedented power exhaust; Operate with sufficiently low tritium inventory; Deploy, operate, study test blanket modules in ITER; Operate very long pulses for blanket test; Provide central fueling in ITER; Assess the performance of power-plant scale magnets; Use RF systems to control the plasma; Deploy turbulence and alpha diagnostics

(ii) Methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power

U.S. BURNING PLASMA ORGANIZATION

- Metric Class I: Scientific Progress
  - Focus of U.S. program = development of underlying science and a *predictive understanding* of the fusion plasma system
  - Comparison of predicted and measured properties of plasma
    - Experimental validation of theory and simulations
    - e.g., explore predicted stability limits once in BP regime
  - Use of knowledge for controlling and extending plasma performance
- Metric Class II: Energy and Technology Progress
  - Performance goals: e.g. fusion power, gain, pulse length, etc.
  - Secondary to scientific metrics, but easier to define - need to be careful!

(ii) Methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power

- Defining a reliable, safe, affordable power plant concept
  - Rely on ARIES studies for operational, economic, safety and environmental goals
  - Provides ARIES-RS/AT as benchmark for performance metrics
  - Not necessarily tokamak-specific
- Understanding & Measuring Science and Technology Progress
  - Research topics coupled to long-term goals: are goals achieved?
  - Overarching goal: Predictive Capability
  - Do integrated predictive codes accurately predict behavior of burning plasmas?
  - Ultimately need evaluation thru peer review (internal and external)

(ii) Methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power

- Progress in Plasma Performance & Fusion Technologies
  - Comparison of present, ITER, and DEMO performance needs
  - Usual suspects: fusion power, Q, duration, power handling, etc.
- Milestones and Decision Points
  - Long-term performance measures being developed for PART planning
  - Predictive Capability for Burning Plasma: benchmarked progress by 2015
- Evaluating Effectiveness of U.S. Participation in ITER
  - In operations: # personnel; # publications; # citations; # experiments led
  - Periodic technical reviews: peers; outside science and technology communities;
  - Outreach to ultimate customers, incl. industry and environmental community

(iii) Description of how work at ITER will relate to other elements of the U.S. fusion program.

- Follow NRC BPAC report: goals for attractive fusion energy

  Maximize the plasma pressure
  Maximize the plasma energy confinement
  Minimize the power needed for sustainment
  Simplify and increase reliability

- A portfolio approach used to develop the predictive understanding of magnetic confinement to achieve these goals
  - Experiment in four leading categories
  - Theory and simulation
  - Fusion engineering science and tools
  - Tests of emerging concepts

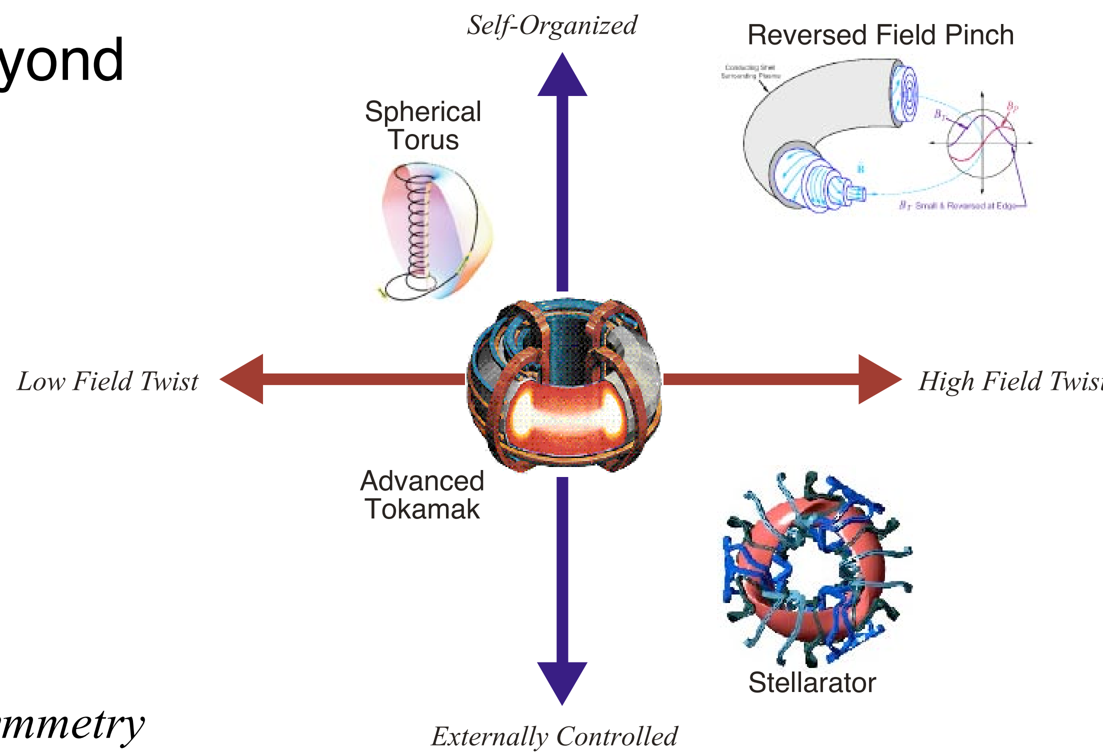
- Relation to ITER and burning plasma research in an integrated fusion program
  - Support
  - Complement
  - Benefit from

(iii) Description of how work at ITER will relate to other elements of the U.S. fusion program.

U.S. BURNING PLASMA ORGANIZATION

- Magnetic configuration portfolio has 4 large programs to complement and look beyond ITER

- Advanced Tokamak:
  - *Extending the tokamak*
- Spherical Torus:
  - *Effects of extreme geometry*
- Stellarator:
  - *3-D plasma with magnetic symmetry*
- Reversed Field Pinch:
  - *Exploiting plasma self-organization*



What We Did Not Do

U.S. BURNING PLASMA ORGANIZATION

- Produce a finalized plan for burning-plasma activities in the U.S. program
  - Needs further development and input from the wider research community
- Set clear priorities among the tasks
  - Some prioritization explicit in tasks chosen for inclusion
  - Some inferred from schedule estimates
  - Not at point to suggest BP priorities in near-term domestic research (but closer!)
- Interface with international environment and partners

U.S. BURNING PLASMA ORGANIZATION

Moving to the Future

- Further develop tasks and timescales
  - Long-term BP Planning Activity in USBPO
  - Continue refining tasks and specific goals as science issues
  - Work with partners through ITPA, USIPO, and ITER for U.S. roles
- Set clear priorities among the tasks
  - As tasks are defined, confront prioritization
  - Lead to suggest BP priorities in near-term domestic research
- Work with FESAC 10-year planning activity as appropriate
  - Address the ITER/BP participation part of the U.S. program

What's Next for this Report…

U.S. BURNING PLASMA ORGANIZATION

- Clean up text, simplify, etc.
- Executive Summary
- Incorporate suggestions from EPAct Task Group and USBPO Council members
- Accommodate feedback from FESAC
- Finalize report
- Submit to OFES by next Friday latest

Consultation with FESAC…

U.S. BURNING PLASMA ORGANIZATION

- Is this a reasonable beginning of a plan for ITER participation?
- Do the 4 main questions capture the unique role of ITER in the fusion science program?
- Is the Research Agenda a fair *initial* representation of activities of interest to the U.S. in addressing these questions?
- Are the metrics for evaluating progress and possible changes in direction reasonable?
- Has prioritization been properly addressed at this stage?
- How should we expand the connection to other elements in the program (support, complement, benefit from)?