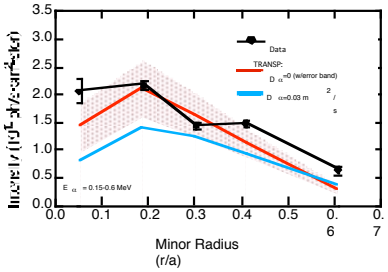
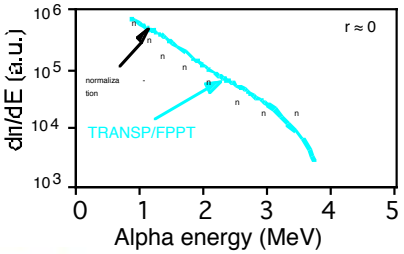
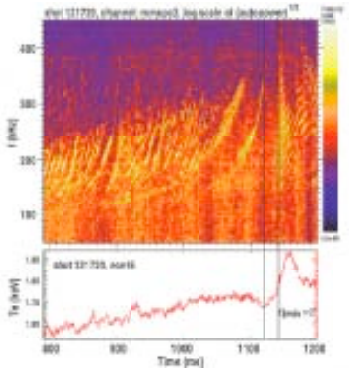
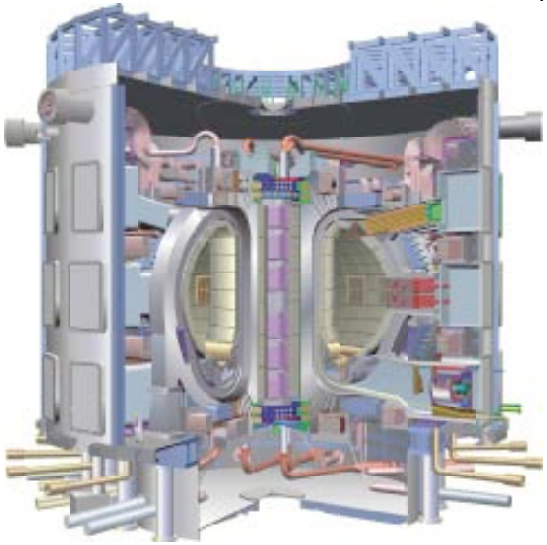
U.S. Burning Plasma Program Development…

U.S. BURNING PLASMA ORGANIZATION









R. J. Fonck

for the

U.S. Burning Plasma Organization

presented to

ITER Town Hall Meeting

APS/DPP, Philadelphia, PA

Oct. 31, 2006

USBPO Formed to Organize BP Research Activities in U.S.

U.S. BURNING PLASMA ORGANIZATION

Mission:

Advance the scientific understanding of burning plasmas and ensure the greatest benefit from a burning plasma experiment by coordinating relevant U.S. fusion research with broad community participation.

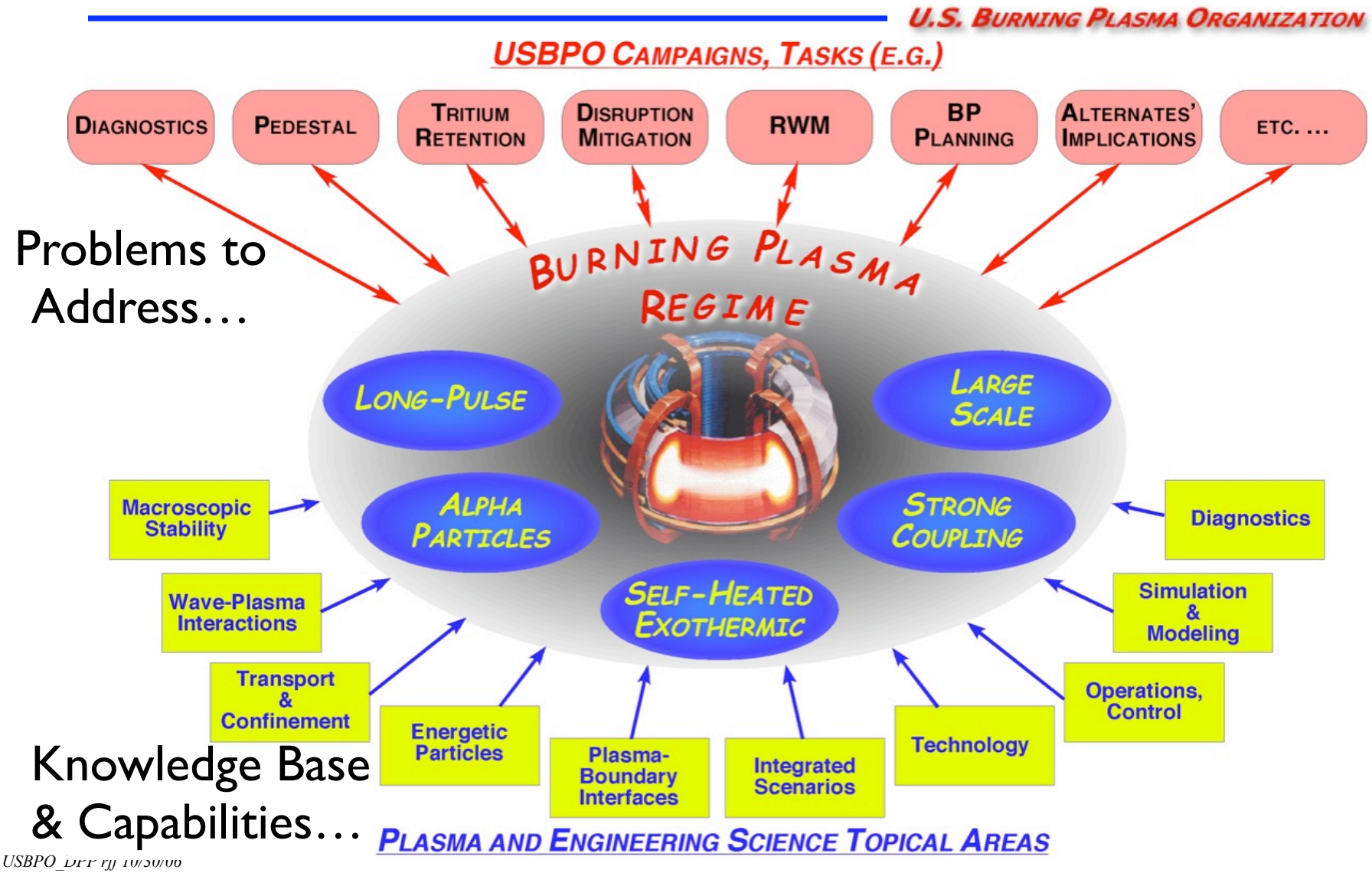
info in this talk: http://www.burningplasma.org

US Burning Plasma Organization: What's Happened in the 1st Year?

U.S. BURNING PLASMA ORGANIZATION

- Community discussions on what to do
  - 1st BP Workshop at ORNL in Dec, 2005
- Building the organization
  - Structural elements: Council, Topical Groups, etc.
  - Communications tools
- Addressing near-term research needs
  - First cut at a BP Research Plan: EPAct Task Group
  - ITER Physics Tasks
  - ITER Design Review Process
- Starting technical/research activities
  - Identifying and coordinating broader BP research tasks

Address BP-Relevant Issues by Combining Community Expertise

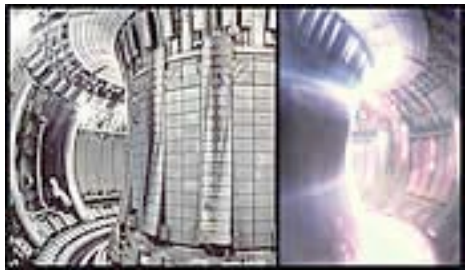


Today's Fusion Tokamaks Are Making Important Contributions to ITER

DIII-D completed system upgrades and modifications in 2006 and began research in ITER-relevant low rotation regimes using balanced (co- and counter-current) neutral beam injection. Demonstrated that the threshold for rotational stabilization of the RWM using this method of slowing rotation is much lower than previously attained with magnetic braking techniques.

Alcator C-Mod researchers successfully coupled ~850 kilowatts of RF power at the lower hybrid frequency to a 1 MA plasma and sustained nearly all of the current for one profile relaxation time. These results are in agreement with theoretical calculations and imply that lower hybrid power could be used for current profile control in ITER.

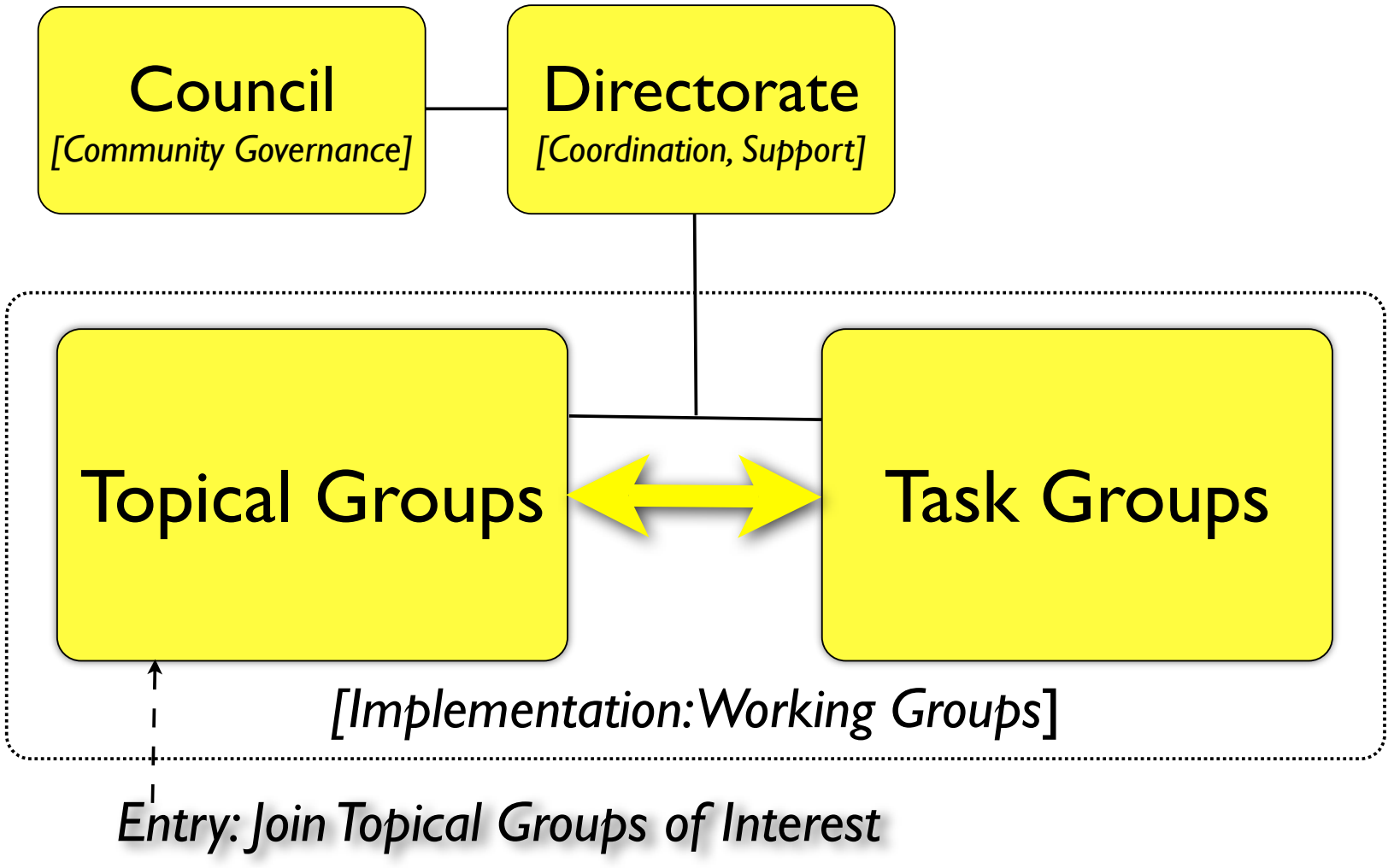
NSTX scientists used a set of six non-axisymmetric feedback coils and improved equilibrium coils to carry out studies of error field reduction, plasma rotation control, and active resistive wall mode control in high performance plasmas. They were able to control the resistive wall mode successfully at high normalized pressure at ITER relevant rotation for a plasma skin time.



Joint ITPA experiments on DIII-D, C-MOD, NSTX, the European tokamaks JET and ASDEX-UG, and the Japanese tokamak JT-60U are investigating the scaling of energy confinement time with plasma pressure in ITER relevant plasmas.

USBPO Comprised of 3 Elements

U.S. Burning Plasma Organization



Council Provides Community Governance

U.S. BURNING PLASMA ORGANIZATION

- Council: Chair = James VanDam (U. Texas)

  Vice-Chair = Amanda Hubbard (MIT)

Steven Cowley (UCLA)
Richard Hawryluk (PPPL)
Gerald Navratil (Col. U.)
Craig Petty (GA)
William Nevins (LLNL)
George Tynan (UCSD)

Steven Allen (LLNL)
Earl Marmar (MIT)
Martin Peng (ORNL)
David Petti (INEEL)
John Sarff (U. Wisc.)
Michael Zarnstorff (PPPL)

ex-officio: Stanley Milora (IPO Chief Technologist, ORNL)
Raymond Fonck (USBPO Dir.; IPO Chief Scientist)

OFES Program Managers: Erol Oktay (Science)
Gene Nardella (Technology)

Council Pursues Policy and Planning

U.S. BURNING PLASMA ORGANIZATION

- Reviews and advises on new activities and issues
  - Overall structure, relation to other organizations, etc.
  - Help identify and recruit leadership candidates
- Monitors BPO activities thru Directorate
  - Bi-weekly conferences with Chair, Vice-Chair, Director, Dep, Director, OFES
  - Full Council videoconference ~ quarterly
- Charter development
  - Policies and rules for organization
- Strategic Planning Activity for BP research

Directorate Manages USBPO Activities

U.S. BURNING PLASMA ORGANIZATION

- Directorate:

  Director = Raymond Fonck (UW)

  Deputy Director = Tony Taylor (GA)

  Research Committee = Topical Group Leaders

  Admin = Joan Welc-Lepain (UW)

  Communications = James Dekock (UW)

- Develops and guides daily USBPO activities
  - Topical and Task Groups: identify and manage BP research activities
  - Identifying and recruiting participants, with Council
  - Interfaces BPO with ITER Project Office and other orgs (e.g., ITPA)
  - Communication, information, outreach…

Topical Groups = Focus of BP Research and Research Community Involvement

U.S. BURNING PLASMA ORGANIZATION

Topical Group	Leader	Deputy Leader
MHD, Macroscopic Plasma Physics	Jon Menard (PPPL)	Chris Hegna (UW)
Confinement and Transport	Paul Terry (UW)	Ed Doyle (UCLA)
Boundary	Dennis Whyte (MIT)	Tom Rognlien (LLNL)
Plasma-Wave Interactions	Cynthia Phillips (PPPL)	Steve Wukitch (MIT)
Energetic Particles	Raffi Nazikian (PPPL)	Bill Heidbrink (UCI)
Fusion Engineering Science	Nermin Uckan (ORNL)	Rich Nygren (SNL)
Modeling and Simulation	Don Batchelor (ORNL)	Jon Kinsey (Lehigh)
Operation and Control	Dave Humphreys (GA)	Dave Gates (PPPL)
Diagnostics	Rejean Boivin (GA)	Jim Terry (MIT), Steve Allen (LLNL)
Integrated Scenarios	Chuck Greenfield (GA)	Chuck Kessel (PPPL)

Research Committee Organizing Research Tasks

U.S. BURNING PLASMA ORGANIZATION

- Bi-weekly videoconference
  - Chaired by Deputy Director - T. Taylor
- Various Tasks undertaken to date
  - Communications standards and tools
  - ITER CODAC
  - Burning Plasma issues identification
  - ITER Physics Tasks for 2005-2006
  - ITER Physics Tasks for 2006-2007
  - ITER Issue Card contributions
  - EPAct BP Planning activity

2005-2006 ITER Physics Tasks In Progress

U.S. BURNING PLASMA ORGANIZATION

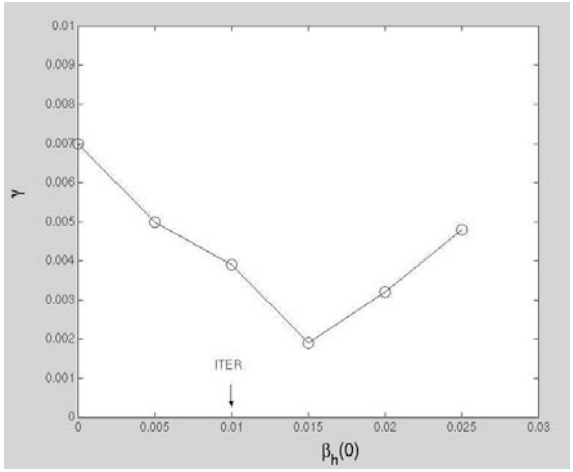
- RWM Control (G. Navratil)
  - Simulations of RWM feedback; feedback coil design for ITER; sensor noise
- VDE, Disruptions and their mitigation in ITER (D. Whyte)
  - Halo current models, VDE simulation, gas injection mitigation
- Fast particle Confinement (N. Gorelenkov)
  - Effects of TAE modes, fishbones, and TF ripple on fast particle losses
- Effects of Radiation Transfer on Divertor Plasma (B. Lipschultz)
  - Assess physics in codes for predicting effects of opacity and radiation transfer
- ICRF Heating and Current Drive (F. Jaeger)
  - Benchmarking ICRF codes for ITER plasma and antenna

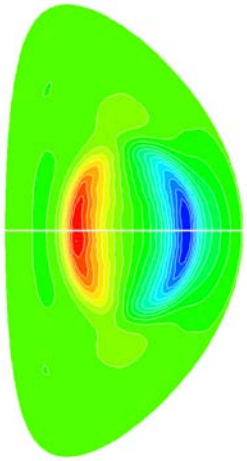
2005-2006 ITER Physics Task - I

- **M3D predicts stability of fishbone mode in ITER**

Alphas beta (~1%) is less than required for fishbone excitation (>~1.5%, Fu G.-Y. IAEA-2006)

Thermal ion kinetic effects reduce ideal kink mode (sawtooth) by half (Kruskal-Oberman), but do not completely stabilize





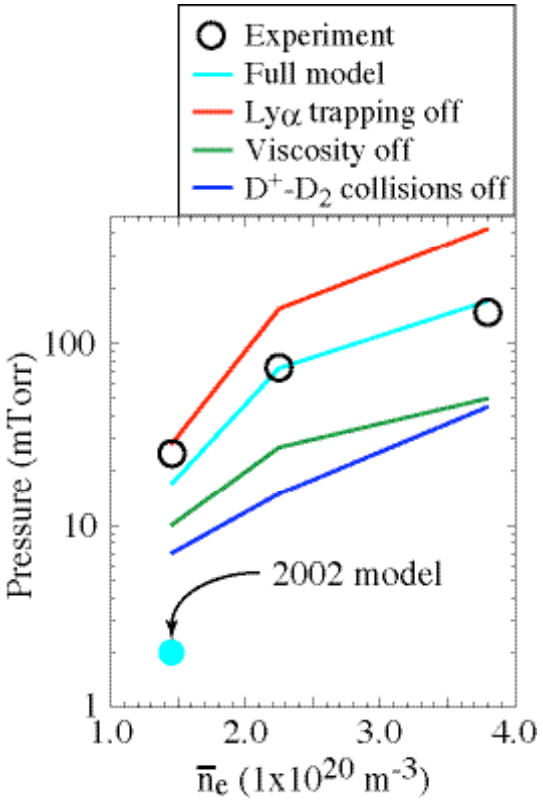
- **Quasilinear Analysis of TAE instability in ITER**
  - Global nature can cause alpha particle loss
  - Strong Pa gradient + low shear = strong TAE

2005-2006 ITER Physics Task - 2

Accomplishments & plans ~ Neutrals
C-Mod results critical to benchmark ITER models for He exhaust

Alcator C-Mod

- C-Mod neutral densities uniquely span that of ITER
  - $\lambda_{D2\text{-}D2}$ ~1.3-7.8 mm << $L_{Divertor}$
  - $\lambda_{D+\text{-}D2}$ ~1-8 mm, small compared to divertor fan
  - Photon absorption mean free paths ~ 1 mm
- **=> excellent test of codes for ITER (US-ITER task)**
  - Lyman alpha trapping - affects the ionization - recombination balance and access to detachment
  - Short neutral mean free path regimes - strongly affects neutral balance and pumping
- Recent inclusion of above processes leads to much closer match to C-Mod divertor pressures (x5)
  - Very positive result for ITER pumping



- **Status and plans**
  - Finish interpretive modelling
  - Move on to self-consistent predictive modelling
  - Divertor Ly_α tomography in C-Mod

U.S. ITER Physics Tasks Proposed for 2007

U.S. BURNING PLASMA ORGANIZATION

- Used existing info to start
  - ITPA priorities; 2005-2006 ITER tasks; USIPO WBS needs; USBPO Workshop; etc.
- Topical Group leaders engaged community for ideas
  - Ongoing discussions on BPO forums
- 76 discrete tasks identified
- High-priority list of 14 advanced to USIPO
  - Used well-defined metrics for evaluation
- Working with USIPO to refine & discuss with ITER team
  - Led by N. Uckan, assisted by C. Greenfield and J. Menard
  - Identifying participants and work plans
  - Topical/Task groups will perform the chosen Tasks

Final List of Recommended ITER Physics Tasks

U.S. Burning Plasma Organization

- Active coil system for ELM suppression and RWM stabilization
- ITER disruption mitigation system design and physics understanding
- Tritium retention and H/D/T control
- Requirements for stabilization of (3,2) and (2,1) NTMs
- Limitations to startup flexibility for advanced scenarios
- ELM mitigation
- ICRF antenna performance and coupling studies
- Critical assessment of heating and current drive mix on ITER and impact on achievable scenarios
- Review measurement requirements related to US diagnostic packages
- Evaluate the feasibility of lost and confined fast ion diagnostic systems for ITER
- ITER CODAC architecture design
- ICRF heating and current drive scenarios (time-independent)
- Development of improved pedestal and L-H transition predictive capabilities and impact on ITER design and performance.
- Locked-modes and error field correction specification

ITER Issue Card Process: Community Participation in the ITER Design Review

U.S. BURNING PLASMA ORGANIZATION

- Identification of Issues in ITER reference design
  - On-going ITER design review process - *see Town Meeting Tues, Night*
- Sub-comm extracted 1st set from 14 priority tasks
  - Some additions from Res Comm and sifting for design impact
  - Initial list of 11 forwarded to USIPO for discussion
- Initial group advanced forward by USIPO
  - Refine and expand as feedback obtained
- Topical Groups engaged to ID more as needed
  - Reaching out to community membership

(details at http://www.burningplasma.org)

Developing a BP/ITER Research Plan

U.S. BURNING PLASMA ORGANIZATION

- Energy Policy Act of July, 2005 called for a Plan for US Participation in ITER
  - The U.S. research agenda for ITER
  - Methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power
  - Description of how work at ITER will relate to other elements of US fusion program.
- DoE/OFES asked USBPO to help develop this Plan
  - Consultation with FESAC
- EPAct Task Group formed to produce this
  - Sent to OFES in early June 2006; available on BPO web site

(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

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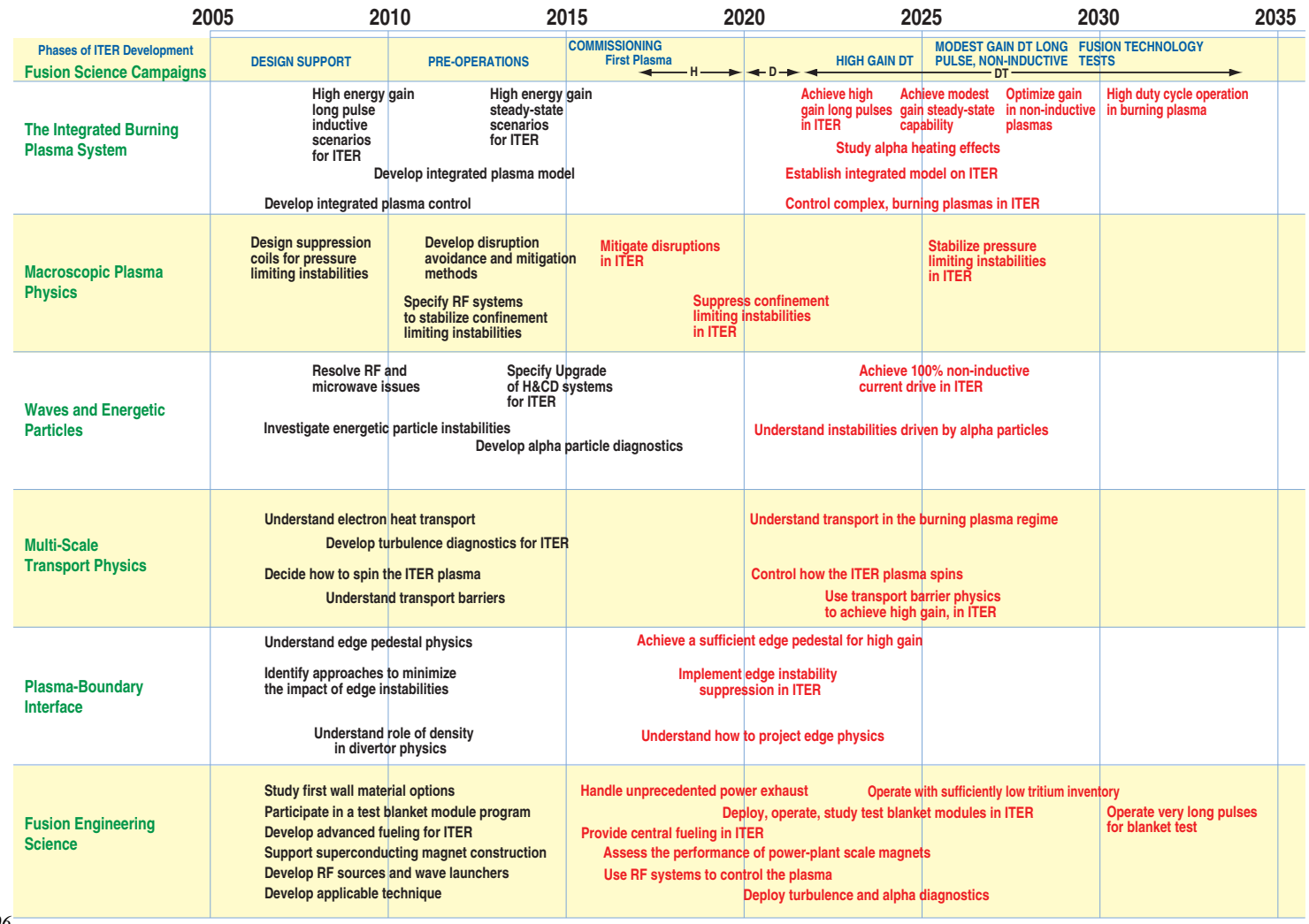


(ii) Methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power

- Metric Class 1: 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!

Future Directions in Developing an Overall Plan for ITER Participation

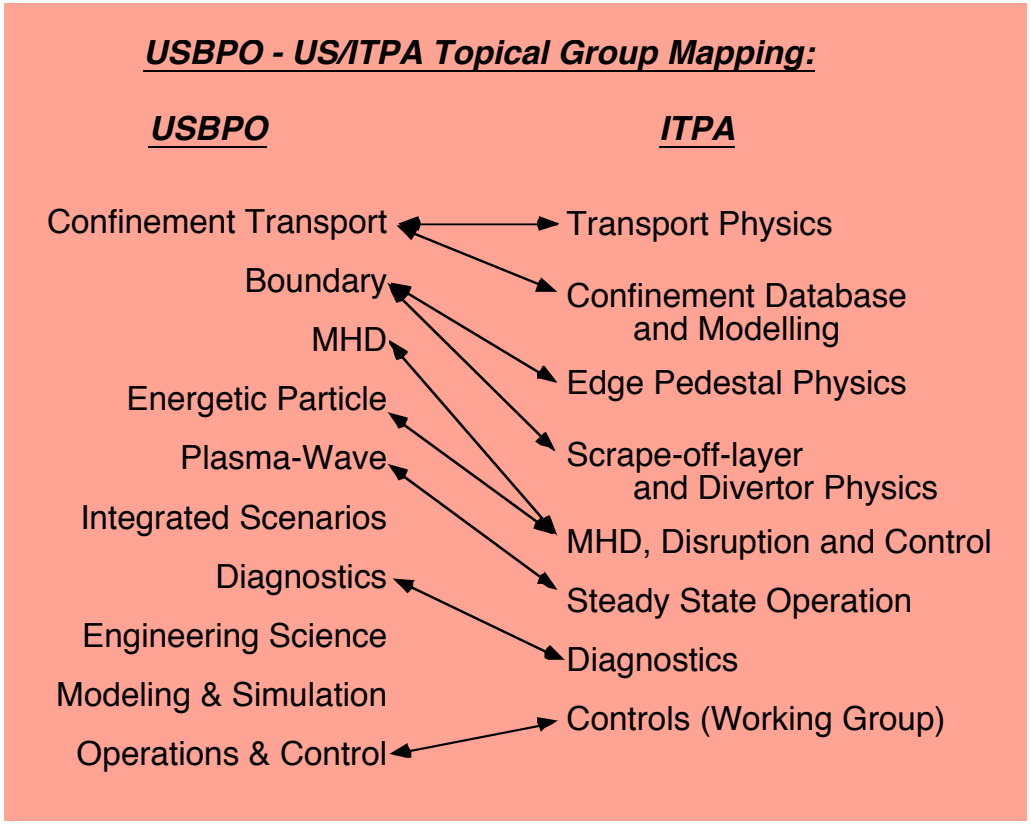
U.S. BURNING PLASMA ORGANIZATION

- Further develop specific goals and timescales
  - Long-term BP Planning Activity in USBPO - Council activity
  - 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 planning activity
  - Address the ITER/BP participation part of the U.S. program

USBPO Integrates with Existing Activities: e.g., USBPO-ITPA coordination

U.S. BURNING PLASMA ORGANIZATION

- Plan: USBPO to facilitate ITPA activities in U.S.
  - Topical Groups interface U.S. community to ITPA activities
  - Provide participants to ITPA activities
  - ITPA participants bring issues and info back to community via USBPO
  - Engages broader US community
  - Communicate ITPA activities in U.S.
- Expands access to ITER:
  - USIPO as Domestic Agency
  - Communication with ITER Team
  - ITPA and Bilateral Agreements



What's Going on This Week & Near-Term

U.S. BURNING PLASMA ORGANIZATION

- NOTE: Many TG leaders available after this session for discussions!

- Topical Group meetings of interested community members

• MHD	- Menard, Hegna	Tues 17:30	Rm 304, Marriot
• Integrated Scenarios	- Greenfield, Kessel	Weds15:30	TBD
• Modeling & Simulation	- Batchelor, Kinsey	Tues 16:30	Tables in poster hall
• Boundary	- Whyte, Rognlien	Tues after Town Mtg	ITER Town Mtg Rm
• Plasma-Wave	- Philips, Wukitch	Tues after Town Mtg	ITER Town Mtg Rm
• Transport / Confine	- Terry, Doyle	Tues after Town Mtg	ITER Town Mtg Rm
• Diagnostics	- Boivin, Terry, Allen	Feb. 6-8	Workshop @ GA
• Control and Ops	- Humphreys, Gates	TBD (see web site)	Videoconference

- Council Meeting (Weds 12:45)

Summary

U.S. BURNING PLASMA ORGANIZATION

- First-cut USBPO organization is established
  - Structural elements: Council, Topical Groups, etc.
  - Quickly becoming a functional research organization
- Several Tasks addressing near-term issues
  - Physics Tasks proposed; Issues Card process underway
  - Strategic planning for BP research in U.S.
- Starting technical/research activities
  - Identifying and initiating BP research tasks
  - Main focus of next year
- Participate in Topical Groups to get involved…