Diagnostics & Control

Breakout Session Progress Report

Burning Plasma Workshop, ORNL

December 9, 2005

Participants during the day

Ian Hutchinson	MIT	Steve Scott	PPPL
Lydia Lodestro	LLNL	Michael Finkental	JHU
David Gates	PPPL	Keith Leonard	ORNL
Ray Fonck	U. Wisconsin	Rejean Boivin	GA
Martin Greenwald	MIT	Mike Cole	ORNL
Dave Humphreys	GA	John Peoples	Fermilab
Brad Nelson	ORNL	Brent Stratton	PPPL
Kenneth Young	PPPL	Dan Cohn	MIT
Christopher Watts	U. New Mexico	Charles Skinner	PPPL
George McKee	U. Wisconsin	Jeff Brooks	ANL
Steve Allen	LLNL	Tony Peebles	UCLA
David Johnson	PPPL	Dave Brower	UCLA
Jim Terry	MIT	Soren Harrison	UW Madison
		G. Taylor	PPPL

Average Attendance ~ 10 people

Question 1 - Progress since Snowmass

Well summarized in plenary talk - some general comments

Diagnostics

- ITPA and special working groups exist
- Port based procurement proposed for diagnostics
- US tentatively responsible for five port assemblies
- Major progress in fluctuation diagnostics
- Profile measurements used in control (ECCD of NTM)

Control

- ITPA has “electronic” working group - write physics basis
- CODAC activity just getting started
- Separate topical group, cross-cutting representation
- *Separate summary by Dave Humphries*

#2. Current Diagnostic Issues

ITPA High Priority Issues

- Alpha particle diagnostics
  - Confined alphas - collective scattering
    - Uncredited, but EU working on this
    - US has expertise - how US involved?
  - Lost alpha is key issue (even if detector survive, what view?) Simulations should be done
- First mirror issues - coatings and erosion, wide range of measurements - experiments on US plasma machines, also modeling - BPO Task group appropriate (assess impact)
- Radiation effects in magnetic sensors (technology group?)
- Dust measurement (explosive limit in kg) - need measurement requirement, local plus calibration at end of hydrogen phase
    - BPO support work on US machines
- Vertical neutron camera - modify vacuum vessel, divertor
  - Needs stronger physics justification
  - Modifications help other diagnostics?
  - (General) - how do we come to a position - BPO?

#2 - Diagnostic Issues - Cont. p2

- US participation in diagnostic design reviews
  - Physicists and engineers, understand environment
  - At least 2wk preparation for each instrument, in person
  - Action if measurement requirement is not met
  - US BPO diagnostic topical group advise ITER (via ITPA?)

- Design and fabrication of non-credited diagnostics
  - BPO recommend Burning Plasma diagnostic initiative
  - BPO advocate prototype development

- Simulations to evaluate ITER measurement specifications
  - Synthetic diagnostics in transport code
  - Noise, spatial resolution --> example MSE (CORSICA), turbulence
  - Work with scenario development group -diagnostic measure relevant physics? BPO

#2 - Diagnostic Issues - Cont. p3

- Integration issues
  - Efficient ITER CAD - CATIA
  - QA and change control
  - Efficient neutronics - neutron “budget” for diagnostics
  - Common test facility for diagnostics - BPO endorsement important for IPO implementation, NASA test facility?
- Reliability and Maintainability
  - Upper port subassembly, Equatorial port “drawer”
  - “Spare” drawers possible
- Neutral beams needed for diagnostics
  - Beam quality, modulation, and size of heating and diag. beams
  - BPO task group needed on neutral beams?
- Workforce issues - increase in young scientists
- DOE diagnostic development program motivated by BPO?

#3: Consequences of Resolving (or not) Issues

- Primarily measurement requirements
  - There are still some that are “tbd”
  - Discussed at every ITPA meeting
  - Dedicated effort for a new look at measurement requirements (BPO) - *with justification*
    - ITPA has made recommendations
  - *(e.g. increased time resolution for TAE mode)*
  - ??Different for physics and control
  - Need documentation!
- Mirror and neutral beam issues are show stoppers

#4: Issues resolved by successful BP experiment

- DEMO (beyond ITER)
  - Less access, fewer diagnostics (less physics?)
  - Control with reduced diagnostic set
  - Codes used to complement poorer diagnostic coverage
  - Demonstration of survivability
  - Deliberately use new technology that will be required for DEMO
  - Diagnostic test module for DEMO - late in ITER lifetime
  - New burning plasma control diagnostics required?

#5: What should US community do?

- New measurement techniques
  - e.g. lost alpha techniques, MSE polarimetry alternatives
- Prototyping on existing experiments
  - Shutters
  - Optical trains typical of ITER diagnostics
  - In-situ alignment and calibration
- Development of uncredited systems
- Mirror degradation - codes and experiments
  - In cooperation with Plasma Surface community
  - Erosion/deposition diagnostics?
  - Could be a task group for BPO

Recommended high priority task groups (preliminary)

- BPO task - review ITER diagnostic measurement requirements to see if US physics emphasis areas needs are met
  - Diagnostic topical group proposals to physics groups
  - Facilitate physics justification
  - April 2006 - first phase, with HTPD meeting
  - Encourage university participation - students
  - Physics and control requirements are different
- BPO task - Mirror survivability
  - Cross-cutting with Boundary, Technology, Operations & control
- BPO task - neutral beams: heating and diagnostic
  - Current density possible - development program?
  - Develop backup measurements
- BPO Task - Diagnostic simulation - with Scenario Development
- BPO task - CODAC planning (Jo Lister, ITER) 1 yr BPO task

BPO Recommendations (cont.)

- Encourage working group to facilitate involvement of US experts in US - assigned ITER diagnostics
- BPO should explore ways to facilitate US researchers involvement in non-US diagnostics (particularly if US interested in physics) - and vice-versa, especially experts for review of instruments
- Working group to identify and promote new measurement techniques and improvements of existing instruments (outside of the USIPO project)
  - Prototype techniques on existing devices, test alternative instruments
  - US involvement in uncredited systems
  - Diagnostics development opportunities (for Darlene Markevich) - satellite workshop at HTPD proposed by US BPO (use existing structures for BPO activities)
  - Advocate burning plasma diagnostic initiative
- Advocate resources for university participation, particularly in topical groups -

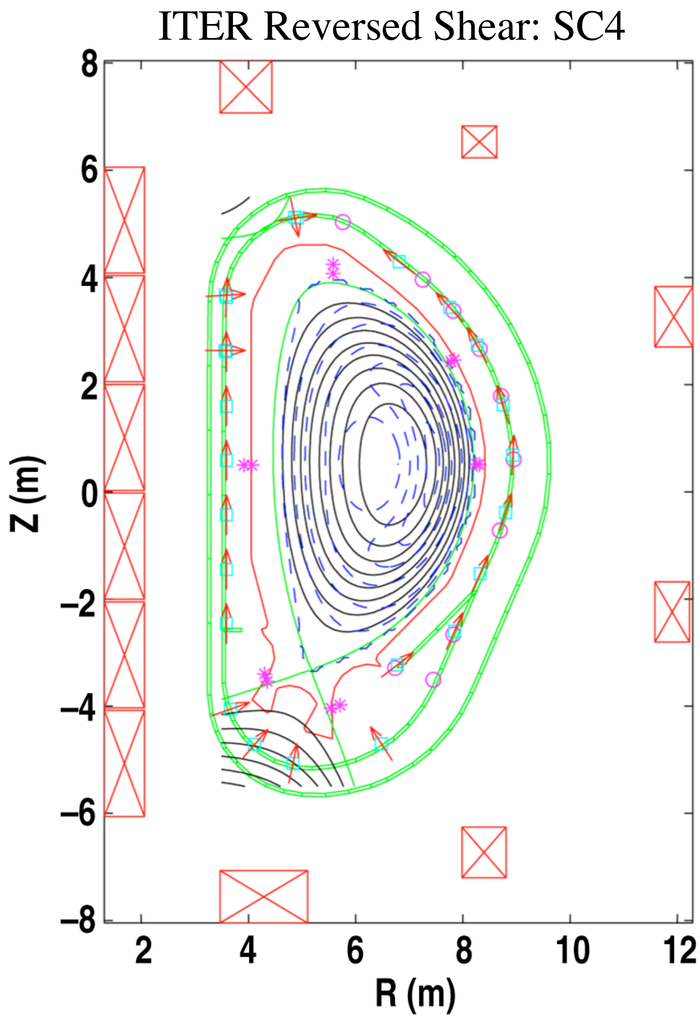
#6: Organization

- Basically comfortable with Topical and Task Group structure shown for BPO
- Clarify communication chain between BPO, IPO, DOE and ITER IT
- Diagnostic topical group have members in (ideally all) of the other topical groups
  - Inform groups of measurement issues in their areas

Operations and Control in the Burning Plasma Organization

D.A. Humphreys, D.A. Gates, and
Operations and Control Breakout Group

Burning Plasma Organization Workshop
Oak Ridge National Laboratory
December 7-9, 2005



Operations and Control Breakout Reflected Early Stages of Organization and Group Identity

- **US fusion control community never really organized before except through**
  - ITER EDA involvement
  - Machine collaborations

- **“Standing attendance” of 4-5 people, with total of ~20 attendees throughout day**
  - Reflects history of control community
  - Reflects cross-cutting nature of the field…

- **ITER control needs require focused effort, coordinated teams**
  - ITER CODAC (COntrol and Data Acquisition Computer) system is the main technological tasks (NOT a package; contract managed by IT)
  - Control R&D: still a great deal to be done, impacts many areas of design/operations

- **BPO represents an opportunity to accomplish a first-time organization to focus US control resources for ITER solutions**

Q1-Progress Since Snowmass 2: US Continued Control Development

- **Development of operational controls for** present experiments
  - Limited ITER-specific control analysis/simulation
- **Great progress in advanced stability control (particularly RWM, NTM, ELM)**
- **Progress in disruption mitigation understanding, tools**
- **Development of control modeling/design/simulation tools to support present experiments (e.g. VALEN, Corsica)**
- **Control analysis/simulations, significant engineering design for FIRE (e.g. TSC)**
- **Collaborative control system development/implementation on US experiments**
- **Design/implementation of control systems and algorithms for next-generation SC tokamaks (KSTAR, EAST)**

Q2 - Selected High Priority ITER Control Tasks/Needs

- **Shape/position/profiles axisymmetric control:**
  - Complete long-pulse solution incorporating coil current and AC loss limits
  - Noise effects/solutions (particularly from ELMs, etc…) **ITPA**
  - q-profile control demonstration **ITPA**

- **MHD Stability control:**
  - RWM control solution, validated models and analysis of capabilities, effects of ELMs, n>1 modes, active RFA/EF control **ITPA**
  - NTM control solution/ validated models of island evolution, rotation effects, modulation effectiveness, sawtooth control, error field effects **ITPA**
  - Experimental demonstrations of ITER-relevant RWM, NTM solutions **ITPA**
  - ELM control/mitigation **ITPA**

- **Off-normal response systems:**
  - Disruption prediction (e.g. rtDCON), effective mitigation methods/triggers **ITPA**
  - Integrated, high reliability supervisory system design (CODAC supervisor)

- **Licensing/commissioning requirements**
  - Development and demonstration of hardware/software performance verification with full scenario simulations

Q3 -Consequences of Failure to Resolve Issues

- **Failure to resolve control issues on ITER will result in failure of the project:**
  - Axisymmetric control: insufficiently accurate dynamic shape regulation produces divertor failure, first wall melting…
  - MHD control: insufficient NTM control leads to disruption…
  - Disruption mitigation: insufficient mitigation leads to runaway damage, divertor erosion…

- **Control is really an enabling field of science/technology:**
  - Successful operation of ITER will demonstrate resolution of key tokamak control issues

Q4: Issues for ITER to Resolve

- **Demonstration of *controlled* thermonuclear fusion**
  - Sustained, high reliability control with attractive economic performance
  - Can complex, integrated control systems produce high performance and reliability while protecting an operating reactor?
  - The ultimate demonstration of our understanding of fusion physics…

- **Control is really an enabling field for ITER, rather than a field with fundamental issues to be resolved:**
  - Successful operation of ITER will demonstrate resolution of control issues

Q5 - Contributions the US Can Make to ITER Control

- **Experimental resources:**
  - Alcator C-MOD, NSTX, DIII-D, HBT-EP, MST, …
  - Experimental control demonstration
  - Model validation
  - RWM, NTM, ELM, and advanced axisymmetric control
  - Disruption mitigation through impurity injection
  - Advanced diagnostics (MSE, …)

- **Computational modeling/design/simulation tools:**
  - MHD stability (linear/nonlinear, ideal/resistive, 3D plasma, 3D structure)
  - Integrated scenario simulation
  - Heating and current drive
  - Edge modeling
  - Controller design

- **Software Infrastructure Supporting Realtime Control:**
  - Networking, data archiving, database management, control interfaces
  - Demonstrated advanced realtime algorithms
  - Experience relevant to design of ITER CODAC (COntrol and Data Acquisition Computer)

Q6- BPO Structure: Coordinate US Plasma Control Activities Toward ITER's Technical and Scientific Success

- **The BPO needs an Operations and Control Topical Group to:**
  - Respond to ITER control needs
  - Coordinate US resources and involvement in control tasks
  - Facilitate communication with ITER IT, ITER Parties, ITPA, BPO Topical Groups, and within US control community

- **The Ops/Control TG should consist of:**
  - Control experts
  - Cross-cutting representation from all other Topical Groups
  - Key cross-cuts include Macroscopic Stability (e.g. RWM, NTM modeling), Integrated Scenarios (e.g. control-level integrated simulations), Diagnostics, Boundary (disruption mitigation, divertor heat load management)

Initial Tasks for the Operations and Control Group

- **Organizational process (meeting?):**
  - Identify interested group members
  - Prepare detailed summary of US control resources
  - Formulate, prioritize proposals to address key ITER control tasks
  - Plan for collaborations with ITER Party control teams, ITER IT

- **Propose ITPA Control Working Group:**
  - Explore possibility to elevate from present Electronic Working Group

- **Contact other ITER Party control teams:**
  - Propose collaborative efforts
  - Begin coordinating discussions at international control team level

- **Contact ITER IT:**
  - Discuss ITER tasks
  - Begin coordinating efforts with ITER IT

US Control Expertise is World-Class with Key Resources to Address All ITER Control Elements

- **ITER control design tasks represent an extraordinary opportunity for high-impact, high-leverage contributions from the entire US fusion community:**
  - Control is central to ITER operations and physics
  - Control draws on expertise of the entire fusion community
  - High impact per $$
  - Area of US strength

- **With added focus and coordination through the BPO, the US control community can be far more effective in providing ITER solutions:**
  - Attention to interoperability of US control tools can improve efficiency to amplify effectiveness under limited budgets
  - Coordination of tasks within US can focus efforts, reduce redundancy, improve sharing of solutions, and help ensure applicability of domestic control developments to ITER
  - With some coordination, many control solutions produced for ITER can be applicable to domestic programs, and vice versa