

# NSTX PAC-15 Debriefing

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For the

NSTX Program Advisory Committee

# TF repair

- TF repair is on schedule for plasma operations is a few weeks
  - Improved design
  - Exceeds design goal on joint resistance
  - Lessons learned:
    - Graded review procedures to avoid future design problems
    - Spare OH solenoid fabrication in FY '05 - 06 budgets
- **CONGRATULATIONS** on the successful completion of this important task!

# Our Charge

1. Do the key elements of the updated FY '04 – '06 research and facility plans effectively address the goals of the 5-year plan?
2. Does the proposed experimental run make the best use of the available run time and capabilities to achieve these key elements of the FY '04 research?
3. Does the proposed NSTX research and facility plan from '04 to '06 effectively address the goals of the 5-year plan in light of the budget constraints? Is the research program well integrated into the national and world program?

# 1<sup>st</sup> Charge

1. *Do the key elements of the updated FY 2004-2008 research and facility plans effectively address the goals of the 5-year plan?*
  - Presentations by
    - Chuck Kessel on NSTX Plasma Operation Scenarios
    - Fred Levington on Progress and Plans for MSE
    - Bick Hooper on the NSTX 5-year Plan review
    - Ed Synakowski on the NSTX 5-year Plan
  - The PAC was pleased to see
    - More use of analysis tools
    - Integrated modeling of NSTX scenarios
  - In following viewgraphs we respond by task-areas

# MHD

- PF1A. To be installed in '06, used in '07. (PAC approves schedule)
  - Given particle control schedule, not clear you want this earlier
  - Split vs. shift (split gives better shape, more expensive)
    - Demonstrate control of high-elongation plasmas this year
    - 1 yr to prepare (manufacture). Funding for start in '05 budget
    - 2-4 months to install
- RWM system plus power supply ✓
  - Coils designed, will be installed in June
  - Power supply ready by Summer
  - 6 weeks run with active RWM system this year
- Equilibrium reconstruction now includes plasma rotation ✓
- MSE (orig. scheduled in '01) ✓
  - The PAC looks forward to seeing data this year
  - Make data generally available through E-fit analysis as soon as possible.

# Transport and Turbulence (1)

- Global confinement studies
  - Parameter scans this year for developing low-A H-mode database.
  - The analysis chain should include  $\mu$ -stability analysis
- Need more understanding of ST transport regimes (H-mode vs L-mode, divertor vs. limiter, ...)
- PAC is pleased to see a resolution of the anomalous ion heating issue
- Fast ion transport
  - Critical for current drive, current ramp-up (500-600 kA fast ion confinement), achieving high-performance
  - What is the loss mechanism? (Orbit losses, wave/particle interactions?)
  - Studies put off a year (PAC is not alarmed)
  - Need to view all frequency ranges to look for loss mechanisms

# Transport and Turbulence (2)

- PAC is pleased to see well-characterized profiles for stability analysis (109070, 107830)
- PAC interested in  $\mu$ -stability calculations of n,T profiles produced by scenario calculations (tools are available for this)
- Electron transport is the issue in NSTX
  - ETG  $\mu$ -stability analysis of NSTX data.
  - Need somebody to apply  $\mu$ -stability codes to NSTX shots
  - Codes for non-linear ETG simulations are available  
(issue is finding someone to devote the time to apply them to NSTX)
- What does  $\mu$ -stability have to say about ion channel? Are there scenarios which would challenge ion diffusivity (for transport understanding)

# Wave-Particle/Start-up

- EBW and 15/21 GHz tube development
  - What is the right frequency
    - Get data from MAST (28 GHz launcher on MAST?)
    - Modeling, emission measurements,
    - Decision by '06 for tube deployment in '08 (a bit late in NSTX schedule)
    - Frequency decision is a critical path
- HHFW
  - HHFW system has delivered 5 MW, higher reliability
  - Compatibility with NB remains an issue
  - If HHFW/NB scenarios are hard, NSTX will dedicate the time
- Start-up. PAC impressed with scenarios presented by C. Kessel
  - Liked plan with three pieces (initiation, ramp-up, sustainment)
  - Look forward to progress on all three pieces



# Boundary Physics

- Density control
  - Two plans (Li or Cyro-pump). Staged decision. Need clear decision strategy between Li and (deferred) cyro-pump.
    - Difficulty of pumping high delta with cyro-pump
    - NSTX program needs to make sure that they have the diagnostics and devote the exp't time to support this decision
    - Handling high power and particle fluxes
  - Density-profile control? Defer until pumping strategy is resolved
- The PAC looks forward to FY '05 edge diagnostic upgrades.

# Integrated Scenario Development

- High-beta/confinement milestone in FY '04
  - Looks like NSTX team will meet this milestone
- More emphasis on integration later in the 5-year plan after you have learned more ST physics.
- PAC is pleased to see that integration is now a key part of the NSTX program.
- CTF scenario.
  - Is this a new target for NSTX research?
  - Should there be a CTF-relevant scenario integrated into the NSTX plan? (connected to long-pulse CD demonstration scenario?)

# 2<sup>nd</sup> Charge

2. *Does the proposed experimental run make the best use of the available run time and capabilities to achieve these key elements of the FY '04 research?*
  - **Presentation by**
    - Stan Kaye
  - **In the following viewgraphs we respond**
    - Commenting on the FY '04 experimental planning
    - by Milestones (defining “key elements”)
    - By selected task areas (if they didn't have a milestone)

# FY '04 Run program

- Overall outline
  - Run-day budget
  - Outline for 90 days of running
  - A commitment to 90 days of productive experiments
  - Detailed run-plans for first 3 weeks (or so ...)
- Committee approves of this approach -- right balance between needed flexibility and development of run-plans
- Committee approves of level of contingency
  - Scientific contingency
  - Commitment to run 90 days

*FY 04-01: assess confinement and stability in NSTX by characterizing high confinement regimes with edge barriers and by obtaining initial results on the avoidance or suppression of plasma pressure limiting modes in high-pressure plasmas.*

- Milestone is a “catch-all”, but drives interesting research in many areas
- ISD: PAC is impressed with the high-elongation strategy for achieving high-beta
  - High elongation increases normalized current. Gives better use of ST concept in achieving a high-beta plasma
    - Ultimate compatibility with particle control
    - Power handling (clearly an issue for follow-on devices, will this be an issue for NSTX operation?)
- Boundary physics
  - Electron transport is the issue, need more Thomson channels in edge (sorry to see this delayed, look forward to implementation next year)
- MHD — will be able to make use of RWM coils

*FY04-02 Measure long-wavelength turbulence in ST plasmas in a range of plasma conditions*

- Have diagnostics to do this
- Experiments should be in a regime which challenges ion transport (so that ion turbulence is present)
  - Is this compatible with the diagnostic set (low density for reflectometer)?
- Produce and characterize fluctuation data sets.
  - Edge fluctuation data.
  - Core fluctuations at low density ( $<2e19/m^3$ ).

*FY04-03: Measure plasma current profile modifications produced by RF, NBI, and Grad-P techniques*

- Important because it requires NSTX to demonstrate that the MSE diagnostic is on the machine and working
- Requires MSE (therefore must be performed after June)
  - Important that MSE is available to support experimental plans soon after channels are installed.
- Current profile changes slowly ( $\tau_{L/R}$ )
  - Analysis of measured current profiles required to infer driven current components (bootstrap, NBI, ...)

## FY04-4. *Conduct initial tests combining available techniques to achieve solenoid-free initiation to substantial currents*

- Now more than one strategy
  - CHI
    - New insulator at absorber; capacitor bank for fast start-up.
    - PAC looks forward to new results.
  - PF-only start-up (outer field coil inductive)
    - Several proposed strategies for PF-only  
(demonstrating that this is a vibrant area of research)
- This is an excellent way of reducing risk in a key area  
(liked strategy of initially separating initiation from current- ramp)
- Have targets for current initiation (100-150 kA)
  - Provides achievable definition of success
  - Experiments required to confirm these goals  
(can HHFW really couple to these high-beta-p plasmas? Can hand-off from current initiation to ramp-up scenario be accomplished)
- This is an extremely important area, and deserves run-time



## *FY04-5. Measure EBW emissions to assess heating and current drive requirements*

- On critical path for defining EBW system
  - Have three antenna (2 working now, third will be available)
  - Coupling at high vs. low frequencies
  - Harmonic overlap? (3rd vs. 2nd)
  - Which frequencies will drive the current where it is required
- Need schedule and criteria for picking frequencies
  - What do you need to learn from the MAST 28 GHz experiments (2005-6 experiments).
  - Schedule relative to tube development (which requires decision on frequency in FY '05) is tight.

# HHFW/EBW

- Modeling of HHFW
  - Ray tracing,
  - Good job on modeling, but need run-time to understand heating and current deposition profile
- Modeling of EBW physics
  - Good coupling to modeling
  - Scenarios for higher harmonics,
    - Coupling EBW waves to plasma
    - Current profile and current drive efficiency
  - Emission expt's are important

# Transport & Turbulence

- 0-D transport analysis.
  - Good start
  - Important because all confinement improvement projected for ST burning plasmas come from current scaling.
  - PAC notes preliminary result that there was no improvement in global confinement with  $I_p$
  - Critical to future of ST
- Electron transport in reversed (or reduced) B-shear
  - An important experiment (electron transport is the issue in STs)
  - Requires MSE
  - Backloading of FY '04 experimental schedule?

# Boundary Physics

- Important' 05 milestone
- Balance is about right
- Boundary turbulence is included in T&T (explaining fewer run days in this area)
- Fueling and particle control is critical to future scenarios
  - Impurity pellet injector (Li approach) this year
  - Fast IR camera next year (have an IR camera now)
  - Supersonic gas injector for more efficient fueling

# 3rd Charge

1. *Does the proposed NSTX research and facility plan from '04 to '06 effectively address the goals of the 5-year plan in light of the budget constraints? Is the research program well integrated into the national and world program?*
- Presentations by
    - Steve Sabbagh on RWM research
    - Martin Peng on the FY '05-06 research plan
    - Masa Ono on the FY '-5-06 facility plan

# Facility Plan — RWM system

- A well thought-through program
- On schedule for initial operation in FY '04 despite budget challenges
- The PAC looks forward to data in Summer of 04
- WELL DONE!

*... is the research program well integrated into the national and world program*

- NSTX generally does an exemplary job in initiating International collaborations
- Coordination of US ST program
  - US ST coordinating committee for national collaborations equipment loans, etc.
  - ITPA, edge similarity experiments with DIII-D, fast ions
  - Collaboration with HIT-II on Chi injection
  - Co-ordinate with the PEGASUS EBW program?  
(can this data arrive in time to effect NSTX frequency decision?)
- The PAC would encourage the initiation of a US/Russian fusion agreement to enable collaborations with Globus-M
- Use IEA upcoming agreement as a framework for developing an International ST data base.

*Does the proposed NSTX research and facility plan from '04 to '06 effectively address the goals of the 5-year plan in light of budget constraints?*

- EBW system depends on out-year budgets (beyond '06) AND on incremental budgets in '05 and '06
  - Critical to NSTX scenarios as presented by Kessel
  - No clear path to completion without incremental budget
  - Off-axis current drive is important to NSTX scenarios. This is a critical path item.
- MSE by June -- this is tight. If this schedule slips NICD milestone and (electron) transport experiment are endangered. 3 channels can give  $q(0)$ . More needed for profiles.
- Drop to 15 run-weeks in '06? It will be difficult to achieve NSTX program goals if this happens.
- The PAC was pleased to see diagnostics, lithium system and OH spare in the base budget, and generally approves of the facility plan.



# Final Words

- The PAC found the presentations by the NSTX team to this PAC meeting to be particularly well-organized and to-the-point
- As always, the PAC is impressed with
  - Princeton's hospitality
  - The quality of the NSTX research program
  - The promise of ST research