Review of the NSTX 5 Year Plan Panel Comments

July 30, 2008

(John S. Sarff, Chair)

1. Importance and Relevance

- ST research explores fusion science in important parameter space accessed by low aspect ratio
  - Natural shaping and very high beta
  - Transport at extreme in toroidicity, with large (and sheared) flow
  - RF science in over-dense plasmas
  - Super-Alfvenic ion effects
  - Naturally large heat flux on PFCs

- NSTX is the most capable ST facility in the world in several areas that are crucial for next-step development
  - Passive and active control above the no-wall ideal MHD limit
  - NBI and HHFW for heating and current drive
  - Advanced liquid lithium and other divertor strategies
  - Energetic ion physics
  - CHI and other solenoid-free formation

1. Importance and Relevance

- Proposed research clearly aims to position the ST as a candidate for future high priority US research missions, as articulated in recent FESAC reports
  - High heat flux facility for PMI research, as embodied in NHTX
  - Nuclear component testing, as embodied in ST-CTF

- The panel agrees that the proposed research priorities address these missions
  - 100% non inductive current drive
  - Particle and heat flux control
  - Non inductive start up and ramp up
  - Sustained high beta operation

1. Importance and Relevance

- The NSTX program is commended for its many important and unique scientific contributions, both specific to ST and tokamak development as well as general fusion science.

- NSTX is an active participant in 17 ITPA joint experiments (contributes to 24 total) in multiple topical areas, leveraging fusion science in low aspect ratio parameter space. NSTX team members are ITPA and BPO leaders.

- NSTX is making important contributions to ITER design
  - IPEC code development and validation
  - Vertical stability
  - ELM studies using RMP coils
  - RWM control

2. Scientific and Technical Merit

The major facility upgrades are appropriately sequenced

1. The liquid lithium divertor (LLD) is an innovative approach to density control
   - Potential for high reward, but no guarantee LLD will provide necessary control
   - Builds on successful work on CDX-U, LTX, and NSTX past experiments
   - Measuring and modeling effects associated with lithium will be critical to understanding the science and projecting future applications. It is not clear that there is sufficient attention paid to this in the proposal.
   - Thin-film approach and in-situ filling are technically feasible and will control the amount of lithium

2. Scientific and Technical Merit

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- If LLD does not operate as expected, scenarios for operation without its removal have been identified
- A backup strategy for density control should be better developed
  - Cryo pump consistent with device mechanics and plasma shaping
  - Understanding particle transport responsible for density rise (all methods)

2. The center stack upgrade is very well motivated and should be installed as soon as possible

- **Will increase operational parameter space essential to high priority mission and research in topical science areas**

3. The second neutral beam source is essential to take advantage of higher BT and current capability from center stack upgrade

- **Enhanced non-inductive current drive and current profile control**

2. Scientific and Technical Merit

- Macroscopic stability
  - NSTX is a world leader in achieving and understanding high beta plasmas at and above the no-wall MHD limit
  - Active and passive control of RWM especially notable
  - Panel strongly encourages work in disruption physics

- Transport physics
  - Focus on electron transport is critical for the ST, and also a major contribution to fusion science
  - New turbulence diagnostics are vital additions
  - Opportunity for improved understanding of particle transport, which would help establish density control
  - Stronger emphasis on impurity transport encouraged

2. Scientific and Technical Merit

- Boundary (other than LLD)
  - We support the installation of the coils required for X- (and possibly Super-X) divertor capability to provide more robust heat flux handling with higher power and longer pulse, and to assess these concepts for future devices
  - We agree that the additional Thomson resolution in the pedestal region is critical and high priority to characterize and understand the pedestal, SOL, and advanced divertor concepts
  - Planned capability to measure the heat flux and plasma footprint should provide important new data to understand the divertor response.

2. Scientific and Technical Merit

- Wave and particle interactions (energetic particles)
  - A world leader in the investigation of energetic ion physics
  - Interaction with theory and computation particularly notable
  - Correctly identified energetic ion redistribution impact on current drive as highest priority

- Wave and particle interactions (RF)
  - We support the modifications to HHFW antenna, aimed to increase coupling and improve resiliency to ELM effects
  - Strongly encourage validation effort in theory and modeling for RF current drive

2. Scientific and Technical Merit

- Non inductive start-up and ramp-up
  - **The higher BT and longer pulse capability from the center stack upgrade and the addition of a 2nd beam source should improve the capability for HHFW and NBI current ramp-up.**
  - It is not clear in the proposal that there are assessment strategies to resolve within the next 5 years whether or not the various start-up options will project to next-step devices.
  - A prioritization of the start-up experiments might be required due to limited resources.
  - The integrated scenario plans are well conceived, but we encourage investigation of the inclusion of HHFW capability, especially since the 2nd beam is not available in the baseline budget scenario.

2. Scientific and Technical Merit

- Manpower development and student training
  - 29 graduate students and postdocs, including those from collaborating institutions
  - Strong association with Princeton University
  - Senior students function as experimental session leaders

3. Personnel and Research Environment

- Highly qualified staff
- PPPL provides excellent support and outstanding research facilities
- Outstanding national and international collaboration
  - Central to the NSTX program (from day one)
  - Non-PPPL Topical Science Group leadership
  - Research Forum effective in identifying and prioritizing research proposals
- Balanced top-down and bottom-up program planning approach

3. Personnel and Research Environment

- Experimental program integrated with theory, computation, and modeling across topical areas, for example,
  - IPEC, Kinetic modifications to MHD (Macrostability)
  - G* codes (Transport)
  - NOVA and ORBIT (Wave-Particle Interaction)
  - TORIC and AORSA (Wave-Particle Interaction)
  - UEDGE, SOL-PS, XGC, OMEGA (Boundary)

- Proposed diagnostic upgrades are well motivated and appear credible, although a detailed review of collaborators proposals isbeyond our charge.

4. Performance and Facility Operations

- Steady increase in shots per hour of operation
- All research and facility milestones were met in last 5 years
- ES&H goals met, award winning safety record

5. Costs

- We are only asked to comment on reasonableness of cost at a summary level
- The costs for facility operation appear reasonable, based on extrapolation of planned run time.
- We support the increased funds in the guidance budget to be primarily applied to major facility and diagnostic upgrades.
- **For an incremental budget increase, we support an acceleration of the center stack and 2nd neutral beam upgrades.**