PAC-25 Day 1 Questions

1. Research needs for (post-upgrade) long-pulse, higher power discharges:
   - Impurity transport? Density control (via LLD)?
   - Plan to develop longer pulse & higher power Li divertor ?
   - Understanding Li physics?
   - Explain how research plan will establish post-upgrade integrated scenarios ?
   - Plan for diagnostic changes due to 2nd NBI
   - Others…

2. How do you characterize the balance between: (1) answers needed for upgrade, (2) toroidal physics, (3) ST development, and (4) ITER support?

3. Why is there no near-term electron transport milestone?

NSTX Response to PAC-25 Question 1 (pg 1)

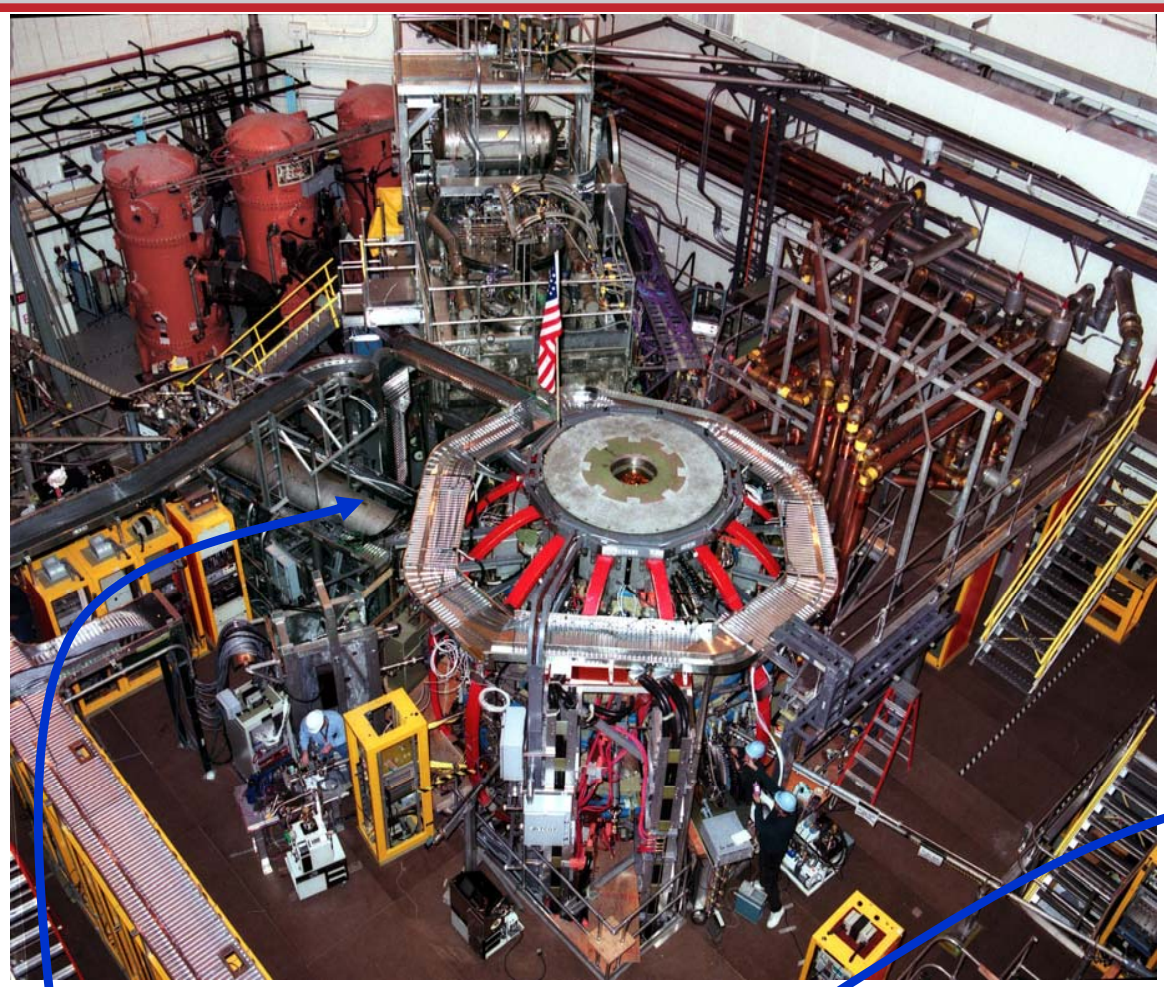
1. Research needs for (post-upgrade) long-pulse, higher power discharges:
   - Impurity transport?
     - Issues: ELM-free operation and Li, C, possibly metal accumulation
       - Have RMP ELM pacing to trigger ELMs, and 3 years to optimize (Maingi talk)
       - Measure Li transport into plasma w/ Li CHERs now + FY11 milestone (Skinner talk)
       - BES to study link between low-k turb (FY11 milestone) & particle x-port (Tritz talk)
   - Density control (via LLD)?
     - Issues: need predictive capability for pumping of LLD to assess if an upgraded LLD is compatible with NSTX-Upgrade pumping requirements – see Skinner talk.
       - Measure retention in FY09 joint milestone, informs LLD operation in FY10
       - Diagnose D retention, Li erosion, transport w/ LLD in FY10, FY11 Li milestones
       - Couple with UEDGE/other modeling (UCSD, Purdue, …)
   - Plan to develop longer pulse & higher power Li divertor ?
     - Issues: active cooling, LLD replenishment, peak heat flux
       - FY10-11 Measure temperature evolution of LLD and compare to prediction (FY11 research milestone), and design active cooling capability accordingly
       - Solid Li re-fueling of LLD being tested now on test stands (L245 with LTX help).
       - Peak heat flux: need to assess impact of high heat flux on LLD in FY10-11 as part of FY10 joint milestone, and scaling of peak heat flux with I_P and Li/LLD, and other parameters (FY10 joint milestone)

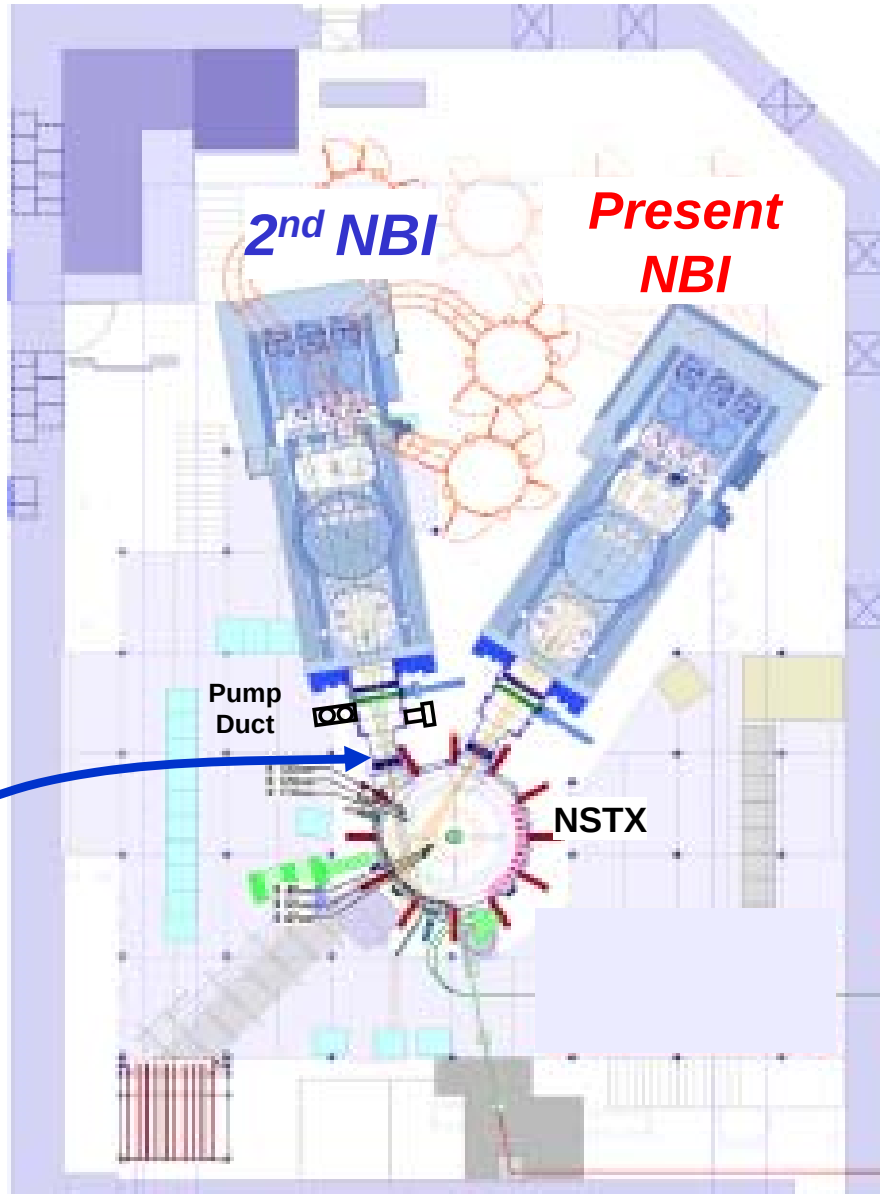
NSTX Response to PAC-25 Question 1 (pg 2)

1. Research needs for (post-upgrade) long-pulse, higher power discharges:
   - Understanding Li physics?
     - This emphasis of FY11 research milestone, also covered by Skinner talk
     - Developing Lithium Research Thrust to involve wider group in analysis and modeling
   - Explain how research plan will establish post-upgrade integ. scenarios?
     - Transport:
       - FY10 milestone on pedestal transport + stability vs. Li/LLD + FY11 milestone on core transport/turbulence (using BES) will aid establishment of transport scaling vs. collisionality to project to optimal integrated scenarios.
       - Could do more to establish H-mode confinement scaling at high Ip ~ 1.5MA for short pulses = few tau-E (not presently planned…) to inform upgrade operation…
     - Stability:
       - FY09, FY10, and FY11 (incremental) milestones will establish EF/RFA/RWM active control to be used on upgrades.
     - Boundary:
       - FY09, 10, 11 joint milestones focus on retention, SOL/div heat flux, pedestal structure, and will aid understanding of Li/LLD on edge transport and stability for upgrades, and if Li divertor can possibly be used for upgrades.
     - Wave-particle, Solenoid-free ramp-up
       - EP: Emphasis on AE avalanche diagnosis (FIDAs) and J(r) redistribution will inform possible NBI-CD redistribution to be expected with 2nd NBI
       - HHFW: FY10 milestone + FY11 research will determine viability of HHFW for ramp-up target for 2nd NBI I_P ramp-up, and for heating during NBI H-mode

2nd NBI Diagnostic System Reconfiguration

2nd NBI Port at Bay-K and Pump-duct at Bay-L





- 2nd NBI to be located at Bay-K
- Pump-duct at Bay-L to be removed
- Bay-L to be a dedicated diagnostic port
- A pump duct to be incorporated into 2nd NBI duct.

2nd NBI Diagnostic System Reconfiguration

Red-Italics: Affected Diagnostics

Profile/Confinement Studies

- Magnetics for equilibrium reconstruction (Columbia)
- Diamagnetic flux measurement
- *Multi-pulse Thomson scattering (30 ch, 60 Hz)*
- *CHERS: $T_i(R)$ and $V_f(r)$ (51 ch)*
- p-CHERS: $V_\theta(r)$ (75ch)
- Density Interferometer (1 mm, 1ch) (UCLA)
- Visible bremsstrahlung radiometer
- Midplane tangential bolometer array
- *X-ray crystal spectrometer: $T_i(0)$, $T_e(0)$*
- X-ray crystal spectrometer (astrophysics) (LLNL)
- MSE-CIF (Nova)
- MSE-LIF (Nova)

MHD/Fluctuation/Waves

- Locked-mode detectors
- RWM sensors (n = 1, 2, and 3)
- Ultra-soft x-ray arrays Š tomography (4 arrays) (JHU)
- Fast X-ray tangential camera (2μs) (PSI)
- Microwave reflectometers (UCLA)
- Scrape-off layer reflectometer (ORNL)
- *FIReTIP (119mm, 6 ch, 600 kHz) (UCD)*
- *Tangential microwave scattering (UCD)*
- Beam Emission Spectrometer (U. Wisconsin)
- Electron Bernstein wave radiometer (ORNL)t

Energetic Particles

- High-n and high-frequency Mirnov arrays
- Fast lost-ion probe (energy/pitch angle resolving)
- Fast neutron measurement
- *Scanning Neutral Particle Analyser (2-D)*
- Solid-state Neutral Particle Analyser (UCI)
- Fast Ion D_a profile measurement (UCI)

Edge/divertor studies

- Reciprocating Langmuir probe (UCSD)
- Gas-puff Imaging (2μs)
- Fixed Langmuir probes (24)
- Edge Rotation Diagnostics (T_i, V_ϕ, V_{pol})
- 1-D CCD H_α cameras (divertor, midplane) (ORNL)
- Divertor bolometer (3-view, 20 ch)
- Fast visible cameras (Nova)
- IR cameras (30Hz) (3)(ORNL)
- Fast IR camea (ORNL)
- Tile temperature thermocouple array
- Edge neutral pressure gauges (U. Washington)
- Sample Probe (MAPP) (Purdue)
- Visible/UV/EUV survey spectrometers (LLNL)
- VUV transmission grating spectrometer (JHU)
- Visible filterscopes (ORNL)
- Wall coupon analysis (SNL)

NBI Related Diagnostic Relocation Issues

- Diagnostics on Bay K (2nd NBI Port) to be relocated or eliminated:
  - Tangential microwave scattering (high-k) - Receiver to be relocated to Bay -L. Will need an upgrade to the system including k_θ capability. Discuss with UCD.
  - FIReTIP interferometer (119μm, 6 ch) - Move launcher to Bay L. Move the two retro-reflectors in Bay F to other location. The system could be useful for the real time density control. Discuss with UCD.
  - Neutral particle analyzer (2D scanning) - Likely to be eliminated. Replace with array of fixed SSNPAs.
  - Fast tangential X-ray camera: Eliminate due to limited utilization.
- Bay L pumping port will be removed and incorporated into 2nd NBI duct. Diagnostics in the pumping port needs to be relocated or eliminated. Bay L port to be a dedicated diagnostic port:
  - MPTS laser dump located in the duct needs to be relocated. Re-aim laser and viewing optics.
  - X-ray crystal spectrometer, SPRED VUV spectrometer, XUES EUV spectrometer: Move to reconfigured Bay-L port.
- Affected by the presence of 2nd NBI
  - T-CHERS: CHERS background view will see 2nd NBI. No suitable solution other than beam notch or use p-CHERS. Likely to be more of research effort than construction effort.

NSTX Response to PAC-25 Question 2

- How do you characterize the balance between: (1) answers needed for upgrade, (2) toroidal physics, (3) ST development, and (4) ITER support?

- Prioritization:
  - ST development is highest priority – research for upgrades is integral part of this
    - 90-100% of experiments contribute to ST development
    - ~50% of run-time for direct support of NSTX milestones + highest priority ST-specific research
  - ITER support is lower priority
    - ~50% of XPs support ITPA, 10% ITER highest priority – both contribute to ST development
  - Fundamental toroidal physics studies underpin ST development and ITER support
- Balance:
  - Research needed for major upgrades is well covered by FY09-11 milestones + high priority ST research (see question 1 response), so balance is appropriate
    - Critical near-term issue for the upgrades: Assessment of projected peak divertor heat flux + pumping requirements - will influence choice of PFCs on divertor(s), and pumping method
  - ST-specific development: non-inductive start-up – high priority longer-term ST issue
    - Investing appropriate resources + run time for HHFW upgrade for ramp-up, + CHI improvements
  - ITER - focus on topics where NSTX can make unique and strong contributions
    - If run time is limited, higher priority will be given to support of upgrades and ST development.
  - Toroidal physics – balance is appropriate:
    - Unique ST physics (e-transport, multi-mode AE physics, strong toroidicity effects in boundary, non-inductive start-up, …) very important for ST development, several issues important for ITER

NSTX Response to PAC-25 Question 3

3. Why is there no near-term electron transport milestone?
   - e-transport research will continue with high priority within T&T group
   - HHFW (for increased core e-heating), LLD (for reduced density and collisionality), and BES (for low-k turbulence measurements) will be vital tools for e-transport research.
   - In FY10 base plan, there is insufficient run-time to support additional milestones that rely upon these capabilities - since LLD, BES, and HHFW (w/ ELM resilience) are only first utilized in FY10.
     - An incremental milestone on e-transport is possible – contingent on additional runtime, and some mixture of successful development of LLD in FY10, successful HHFW heating (possibly only in L-mode), and sufficient BES commissioning progress. GAE e-transport could also be element of this incremental milestone.