NSTX Program Update

- Milestones for FWP
- Upgrades for FY09-11
- PAC charge
- PAC agenda
- PAC dry run schedule
- Lithium research thrust

NSTX FY2009-11 Research Milestones

(base and incremental)

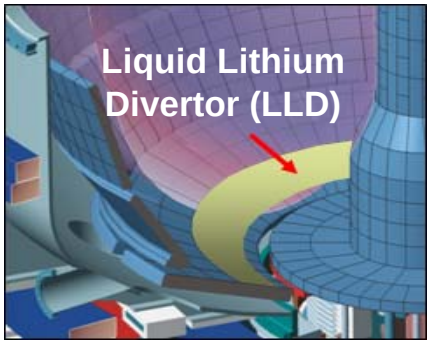
	FY2009	FY2010	FY2011
Expt. Run Weeks:	14 (20)	15 (20)	15 (20)
1) Transport & Turbulence			Study turbulence regimes responsible for ion and electron energy transport (formerly FY2010)
2) Macroscopic Stability	Understand physics of RWM stabilization & control vs. rotation	Assess sustainable beta and disruptivity near and above the ideal no-wall limit.	Assess sustained operation above the no-wall limit at reduced collisionality
3) Boundary Physics		Assess H-mode characteristics as a function of collisionality and lithium conditioning	Relationship between lithiated surface conditions and edge and core plasma conditions
4) Wave-Particle Interaction	Study how j(r) is modified by super-Alfvénic ion-driven modes	Characterize HHFW heating, CD, and ramp-up in deuterium H-mode *Joint milestone w/ solenoid-free TSG*	Assess predictive capability of mode-induced fast-ion transport
5) Solenoid-free start-up, ramp-up			
6) Advanced Scenarios & Control	Perform high-elongation wall-stabilized operation at lower n_e		Dependence of integrated plasma performance on collisionality *(FY2010 incremental accelerates this by 1yr if LLD and/or HHFW achieve FY2010 goals)*
	Integrate MHD mode modification of j(r) into optimized operation	←	

Joint Research Targets (3 US facilities):

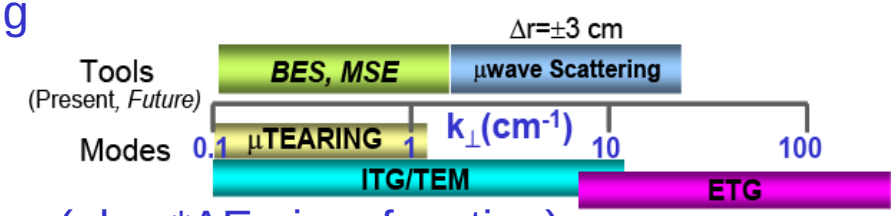
Particle control and hydrogenic fuel retention	Improve understanding of the heat transport in the scrape-off layer	TBD *(…Characterize H-mode pedestal structure…)*

FY09-11 upgrades support highest priorities and enable key research thrusts:

1. FY10 - Implement liquid lithium divertor for pumping, and investigate other potential benefits:
   - Improved confinement
   - Reduction/elimination of ELMs
   - Compatibility of LLD with high flux expansion
   - Longer-term: steady-state high-heat-flux handling

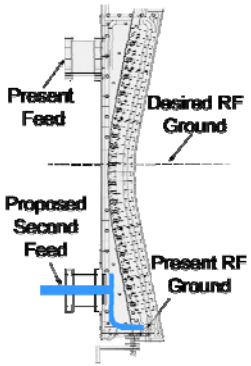


2. FY10 - Implement BES to complement existing high-k scattering diagnostic



   - Measure full wavenumber spectrum of turbulence (also *AE eigenfunction)
   - Determine modes responsible for anomalous transport of energy & momentum

3. FY09-11 - Upgrade HHFW system for higher P_{RF} + ELM resilience
   - Full power end of FY09, electronic resilience FY10, hybrid ELM-dump FY11?
   - Determine if HHFW can ramp-up I_P in H-mode (BS+RF overdrive)
   - Determine if HHFW can heat high-β_N advanced H-mode scenarios
   - HHFW/ICRF also important for NHTX/CTF/ITER



4. FY11 Implement MSE-LIF for pitch angle and |B| w/o heating beam
   - Greatly expanded research flexibility, reconstruct fast-ion p (from total – thermal)

Also considering 10-15 additional MPTS channels by FY11 for pedestal/SOL + core to support FY11 joint facility + theory milestone on "characterizing H-mode pedestal structure"

25th meeting of the NSTX Program Advisory Committee

Princeton Plasma Physics Laboratory
Conference Room LSB-318
February 18-20, 2009

BACKGROUND and CHARGE

During the last year, considerable changes have taken place within the U.S. spherical torus program. In May 2008, DOE terminated the NCSX construction project and encouraged a "renewed focus on the Spherical Torus confinement concept", and stated that "proposed upgrades for NSTX can keep this facility at the forefront of fusion science research... well into the future." In the summer of 2008 the NSTX research team completed the "Research Program Five Year Plan for 2009-2013" which was successfully peer reviewed in July 2008. Two major facility upgrades were proposed in the 5 year plan: 1) a new center-stack (CS) for higher toroidal field, plasma current, and pulse duration to enable access to plasmas with reduced collisionality with relaxed profiles, and 2) a second more tangential neutral beam injection (NBI) system for increased non-inductive current drive and profile control enabling access to high beta at reduced collisionality. A few examples of the many scientific opportunities enabled by these upgrades include: the first opportunity to study NBI current ramp-up in an ST, new understanding of the modes responsible for electron transport, prototyping of heat and particle exhaust solutions for next-step facilities, and comprehensive studies of energetic particle transport induced by non-linearly interacting Alfvén Eigenmodes relevant to ITER burning plasmas and next-step STs.

The present NSTX plan is to implement the CS and NBI upgrades in a single extended outage period to minimize the resources required to complete both upgrades and to maximize NSTX capabilities resulting from the outage. An extended outage period of up to 2 years is likely required and could begin as early as FY2012. As a result, very few (possibly no) additional major facility or diagnostic capabilities beyond those already initiated will be possible in the FY10-13 time-frame. New capabilities already initiated include: a liquid lithium divertor (LLD) for particle pumping, higher-power fast-wave heating for current ramp-up studies and electron heating in advanced scenarios, a beam-emission spectroscopy (BES) diagnostic for low-k turbulence measurements, and a motional-stark-effect diagnostic using laser-induced fluorescence (MSE-LIF) to measure magnetic field pitch-angles and |B| without a heating beam – a capability that is highly useful for transport, energetic particle, and RF research. These new capabilities will become operational in the FY2009-11 time-frame, and it is vital that the FY2009-11 run period fully exploit these capabilities and collect the most complete data sets possible for analysis and publication prior to a possible major upgrade outage period.

Also during 2008, the FESAC Toroidal Alternates Panel (TAP) assessed the ITER-Era goal for the Spherical Torus (ST) which is to: "Establish the ST knowledge base to be ready to construct a low aspect-ratio fusion component testing facility that provides high heat flux, neutron flux, and duty factor needed to inform the design of a demonstration

fusion power plant." The ST physics issues identified for this goal are: start-up and ramp-up, plasma-material interface, electron energy transport, integration, disruptions, RF heating and current drive, 3D fields (ELM/EF/RWM), ion scale transport, fast particle instabilities, and NTMs. These prioritized issues clearly frame the NSTX research program in support of developing the knowledge base for a component test facility (CTF). Of comparable importance, however, are the significant contributions that NSTX makes to the knowledge base for ITER, for proposed next-step facilities to "Tame the plasma material interface" (such as NHTX), for an ST-based demonstration power plant (ST-Demo), and to fundamental toroidal confinement science.

NSTX has been productive in advancing fusion physics understanding for the Spherical Torus (ST) and for the broader range of magnetic configurations – including ITER. In 2008, NSTX achieved significant advances in understanding the impact of plasma rotation on confinement and stability, measured poloidal rotation to be consistent with neoclassical predictions, assessed scrape-off layer width and divertor heat-flux scalings, enhanced High-Harmonic Fast Wave (HHFW) coupling and heating in H-mode with Lithium conditioning, coupled Coaxial Helicity Injection (CHI) start-up to an inductively-driven NBI-heated H-mode plasma, and implemented error field correction and RWM control for a wide range of operating conditions to improve overall NSTX performance. Further, NSTX provided important vertical control data for ITER and developed new ELM control scenarios in which Lithium was utilized to suppress ELMs and 3D resonant magnetic perturbation (RMP) fields were used to trigger ELMs and expel impurities. The new understanding that the NSTX ELM control results are providing is also highly relevant to ITER. Thus, the ST concept in general and NSTX in particular are advancing a broad set of topics that are crucial to the advancement of magnetic fusion.

With these considerations in mind, we ask the NSTX Program Advisory Committee to address the following questions for both the upcoming run period (FY2009) and for the medium term (FY2009 – 2011):

1) Does the research plan provide the correct balance and focus to optimize the contributions of NSTX in the areas of: next-step ST development, ITER high-priority research needs, and fundamental toroidal confinement science?

2) Does the research plan fully exploit the upcoming (FY2009-2011) facility and diagnostic upgrades?

3) Is the NSTX research plan responsive to the four highest priority ST physics issues identified in the FESAC-TAP report - namely: start-up and ramp-up, plasma-material interface, (electron) energy transport, and integration?

Additional information:

The NSTX 2009-2013 Five Year Plan chapter text and presentations are archived at:
http://nstx.pppl.gov/DragNDrop/Five_Year_Plans/2009_2013/

NSTX PAC-25 AGENDA
February 18-20, 2009
Conference Room LSB-B318, PPPL

Wednesday, February 18, 2009

1:00	Coffee & Cookies, PAC Executive Session	
1:15	Stewart Prager	Welcome and charge to the PAC
1:20	Steve Eckstrand	Comments from DOE
1:25	Michael Mauel	New PAC members, agenda and plan of meeting
1:35	**Michael Bell**	**FY2008 Run Campaign Accomplishments**
2:30	**Jon Menard**	**Program Overview for 2009-11 and Beyond** ***(includes discussion of physics motivation for major upgrades of NSTX)***
3:30	Coffee	
3:45	**Masa Ono**	**Facility & Diagnostic Overview for 2009-11 and Beyond** ***(includes discussion of design status/plans for major upgrades of NSTX)***
4:45	Michael Mauel	PAC Executive Session
6:15	Michael Mauel	Feedback and questions to NSTX team (as requested)
6:45	Adjourn	
7:30	**PAC dinner**	Hosted by Jon Menard

Thursday, February 19, 2009

8:00	Coffee & Donuts	
8:30	Michael Mauel	Feedback and questions, response to any previous questions
9:00	**Roger Raman**	**Overview of Run Plan for FY2009**
9:35	**Rajesh Maingi**	**Boundary Physics Progress and Plans**
10:00	**Charles Skinner**	**Lithium Research Status and Plans**
10:20	Coffee	
10:35	**Steve Sabbagh**	**Macroscopic Stability Progress and Plans**
11:00	**Kevin Tritz**	**Transport and Turbulence Progress and Plans**
11:25	**David Gates**	**Scenario Integration and Control Progress and Plans**
11:50	**Eric Fredrickson**	**Energetic Particle Physics Progress and Plans**
12:15	**Gary Taylor**	**HHFW Progress and Plans**
12:35	**Dennis Mueller**	**Solenoid-free Start-up & Ramp-up Progress and Plans**
1:00	Lunch and PAC Executive Session	
3:30	Coffee	
3:45	PAC Executive Session	
5:30	Michael Mauel	Feedback and questions to NSTX team (as requested)
6:00	**Adjourn for Tour**	**NSTX tour**

Friday, February 20, 2009

8:30	Coffee & Donuts	
8:40	Michael Mauel	NSTX team response to PAC questions
8:55	PAC Executive Session	
(10:00	Coffee)	
(12:00	Lunch)	
12:45	Michael Mauel	Debriefing
1:30	Adjourn	

Dry Run Date	Time	Speaker	Talk duration [mins]	Talk duration including time for Q&A [mins]	Tentative title	Location	Confirmed?
Friday, February 6, 2009	9:30-11:30AM	Eric Fredrickson	18	25	Energetic particle physics progress and plans	B318	
Friday, February 6, 2009	2-3:30PM	Gary Taylor	15	20	HHFW progress and plans	B318	OK
Friday, February 6, 2009	3:30-5:30PM	Rajesh Maingi	18	25	Boundary Physics Progress and Plans	B318	OK
Monday, February 9, 2009	1-2:30PM	Charles Skinner	15	20	Lithium Research Status and Plans	B318	OK
Monday, February 9, 2009	2:30-4PM	Kevin Tritz	18	25	Transport and Turbulence Progress and Plans	B318	OK
Monday, February 9, 2009	4-5:30PM	Dennis Mueller	18	25	Solenoid-free start-up and ramp-up	B318	OK
Tuesday, February 10, 2009	9AM-12PM	Jon Menard	40	60	Program Overview for 2009-11 and Beyond	B318	OK
Tuesday, February 10, 2009	1-4PM	Masa Ono	40	60	Facility & Diagnostic Overview for 2009-11 and Beyond	B318	OK
Tuesday, February 10, 2009	4-6PM	Roger Raman	25	35	Overview of run plan for FY2009	B318	OK
Wednesday, February 11, 2009	9AM-12PM	Michael Bell	40	55	FY2008 Campaign Accomplishments	B318	OK
Wednesday, February 11, 2009	1-3PM	Steve Sabbagh	18	25	Macroscopic stability progress and plans	B318	
Wednesday, February 11, 2009	3-5PM	David Gates	18	25	Advanced scenarios and control - progress and plans	B318	

Li questions to address from PAC-23 report

- Are the positive effects on plasma performance and plasma profiles the result of changes in recycling (pumping)?
- If the Li pumping is the dominant effect, is the important pumping occurring at the divertor or around the first-wall generally?
- Is it possible that lithium coatings primarily bind deuterium loaded into the carbon wall, making it unavailable for recycling?
- Could it be that the positive effects correlating with Li usage are due to suppression of some impurities (e.g. C, O) and/or their replacement with Li in the plasma?
  - Closer collaborations with FTU, which is the largest metal-walled tokamak performing extensive lithium PFC work, may also provide information on the role of carbon-lithium interactions.
- Experiments should include particle accounting (i.e., how much gas is injected versus how much is left in the vessel after a shot, as well as postmortem analysis of the tiles).
- Experiments should be done with bare walls after a vacuum break (no Li on surfaces) and then, after lithium is introduced, for each shot (which was a direct recommendation from PAC-21).

Formation of Lithium Research Thrust

- Why
  - Need to better understand underlying physics of how Li impacts plasma
    - And how plasma and non-Li PFCs impact Li PFCs
  - Impact of Li is cross-cutting
    - Cuts across all NSTX topical science areas, and several programs at PPPL
- Who
  - C. Skinner (leader, NSTX rep – coordinates NSTX expt Li program)
  - R. Kaita (deputy – LTX rep, NSTX Li diagnostics)
  - D. Stotler (Li theory and modeling coordinator for NSTX and LTX)
  - Meet with all TSG leaders as needed to capture cross-cutting issues
- What
  - Develop integrated NSTX Li research plan – 3 year time horizon
    - Increase emphasis on Li diagnostics, theory, simulation support
  - Coordinate Li research plans between NSTX, LTX, theory
- When
  - Initiate in parallel with TSGs in next few weeks…