27th meeting of the NSTX Program Advisory Committee
Princeton Plasma Physics Laboratory
Conference Room LSB-318
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BACKGROUND and CHARGE

BACKGROUND:

During the last year, the Office of Fusion Energy Sciences (OFES) held a series of Research Needs Workshops (ReNeW) to identify research needed to bridge gaps from ITER to a demonstration fusion power reactor (Demo), and to ensure ITER's burning plasma mission is successful. The ReNeW research needs were divided into 5 themes and subdivided into 18 research thrusts. The 5 ReNeW themes are: "Burning plasmas in ITER", "Creating predictable, high-performance, steady-state plasmas", "Taming the plasma material interface (PMI)", "Harnessing fusion power", and "Optimizing the magnetic configuration". The spherical torus (ST) configuration and NSTX in particular are well positioned to make valuable contributions to all 5 themes and many research thrusts. For example, the ability to access regimes of non-linearly interacting Alfvén Eigenmodes is relevant to ITER burning plasmas and next-step STs, NSTX Upgrade will enable access to fully-non-inductive high-performance ST operation, the compact ST geometry enables access to high heat flux and (longer term) high neutron wall loading for PMI and fusion nuclear science (FNS) research, and finally, the ST extends the tokamak configuration to lower aspect ratio and higher beta.

The NSTX upgrade project builds on existing capability and extends the reach of this important national facility. The two major elements of the upgrade project are 1) a new center-stack (CS) for 2× higher toroidal field and plasma current and 3-5× longer 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 full non-inductive current ramp-up and sustainment and profile control simultaneously 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 in the ST and all toroidal magnetic fusion configurations, and prototyping of solutions for mitigating very high heat and particle exhaust for next-step facilities.

The NSTX Upgrade project received DOE CD-0 (Mission Need) approval in February 2009, recently underwent a conceptual design review and Lehman review in preparation for the submission of the application for CD-1 (Alternative Selection & Cost Range) in January 2010, and plans to apply for CD-2 (Approve Performance Baseline) in July 2010. The upgrade project 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 1.5-2 years is required and would likely begin following either the FY2012 or FY2013 run campaign depending on project cost and available funding.

To provide resources for the major upgrade project, very few additional baseline facility or diagnostic capabilities beyond those already completed will be implemented in the FY10-15 time-frame. Recently completed upgrades 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, and a beam-emission spectroscopy (BES) diagnostic for low-k turbulence measurements. Very fortunately, stimulus funding will enable additional upgrades including: enhanced Thomson scattering diagnostic resolution at the plasma edge, real-time rotation measurements for real-time rotation control, an additional 3 channel switch power amplifier (SPA) for independent control of all 6 non-axisymmetric control coils, improved diagnosis and refueling of the LLD, and completion of the motional-stark-effect (MSE) 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. The stimulus-funded upgrades will become operational in the FY2011 time-frame and can be fully exploited in the FY11-12 campaigns. Thus, it is vital that the FY2010-12 run period fully exploit these capabilities and collect the most complete data sets possible for analysis and publication prior to a major upgrade outage period.

NSTX has been productive in advancing fusion physics understanding for the ST and for the broader range of magnetic configurations – including ITER. In 2009, NSTX achieved significant advances in understanding the retention of hydrogenic species in graphite and lithiated graphite walls, systematically assessed the scaling of the H-mode threshold on ion species (He vs. D) and other parameters for ITER and the ST, assessed ELM and inter-ELM divertor heat-flux profiles with high time-resolution using fast IR cameras, upgraded the High-Harmonic Fast Wave (HHFW) antenna to increase the coupled power and achieve record ST plasma electron temperatures of 6keV, nearly quadrupled the coupled Coaxial Helicity Injection (CHI) start-up current savings from 50kA to 180kA, showed that resistive wall mode stability depends sensitively on thermal and energetic particle kinetic effects, sustained very low loop voltage and (independently) high-beta plasmas by exploiting high elongation and RWM stabilization, and implemented beta feedback and strike-point control to support advanced scenarios and operation with a liquid lithium divertor, respectively. Further, NSTX optimized the controlled triggering of ELMs to expel impurities and control the density using 3D resonant magnetic perturbation (RMP) fields and showed that vertical jogs can also trigger ELMs. 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.

CHARGE:

With these considerations in mind, we ask the NSTX Program Advisory Committee to address the following two questions for both the upcoming run period (FY2010) and for the medium term (FY2010 – 2012):

1) Does the research plan optimally support preparation for the implementation and exploitation of the NSTX Upgrade Project?

2) Does the NSTX research plan provide proper balance and focus relative to the 5 ReNeW theme areas:

   I. Support of ITER high-priority research needs
   II. High-performance steady-state plasmas
   III. Plasma material interface research
   IV. Advancing the ST as a candidate Fusion Nuclear Science facility
   V. Optimizing the ST as an alternative magnetic configuration and supporting basic toroidal plasma science

Additional supporting information:

The final report of the Research Needs Workshop (ReNeW) is archived at:
http://burningplasma.org/web/ReNeW/ReNeW.report.web2.pdf

Information on ST-FNSF (and ST-CTF) can be found at:
http://nstx.pppl.gov/DragNDrop/CTF_Information/Peng_IAEA_FEC2008_FT-P3-14.pdf

A description of the "NSTX Upgrade Scientific Motivation and Project Requirements" presented at the Lehman review in preparation for CD-1 is archived at:

http://nstx.pppl.gov/DragNDrop/NSTX_Upgrades/NSTX_Upgrade_Science_Requirements_v3.pdf

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