NSTX-U: ST research to accelerate fusion development

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The Upgrade of the NSTX facility to NSTX Upgrade (NSTX-U) is nearly complete with first plasma expected in early calendar year 2015. The components of the Upgrade consist of (1) a new center stack to double the magnetic field and plasma current and quintuple the plasma pulse duration and (2) a second more tangential neutral beam injector (NBI) projected to double the NBI current drive efficiency and enable non-inductive current ramp-up and sustainment at the ~1MA level.

NSTX-U will provide world-leading research capabilities across all 5 ReNeW Themes. In support of Burning Plasmas in ITER (Theme 1), NSTX-U is poised to test for the first time a MSE-LIF diagnostic applicable to ITER conditions to constrain the safety factor and total pressure profile without using a heating beam. To understand the role of alpha particles in ITER, NSTX-U will access, study, and ultimately control non-linear Alfven eigenmodes with flexible variation of the fast-ion distribution function and a full diagnostic set and modelling tools. In support of Predictable, High-Performance, Steady-State Plasmas (Theme 2), NSTX-U aims to control and sustain 100% non-inductive plasmas with high-β_T ~15-20% supported by real-time control of the rotation profile, q profile, and a range of beta-limiting MHD modes. NSTX-U will explore high normalized beta scenarios complementary to MAST-U approaches, and will also complement DIII-D higher aspect ratio sustainment approaches for FNSF/DEMO. NSTX-U will significantly extend predictive capability by testing and validating models in unique regimes of low aspect ratio, high beta at low collisionality, via strong fast-ion instability drive. NSTX-U will also implement real-time disruption prediction/warning and assess the poloidal location dependence of massive gas injection for disruption mitigation. For Taming the Plasma-Material Interface (Theme 3), NSTX-U will contribute low-aspect-ratio and high-beta data in the pedestal and scrape-off-layer regions and measure/model edge transport and turbulence. NSTX-U is leading the effort to extend lithium-based plasma facing components (PFCs) to high-power and long-pulse including effects of vapor-shielding. Over the longer term, NSTX-U aims to test the integration of a high-performance plasma core with novel "snowflake/X" divertor configurations, radiative detachment, and liquid metals on high-Z PFC substrates. For Harnessing Fusion Power (Theme 4), PPPL/NSTX-U leads in providing the physics basis and integrated designs for low-A fusion power systems. In Optimizing the Magnetic Configuration (Theme 5, Thrust 16), the ST is proposed as a leading candidate for a fusion nuclear science facility (FNSF), and NSTX-U is the most capable ST facility world-wide to assess the ST as a possible FNSF.

In the context of ReNeW Theme 5, Thrust 16: "Developing the ST to advance FNS", research gaps were identified including: non-inductive start-up/ramp-up, electron energy confinement, plasma sustainment, power exhaust, and radiation-tolerant magnets. Progress in narrowing these gaps since ReNeW, expected further narrowing/closing of these gaps in NSTX-U, and upgrades and initiatives needed to close remaining gaps for assessing the ST for FNSF will be described. NSTX-U contributions to broader initiatives for ITER and/or FNSF including disruptions, fast-ion-instability control, liquid metals, electromagnetic turbulence, and tools to simplify the AT and ST will also be discussed.