Supported by
U.S. DEPARTMENT OF ENERGY | Office of Science

Draft Boundary Physics research goals and relevant diagnostics in the first years of NSTX-Upgrade

College W&M
Colorado Sch Mines
Columbia U
Comp-X
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Maryland
U Rochester
U Washington
U Wisconsin

V. A. Soukhanovskii, TSG Leader

Lawrence Livermore National Laboratory, Livermore, CA

A. Diallo, TSG Deputy

Princeton Plasma Physics Laboratory, Princeton, NJ

D. P. Stotler, Theory & Modeling

Princeton Plasma Physics Laboratory, Princeton, NJ

R. Maingi, ITER&CC TSG Deputy

Oak Ridge National Laboratory, Oak Ridge, TN

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

NSTX Boundary Physics TSG Meeting

14 September 2011

Princeton, NJ

Introduction – motivation and implementation of this discussion

- Goal: Comment on and discuss the draft Boundary Physics research goals for FY2014-2018 proposed by NSTX Program (Jon Menard)
  - In view of many current uncertainties in program and budget we decided to limit the discussion to Year 1 and Year 2 of NSTX-Upgrade research

- Goal: Discuss and prioritize diagnostics addressing the above research goals as input to NSTX diagnostics proposal process
  - Decided to provide general comments on needed measurements and capabilities to avoid endorsing particular diagnostics or institutions

NSTX-U research in Year 1 and Year 2 will be defined by

- Expected NSTX-Upgrade capabilities
  - Graphite PFCs (moly in year 2 or 3?)
  - Wall conditioning techniques: boronization, lithium coatings
  - Development of new operational scenarios
    - Fueling, shaping, H-mode access, MHD etc
  - Current, TF, NBI, pulse duration

	Year 1	Year 2	Year 3	Year 4
$I_p \leq 1$ MA	2-4 sec.	5 sec.	aLaP	---
$I_p \leq 1.5$ MA	1-2 sec.	2-4 sec.	5 sec.	---
$I_p \leq 2.0$ MA	--	1 sec.	2-4 sec.	aLaP
TF=	0.65-0.75 T for 5 s	0.75 T for > 5 s, 1.0 T for 2 s	1.0 T for 4 s	1.0 T for full I^2t limit.

Table courtesy of S. Gerhardt

Boundary Physics TSG research in Year 1 and Year 2 of NSTX-Upgrade will be driven by

- Incomplete tasks from FY2011-2012 run
  - Pedestal structure
    - Dependence on B_t, I_p, , shaping
  - Response to 3D magnetic field perturbations
    - ELM studies, ELM control development, pedestal transport
  - H-mode research
    - EPH mode, I-mode development
  - Edge and SOL physics
    - Midplane and divertor turbulence, zonal flows, L-H transition
  - Divertor research
    - Snowflake divertor studies and control development
    - Radiative divertor with impurity seeding and detachment control
  - Pumping and fueling studies
    - Validation of cryopump designs, SGI with new nozzles
- New goals toward advanced NSTX-U operation, FNSF / Pilot Plant and ITER support

NSTX-Upgrade Research Priorities for FY 2015 and Beyond (From NSTX Program Letter for collaborations)

- III-1. Measure and interpret **energy and particle transport and turbulence in the Scrape-Off-Layer** (SOL), and understand the linkage between SOL parameters and the peak heat flux to the divertor to develop means for **heat-flux mitigation and control.**
- III-2. **Measure and analyze the surface characteristics** of lithiated and non-lithiated divertor and first-wall plasma facing components, and relate these characteristics to the core and edge plasma confinement and stability under both steady-state and transient edge conditions.
- III-3. Measure and understand **boundary plasma response to applied 3D magnetic field perturbations** and other perturbations designed to control edge plasma transport and stability.

NSTX Program office suggested the following priorities

	2015	2016	2017	2018
Pedestal	Assess pedestal structure (especially Te height) and SOL heat-flux width at higher field and current up to 1.5MA	Assess pedestal and SOL at up to 2.0MA, project size, power, heat-flux mitigation requirements for FNSF/Pilot. Design real-time control of divertor gas/impurity puffing for heat flux mitigation.	Utilize divertor radiation and new 3D field coils to modify/optimize pedestal transport, divertor detachment and performance. Implement divertor real-time gas/impurity puff control.	Real-time control of snowflake + radiation + 3D fields to control and mitigate divertor heat flux
Divertor	Assess impact of modified pedestal and SOL at high Ip on snowflake divertor performance, initial usage and assessment of cryo-pumping performance	Assess impact of modified pedestal and SOL at highest Ip=2MA on snowflake divertor performance, and assess cryo-pumping performance with snowflake divertor	Assess synergies of snowflake divertor, radiative impurities, and 3D fields for particle and power exhaust at very high unmitigated heat flux - project to FNSF/Pilot	

NOTE: There may be insufficient resources to implement cryo-pumping by 2015-16

NSTX Program Letter for diagnostic collaborations outlined high-priority measurements

- Measurements of plasma kinetic profiles (density, temperature, flow), neutral density profiles, and transport and turbulence in the SOL at the outboard midplane and in or near the divertor region. Diagnosis of divertor heat flux profiles, divertor plasma density and temperature, divertor neutral pressure, impurity density and radiation (especially for characterizing detachment), and measurements of divertor power and particle balance, and particles sources. Diagnostics suitable for real-time divertor radiation and PFC temperature and/or heat flux control are also encouraged.
- Measurements of hydrogenic and impurity ion sources, sinks, and transport in the boundary region and in-situ measurements of the divertor surface conditions with active and passivated Li coatings on carbon and/or molybdenum PFCs, with a goal of relating PFC surface conditions to particle inventories during steady-state operation, ELMs, and disruptions.
- H-mode pedestal profile diagnostics with increased time and spatial resolution to enhance predictive capability for the H-mode pedestal structure and stability, especially for understanding the effects of lithium and 3D fields on the pedestal thermal and particle transport including both low-Z and high-Z impurities.

To support program goals in Year 1 and Year 2 of NSTX-Upgrade, additional diagnostic capabilities will be needed

- Improved main chamber edge and SOL diagnostics
  - T_e, T_i, n_e, n_i, n_0, n_z profile diagnostics with high pedestal / SOL spatial resolution
  - Fluctuations $\tilde{n}_e$, $\tilde{T}_e$
  - q, Γ_i, Γ_z on inner wall, outer edge, passive plates
  - Ion or impurity SOL flow direction and velocity
  - SOL currents
  - Higher spatial resolution and coverage, sub-ms time resolution where appropriate
- Improved divertor diagnostics
  - T_e, T_i, n_e, n_i, n_0, n_z, q_e, q_i, T_{surf}, Γ_i, Γ_z, P_0, P_{rad} – 2D where appropriate
  - Fluctuations $\tilde{n}_e$, $\tilde{T}_e$
  - Upper and lower divertor coverage
  - Higher spatial resolution and sub-ms time resolution
- Real-time measurements for divertor control
  - T_e, Γ_i, P_{rad}, n_0, P_0, T_{surf}, additional magnetic sensors
- PFC surface diagnostics – see LR TSG documents

During outage, several working groups (or thrusts) within BP TSG can provide insights for Year 1 and 2 experiments

- Divertor
  - Heat transport modeling
  - Heat flux mitigation scenarios (radiative divertor, snowflake, double-null)
  - Detachment and configuration control
  - Plasma-facing components (material and implementation strategy)
  - Complex diagnostic design studies
- Pedestal and ELMs
  - Stability calculations
  - Pedestal transport
  - Response to 3D field perturbations
- Others?