NSTX-U

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NSTX-U Collaboration Status and Plans for: University of Illinois at Urbana-Champaign

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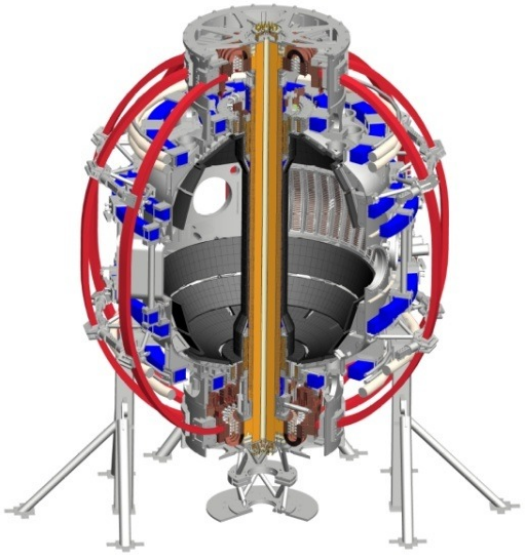
U Washington
U Wisconsin
X Science LLC

Prof. J.P. Allain

C.F. Bedoya, A. Neff, S. Gonderman, J.J. Pavón, E. Yang

NSTX-U Collaborator Research Plan Meetings
PPPL – LSB B318
April / May 2014



Culham Sci Ctr
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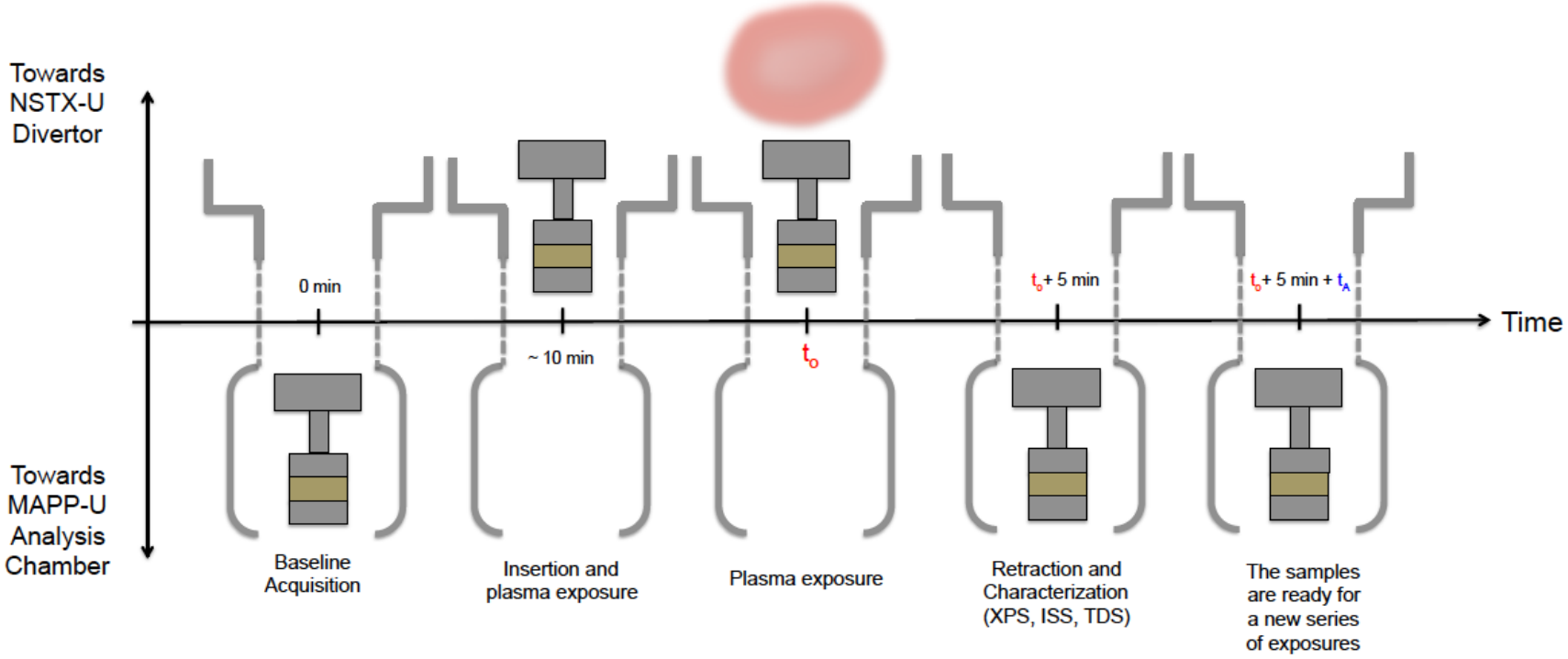
Research plans and needs for this year (FY2014) in preparation for NSTX-U operations in FY2015

- MAPP full operation capabilities:
  - Implementation and calibration of remaining techniques:
    - Thermal Desorption Spectroscopy (TDS)
    - Ion Scattering Spectroscopy (ISS)
    - Direct Recoil Spectroscopy (DRS)
    - Development of remote control interface for this set of techniques.
  - Continuation of experiments in LTX:
    - Exposure of stainless steel substrates at different temperatures.
      - Results will be correlated with *off line* laboratory experiments at University of Illinois.
    - Continuous operation in LTX will give an opportunity to test experimental capabilities, as well as a good scenario to debug and fix any potential flaws in the remote control system.

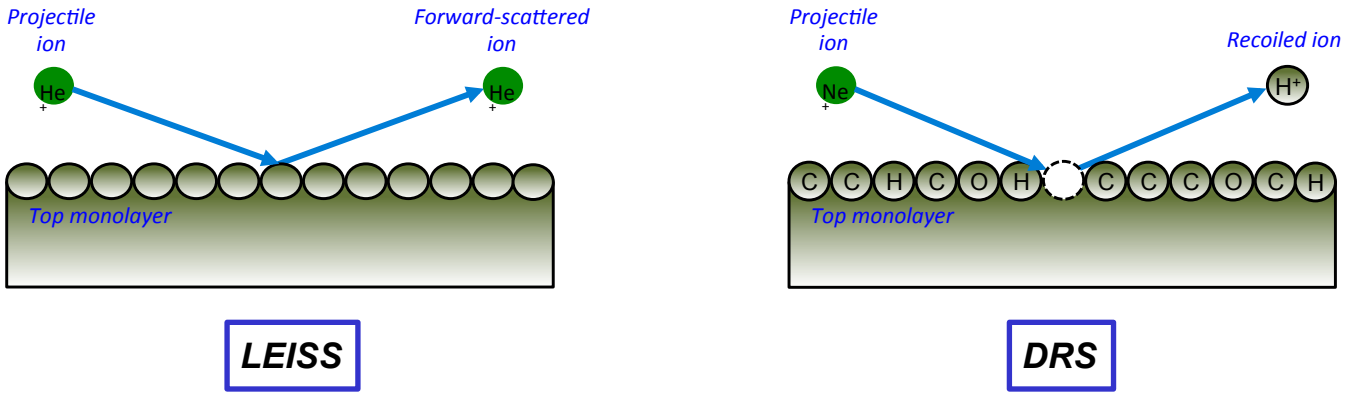
Development of remote control interface and interlock coordination with NSTX-U MAPP insertion protocol

Main Objectives

- In-vacuo analysis of materials exposed to plasma discharge.
- Provide immediate, shot-to-shot analysis.
- Remote Control interface.
- Operate within 12 min minimum between-shot time window.

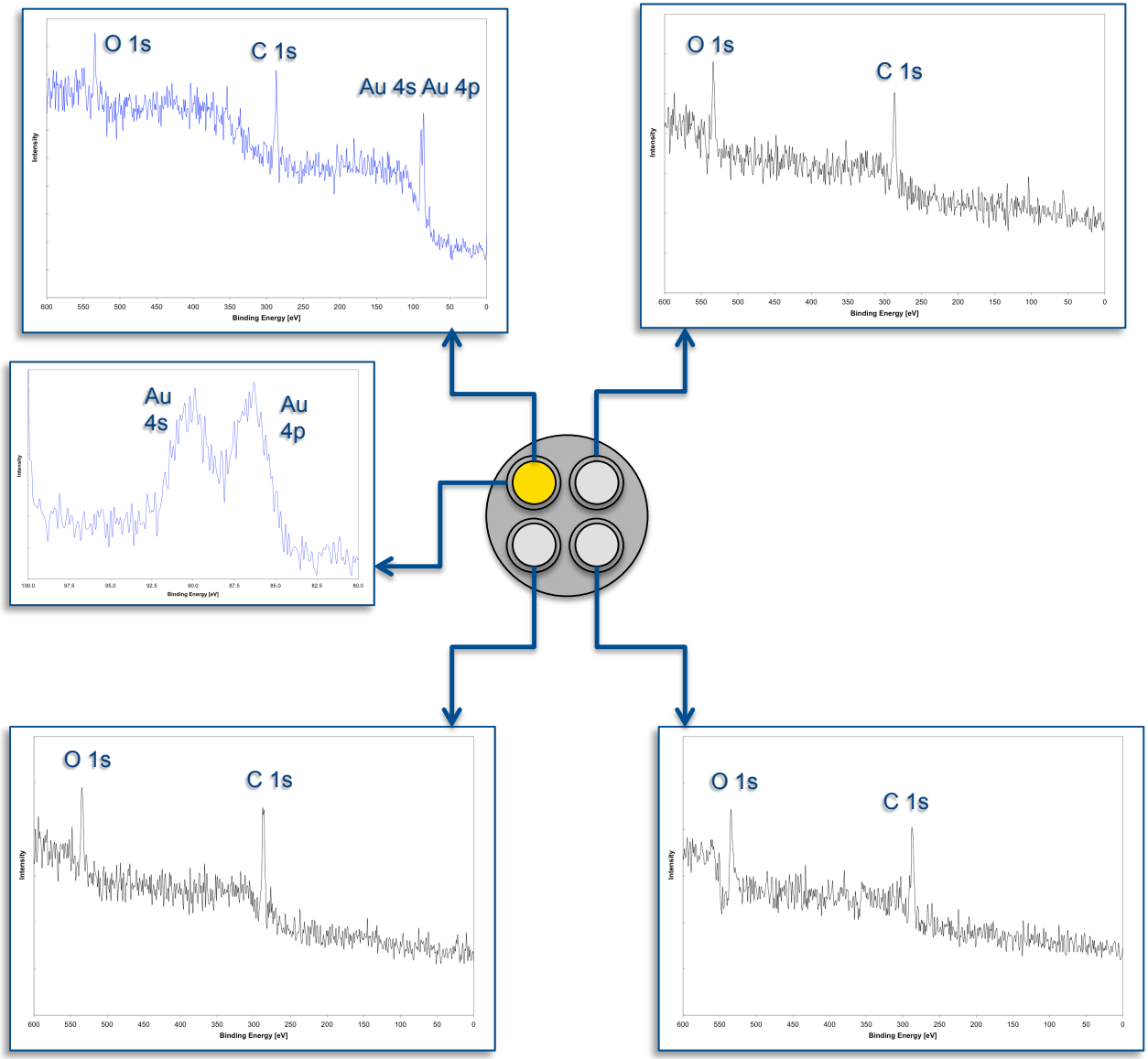


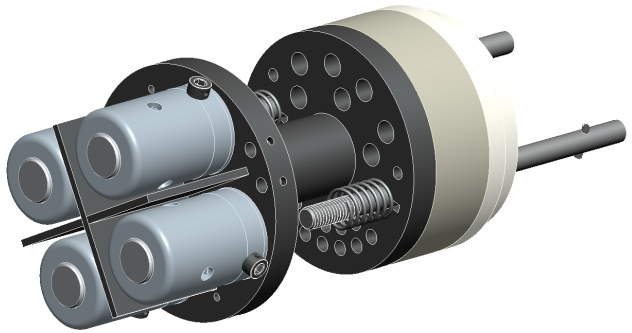
Integration of MAPP surface analysis



- Thermal desorption spectroscopy (TDS) relies on controlled heating of MAPP head
- New heaters integrated into manipulator system and checked
- Low-energy ion scattering spectroscopy (ISS) and direct-recoil spectroscopy (DRS) currently under optimization tests at Illinois
- Need for integration of gas system to MAPP control rack in NSTX-U to provide at a minimum gases for analysis: He, Ne, Ar
- PhD student, Felipe Bedoya, visited in March 2014 working with LTX PhD student (Matt Lucia). Bedoya at PPPL this summer for final integration activities and interface with NSTX-U engineers

MAPP probe head control experiments and fit-up





- Successful fit-up in Bay J earlier this year on NSTX-U
- Clearance for access assessed
- Control experiments already underway in LTX with standard samples
- Lab-supported checks of XPS and ISS spectra

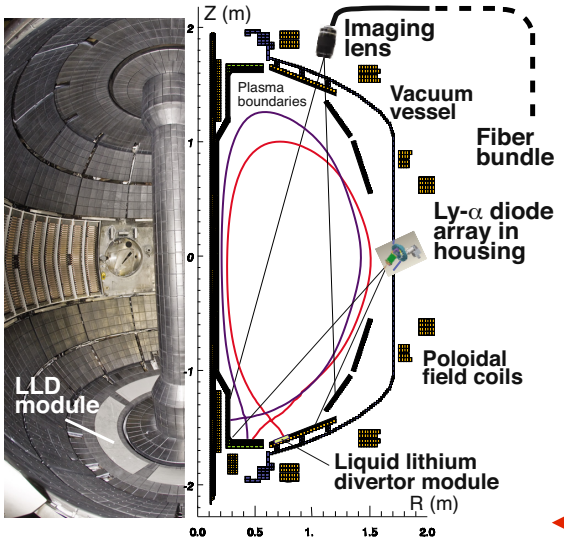
Elucidate the role surface chemistry and topology has on the ability of lithium-based surfaces (solid and liquid) on graphite and refractory metal (e.g. W, Mo) substrates to control particle pumping and plasma performance in NSTX-U plasmas.

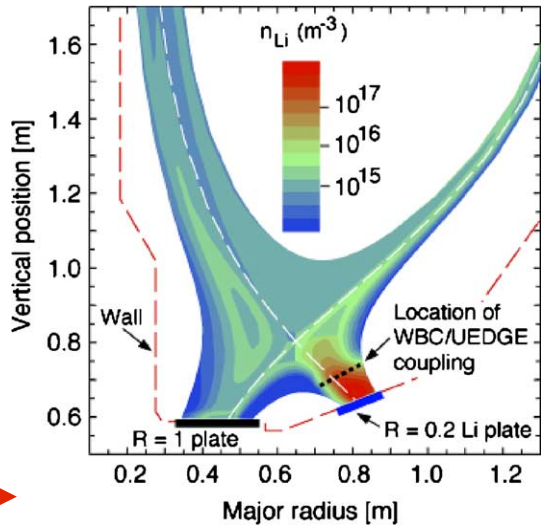
IGNIS: in-situ surface chemistry, sputtering, morphology and MAPP: NSTX-U PMI probe
Prof. J.P. Allain (Illinois)

DIFFER high-flux plasma linear device facilities
Dr. Greg DeTemmerman

Computational modeling: atomistic irradiation and multi-scale surface evolution under hydrogenous plasma irradiation

Prof. Brian Wirth (UTK)

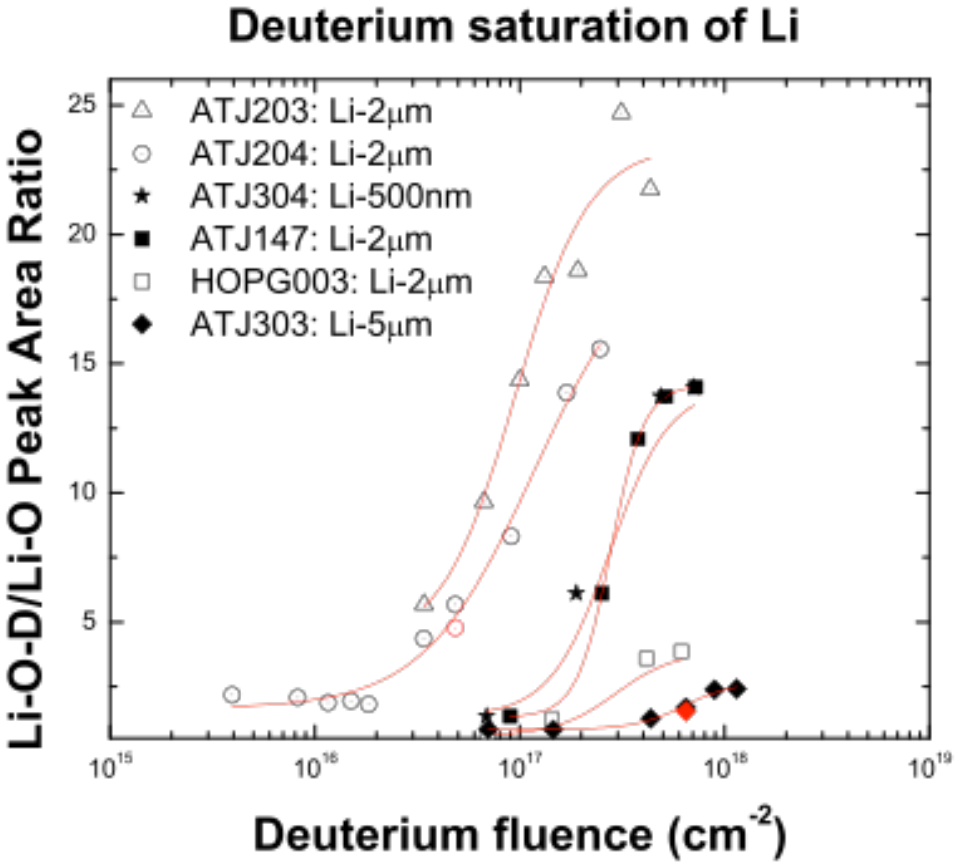


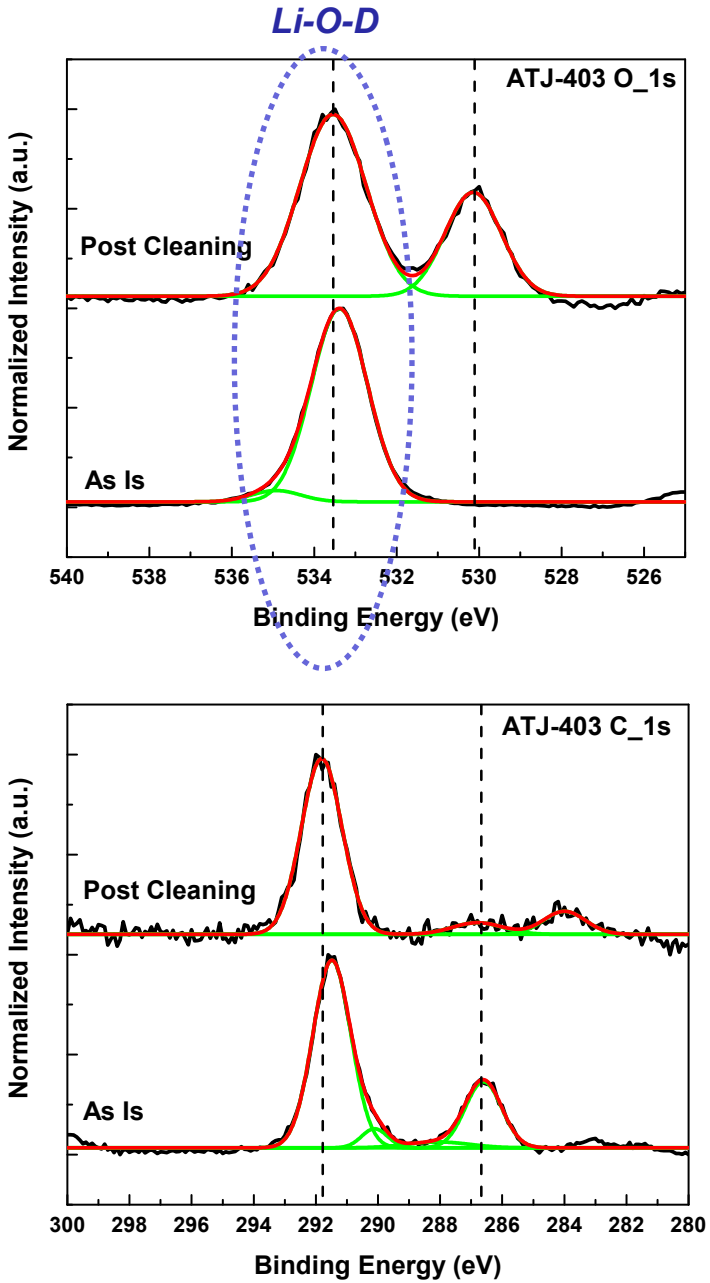


NSTX-U edge diagnostics

Plasma edge codes

Lithiated graphite under high fluence conditions: scaling D uptake under NSTX-U long pulse plasmas





- O1s, C1s, Li1s XPS spectra monitored after exposure to high-fluence (10^{20} cm^{-2}) plasmas at Magnum-PSI
- High-flux regime leads to "super-saturated" regimes, where high D retention is observed
- Encouraging news for longer pulsed NSTX-U plasmas

Research plans and needs for this year (FY2014) in preparation for NSTX-U operations in FY2015

- PMI studies of coarse-grained, multimodal, and nano-grained W samples with and without Li coatings within the NSTX-U divertor using MAPP.
  - These experiments will require integration and calibration of the MAPP probe attached to the divertor region of NSTX-U.
    - This includes calibrating the timing for surface (XPS, LEISS, and etc.) measurements.
  - These measurements will allow us to monitor the oxygen surface chemistry to better understand the D retention in the Li coating.
    - These tests will be ran throughout a day of standard NSTX-U plasma shots with lithium evaporation taking XPS measurements between shots.
    - The MAPP probe will have a sample of each W grade.
  - In addition, we will investigate the erosion behavior of Li coating on a W substrate to determine coating lifetime.
    - This test will start with one shot with lithium evaporation and then no new deposition on the rest of the shots for the day.
    - The MAPP probe will have a sample of each W grade.
  - Lastly, these tests will allow us to determine if Li will prevent the surface morphology changes like bubbles and blisters on the different grades of W.
    - These can be measured from the tests above.

Research Plans for FY2015 beyond

- Year 1: *Sept 2014 - August 2015*
  - *In-situ* surface characterization of dynamic lithium conditioned ATJ graphite surfaces as a function of deuterium fluence and surface temperature
  - Compare predictions from computational codes from Wirth with in-situ experiments by Allain for mixed systems including: Li/C, Li/B/C, Li/W
    - Modeling validation in close collaboration with Wirth Group at UTK
  - Studies on advanced nanostructured refractory metal substrates with and without lithium coatings in PRIHSM and Magnum-PSI (DIFFER)
- Year 2: *Sept 2015 - August 2016*
  - Study of re-deposited lithium-treated hydrogenated amorphous graphite coatings under various irradiation conditions (effect on D uptake) and comparison with computer modeling
  - Study of alternative nanostructured matrices containing lithium for dynamic delivery of lithium coatings to PFC surfaces (coordinated tests with MAPP included)
    - MAPP experiments contingent on available dedicated experiment days

Research Plans for FY2015 beyond

- Year 3: *Sept 2016 - August 2017*
  - Conduct coordinated and support experiments with MAPP-U diagnostic and other surface analysis facilities on lithium coatings on high-Z metals and liquid Li surfaces
    - Can be run as piggy-back experiments in NSTX-U
  - Conduct mixed-material studies of C, W and Li and their surface chemistry effect on D uptake properties
    - Elucidate effect of high-fluence exposures on liquid lithium surfaces and its chemistry effects
  - Irradiation of nanostructured tungsten and molybdenum with and without lithium coatings in ELM simulated experiments coupled to steady-state plasma (Magnum-PSI)
    - Contingent on DIFFER facilities back online after move to Eindhoven
- Year 4: *Sept 2017 - August 2018*
  - Study of hot lithium coatings on candidate substrates and correlate with NSTX-U MAPP experiments and DIFFER exposures

Ideas to enhance participation in NSTX-U research/program by U.S. Universities, early-career researchers, and students

- Faculty early-career grants
  - Key gap that needs to be addressed is exodus of young talent to areas outside of fusion science and technology
  - Support from internal sources at institutions challenged by priority areas outside fusion (e.g. biotech, nanotech, etc…)
    - Early-career grants can establish a *sustainable* bridge of young talent and also of students to the NSTX-U program
- Faculty mid-career affiliations: e.g. Fellow or Scholar program to indicate level of collaboration activity with NSTX and PPPL scientists
  - Early-career transitioning to mid-career levels are also threatened by limited funding opportunities
  - Sustainable engagement with experienced groups must be recognized and can aid in promotion protocols at local institution
    - Providing minimal seed funding for travel can help support students in projects affiliated with NSTX-U form their home institutions

Highest-priority incremental measurement capability
(For diagnostic solicitation grantees funded for 2012-2015)

- QCM-DCU system in MAPP-U
  - In-house design at Illinois using low-noise microbalance that can address challenges with local heat instabilities. New design will enable study of erosion/re-deposition regimes
    - New design will likely lead to new MAPP-U head design
- Mapping spectroscopically at higher fidelity MAPP region
  - In collaboration with V. Soukanovskii. Plans for a spectrometer view and for a filtered camera close-up view of the MAPP head
    - This capability would enable much more robust plasma edge code and surface response simulation code validation with MAPP-U data