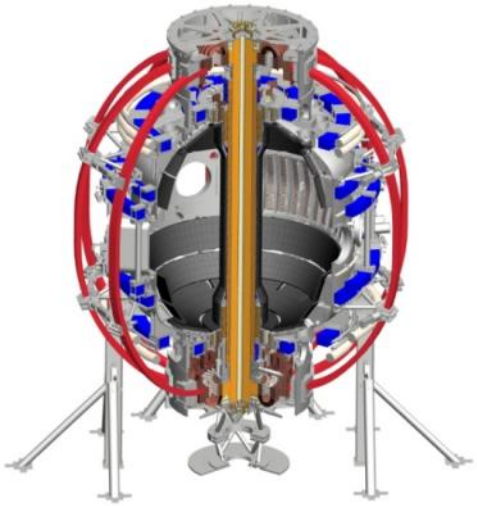
NSTX-U Project / Facility Status

Masa Ono and Jon Menard

for the NSTX-U Team

NSTX-U FY 2015 Q1 Review Meeting
January 30, 2015

Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
ORNL
PPPL
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin



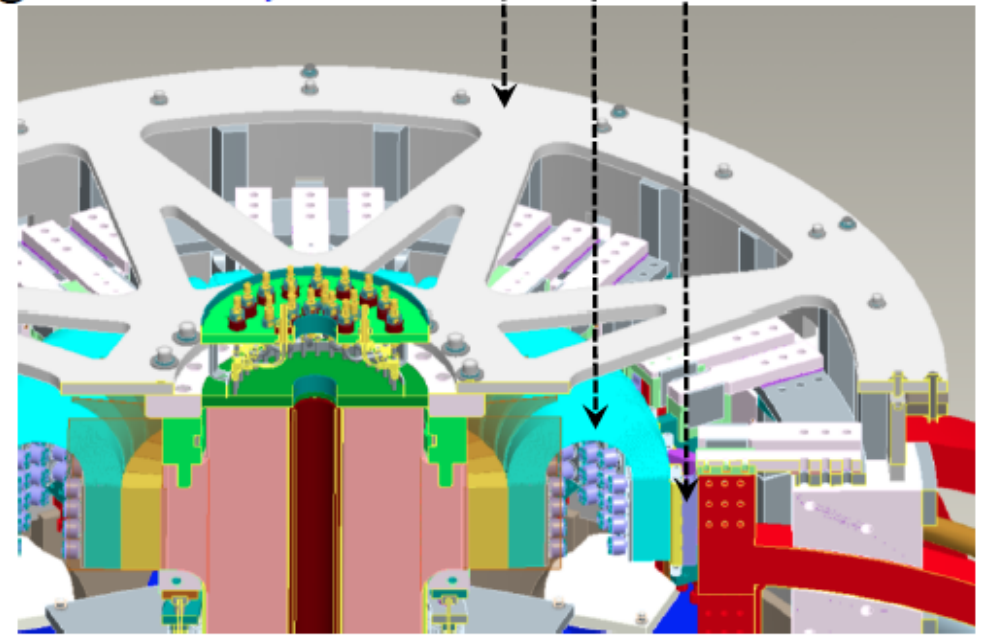
Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Tsukuba U
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
NFRI
KAIST
POSTECH
SNU
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

Outline

- **Upgrade Project Status**
- **Preparation toward Operation**
- **Research Operation Schedule**
- **Explanation of budget**
- **Summary**

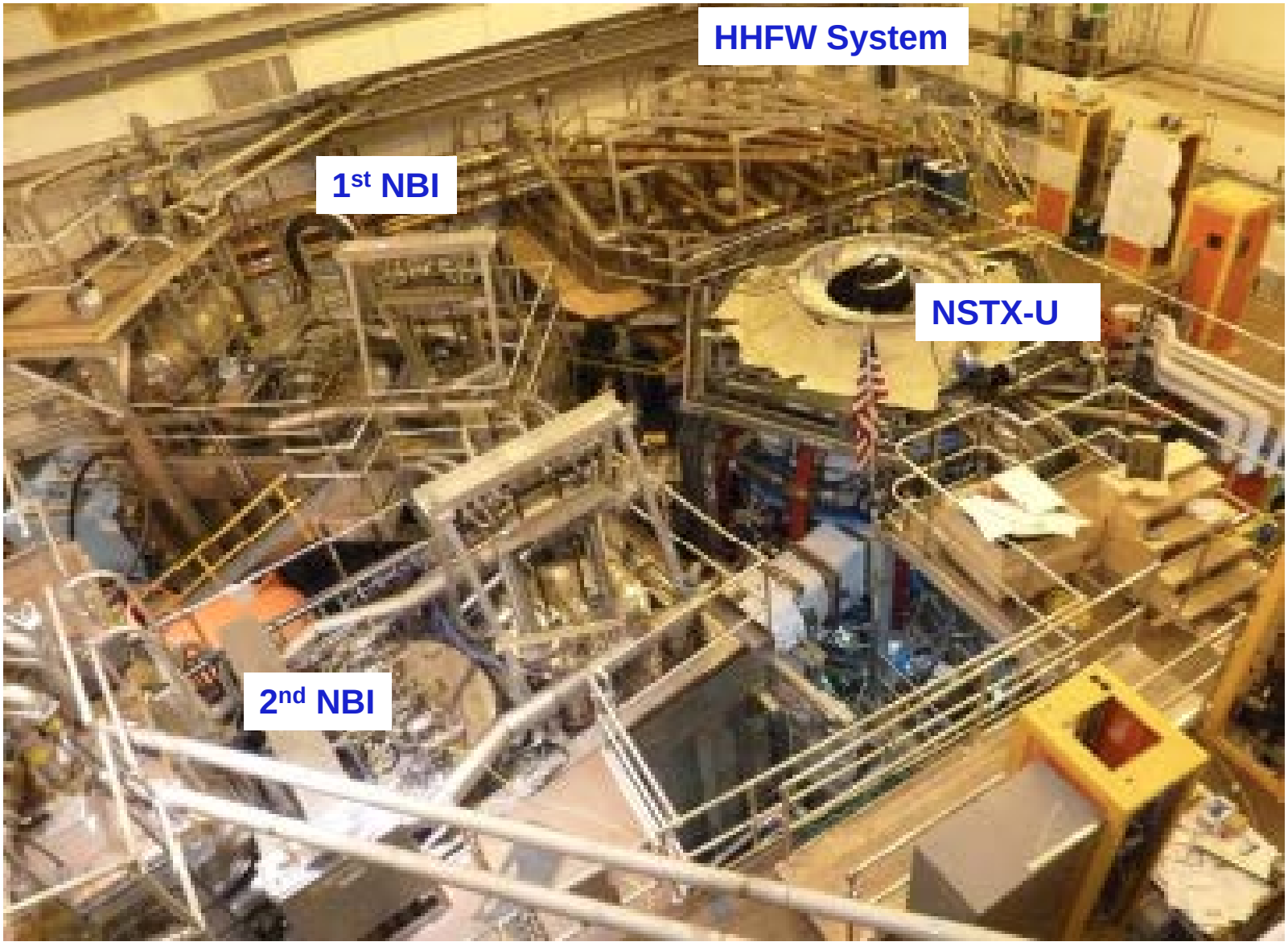
Remaining Construction Work in NSTX-U Test Cell CD-4 date depends on how well ISTP goes

- Pumpdown - *Started in December*
- Leak check - *On-going*
- Install bus inside umbrella and back to racks *November - January*
- Install new TF lead extensions *January-February*
- Install TF flex bus *January-February*
- Install new umbrella lids - *February*
- Install umbrella lid support rings - *February*
- Bakeout *March*
- ISTP - *March*



NSTX Upgrade Project Is Nearly Complete

Recent aerial view of NSTX-U Test Cell (January, 2015)



Status of Power Systems

- **D-MG#1 has been fully restored to operation. Considering similar D-MG#2 weld crack repair (~ $1M).**
- **Rectifier reactivation (open circuit testing) is complete**
- **Rectifier Dummy Load testing is ready to start**
  - **Will concentrate on systems needed for the CD4 plasma (TF, OH, PF3U/L, PF5)**
- **Expect to be ready to start ISTP-001 on March 23rd**
- **SPA's, HF power supply (SPA primary power) will be recommissioned following CD4**
- **CHI Cap Bank is being restored to previous ops levels**
  - **Control System will have to be re-evaluated**
  - **CHI Handiscope is being recommissioned. MOV's re-installed**

Status of Control Systems

- Control Room is adequate to resume operations
  - Workstation upgrades are pending
- Clock System, EPICS, MDSplus and networks are ready
- Junction Area DCPS & PCS/PSRTC are almost ready
  - The FCC DCPS integration will follow shortly (needed for ISTP-01)
- Magnetics and FCPC data acquisition ready
- T/C data acq software ready. Instrumentation cal pending
- NB data acq ready. NB T/C and NB timing soon
- Awaiting Diagnostics want/need list
- Test Cell network patch cables ready soon

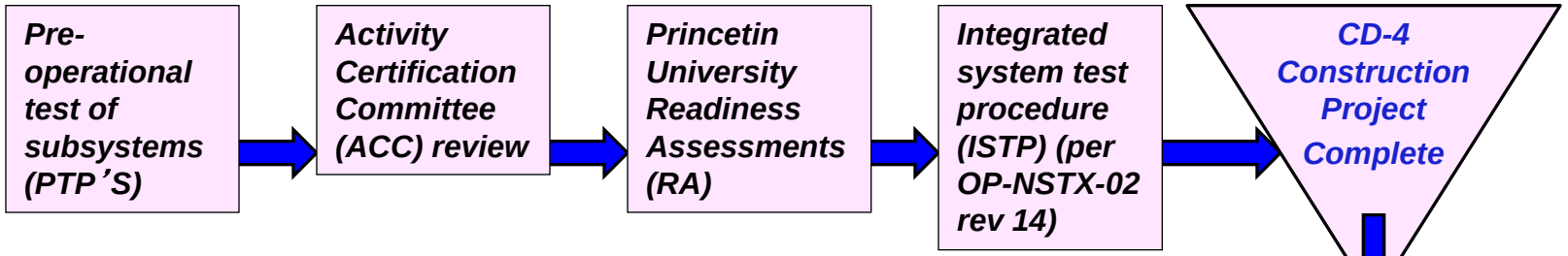
Both neutral beams should be available for research operations

- **NB2 is preparing for the CD4 milestone in March, 2015.**
  - NB2 is under vacuum and ion sources are installed
  - The He refrigerator is operating and making liquid
  - Expect to be ready to cool down NB2 in late Feb.
  - Low level ion source conditioning in early March, followed by beam conditioning and CD4 injection (late March as test cell access allows
- **NB1 should be ready for the research operation.**
  - NB1 is under vacuum and ion sources are installed
  - Plan to cool down NB1 in parallel with NB2
  - Expect to condition the NB1 ion sources during the vessel bake

Transition Construction to Operations

NSTX-U Start-up Process Similar to NSTX

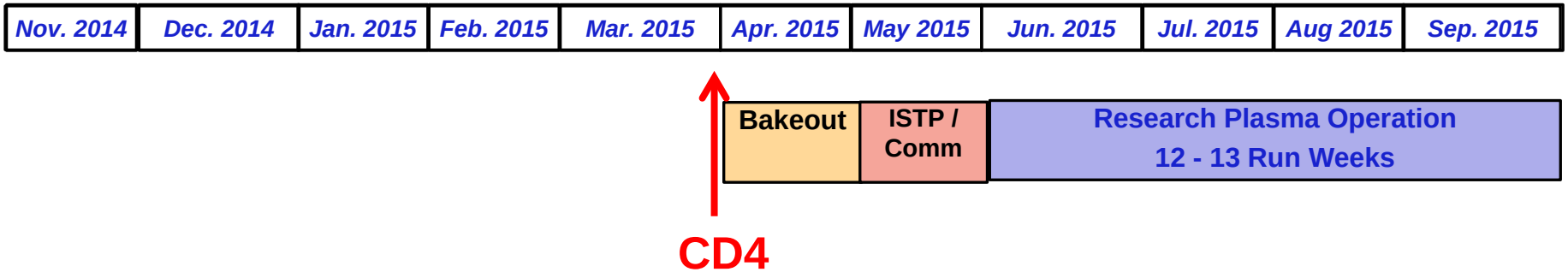
NSTX-U ISTP, Commissioning, and Startup will follow a similar process as NSTX initial commissioning and startup from February 1999.



- **The NSTX-U Activity Certification Committee (ACC) reviews continue, and is comprised of representatives from PPPL Engineering, Research, Safety, and the DOE PSO is currently reviewing technical and safety systems for NSTX-U**
- **A PPPL Internal QA Audit of NSTX-U Start-Up has been performed, and has resulted in a punch list of critical Start-Up and Test Procedures for both CD-4 and subsequent physics operations.**
- **A Readiness for Operations review by a committee from GA, Culham, ORNL, MIT, JLAB, Brookhaven & CCFE was held in December. In general, the committee believed that NSTX-U was on track to begin operations and could meet its design goals.**

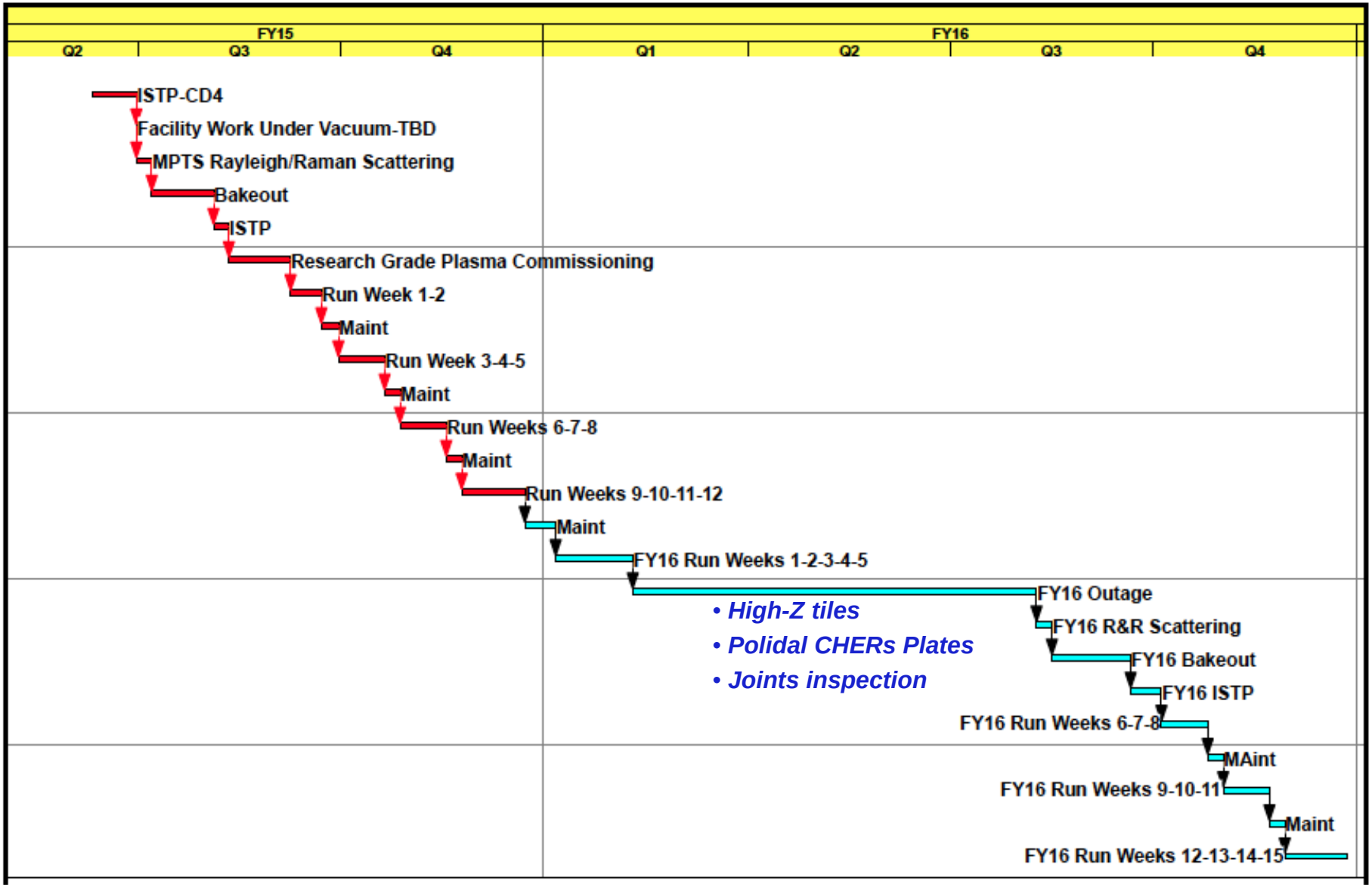
Final Preparation for Research Campaign

Nominal NSTX-U run schedule for FY2015



- **CD-4 is now projected to be in late March, 2015.**
- **~ 2 month period allocated between CD-4 and research plasma operations → Research ops begin in late-May**
- **Plan: ~12 - 13 run weeks (assumes 1 maintenance week / month)**
- **If machine is running well at end of FY15, may run into early FY16**
  - **Provide additional data for APS 2015 and IAEA synopses for 2016**

Nominal NSTX-U run schedule for FY2015 - 2016



NSTX-U diagnostics to be installed during first year

All center stack sensors mounted & ex-vessel terminations in progress

MHD/Magnetics/Reconstruction

- Magnetics for equilibrium reconstruction
- *Halo current detectors*
- *High-n and high-frequency Mirnov arrays*
- Locked-mode detectors
- RWM sensors

Profile Diagnostics

- MPTS (42 ch, 60 Hz)
- T-CHERS: $T_i(R)$, $V_\phi(r)$, $n_C(R)$, $n_{Li}(R)$, (51 ch)
- P-CHERS: $V_\theta(r)$ (71 ch)
- *MSE-CIF (18 ch)*
- *MSE-LIF (20 ch)*
- *ME-SXR (40 ch)*
- Midplane tangential bolometer array (16 ch)

Turbulence/Modes Diagnostics

- *Poloidal FIR high-k scattering (installed in 2016)*
- *Beam Emission Spectroscopy (48 ch)*
- Microwave Reflectometer,
  Microwave Interferometer
- Ultra-soft x-ray arrays – multi-color

Energetic Particle Diagnostics

- *Fast Ion D_α profile measurement (perp + tang)*
- Solid-State neutral particle analyzer
- Fast lost-ion probe (energy/pitch angle resolving)
- Neutron measurements
- *Charged Fusion Product*

New capability,
Enhanced capability

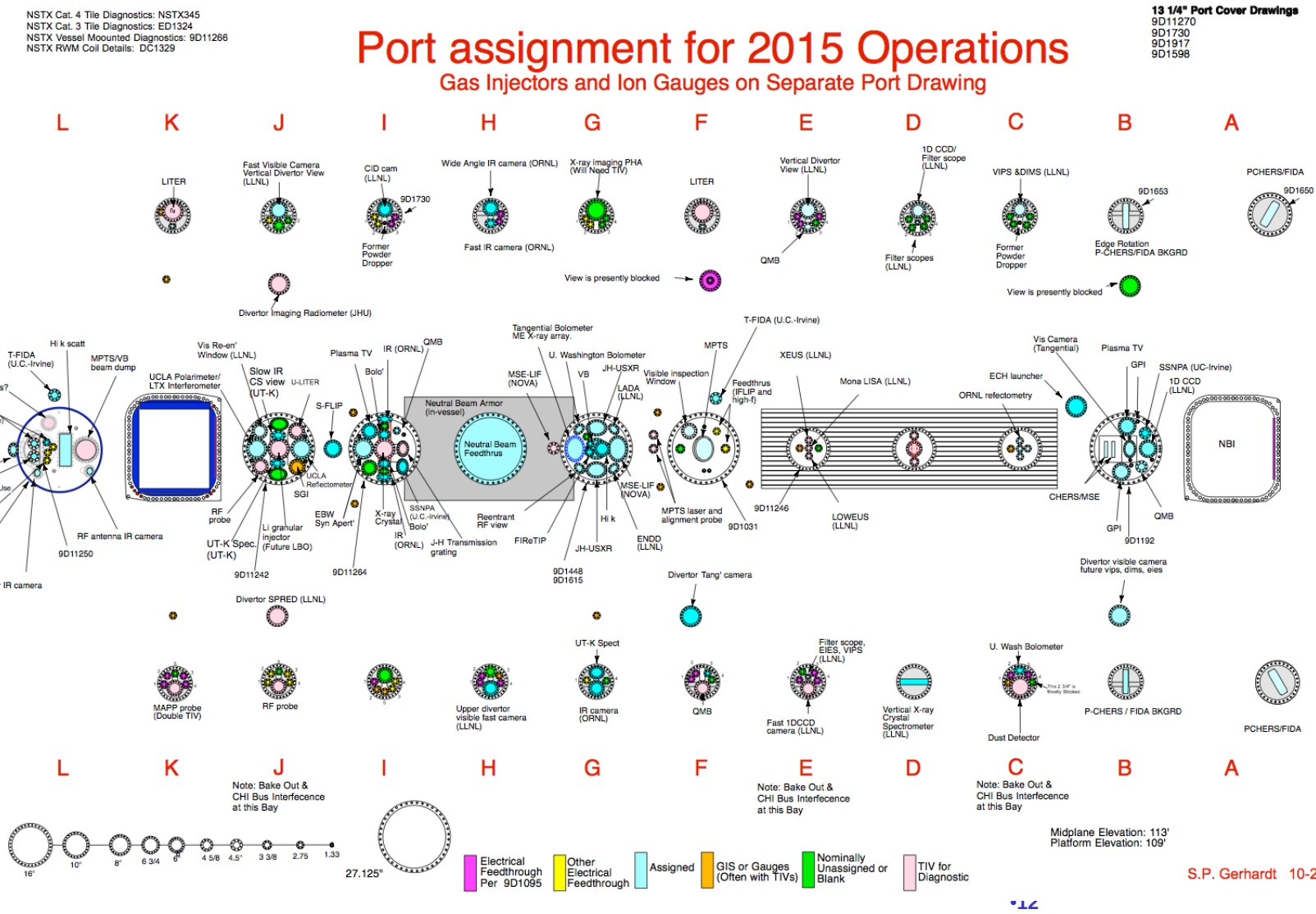
Edge Divertor Physics

- Gas-puff Imaging (500kHz)
- Langmuir probe array
- Edge Rotation Diagnostics (T_i, V_ϕ, V_{pol})
- *1-D CCD H_α cameras (divertor, midplane)*
- *2-D divertor fast visible camera*
- Metal foil divertor bolometer
- AXUV-based Divertor Bolometer
- IR cameras (30Hz) (3)
- *Fast IR camera (two color)*
- Tile temperature thermocouple array
- *Divertor fast eroding thermocouple*
- Dust detector
- Edge Deposition Monitors
- Scrape-off layer reflectometer
- Edge neutral pressure gauges
- *Material Analysis and Particle Probe*
- *Divertor VUV Spectrometer*

Plasma Monitoring

- FIReTIP interferometer
- Fast visible cameras
- Visible bremsstrahlung radiometer
- *Visible and UV survey spectrometers*
- *VUV transmission grating spectrometer*
- *Visible filterscopes (hydrogen & impurity lines)*
- Wall coupon analysis

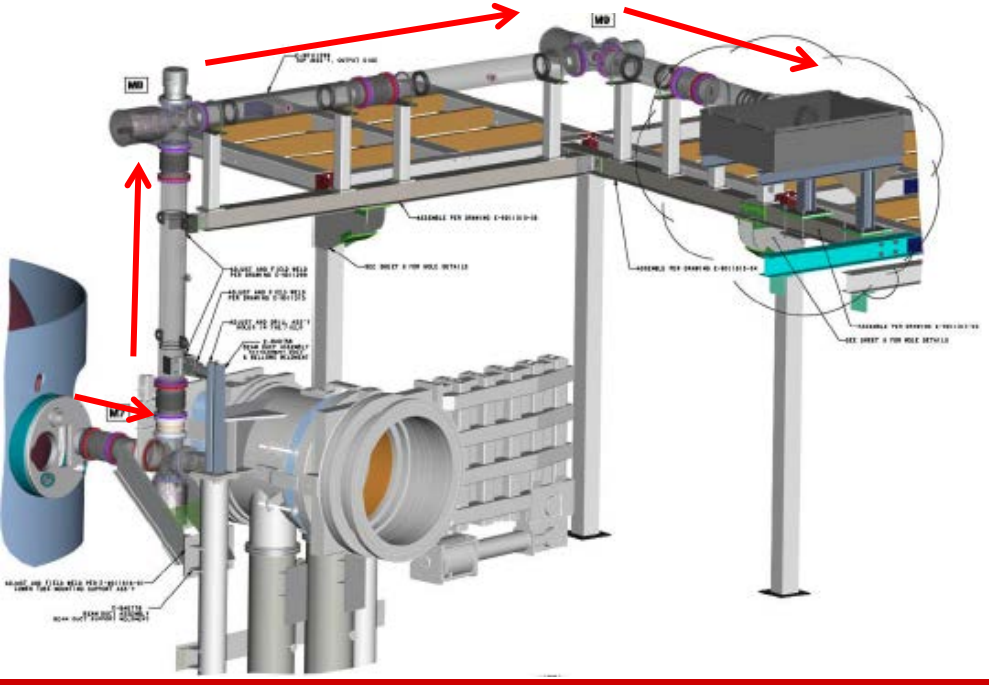
Diagnostic Port Map (Ports Fully Allocated)



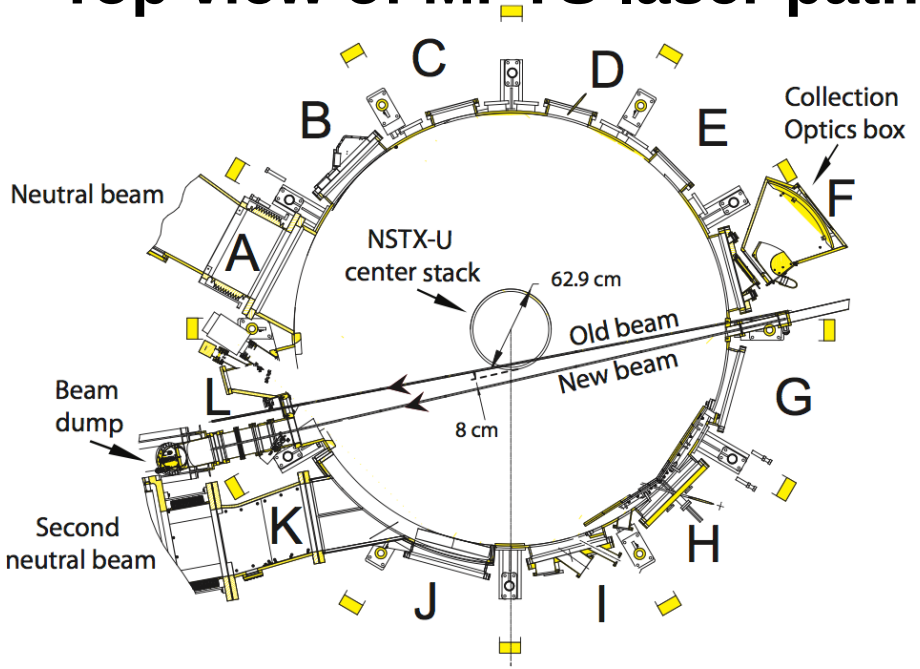
Multi-Pulse Thomson Scattering System
Laser exit flight tube being installed

- Installation of remainder of exit flight tube will start soon
- 42 spatial channels – improved spatial resolution in pedestal
- Plan to have system ready for calibration in April
- M. Coury will join MPTS group hired under A. Diallo's Early Career Award of pulse burst MPTS

MPTS laser exit flight tube



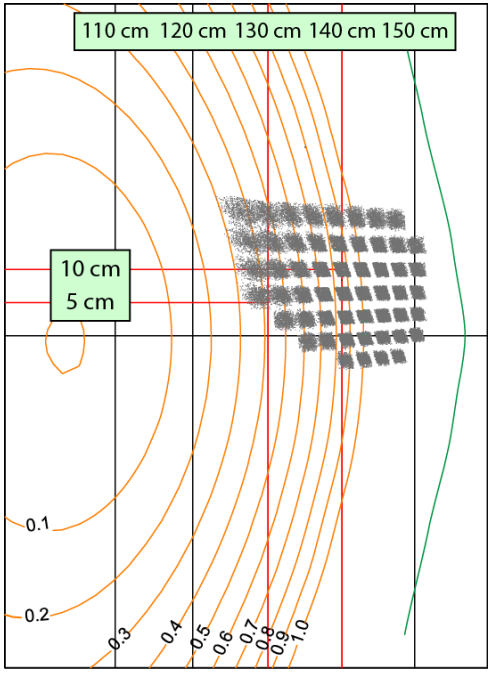
Top view of MPTS laser path



Other diagnostic highlights

Motional Stark Effect Diagnostics (Nova Photonics)

- MSE/CIF: B-field pitch, q(R) with reconstruction, 18 spatial channels
- MSE/LIF: B-field pitch, **|B|**, q(R) with reconstruction, pressure profile, 10 spatial channels to be expanded to 32 over time
- MSE/CIF & MSE/LIF: $E_r(R)$
- Both systems re-installed and spatial calibrations performed
- Y. Sechrest will join Nova Photonics MSE group



Beam Emission Spectroscopy (U. Wisconsin)

- New 2-D fiber holder will provide better radial and poloidal coverage of r/a~0.4-SOL region
  - Fibers will be installed in new holder in February
- 48 detector channels

Operations Team Continuing to Make Progress in Boundary Physics Operations to Prepare the Facility for Research

Massive Gas Injection	• Installation procedures for MGI valves have been released. • Critical valve components delivered to PPPL (from U. Washington), and support brackets fabricated. • Being installed in parallel with the inner-PF bus work.

Fuelling and Density Control	• All gas valves will be under PCS control
	  • Allowing SGI to be used for density feedback
	  • Divertor injectors for radiation control

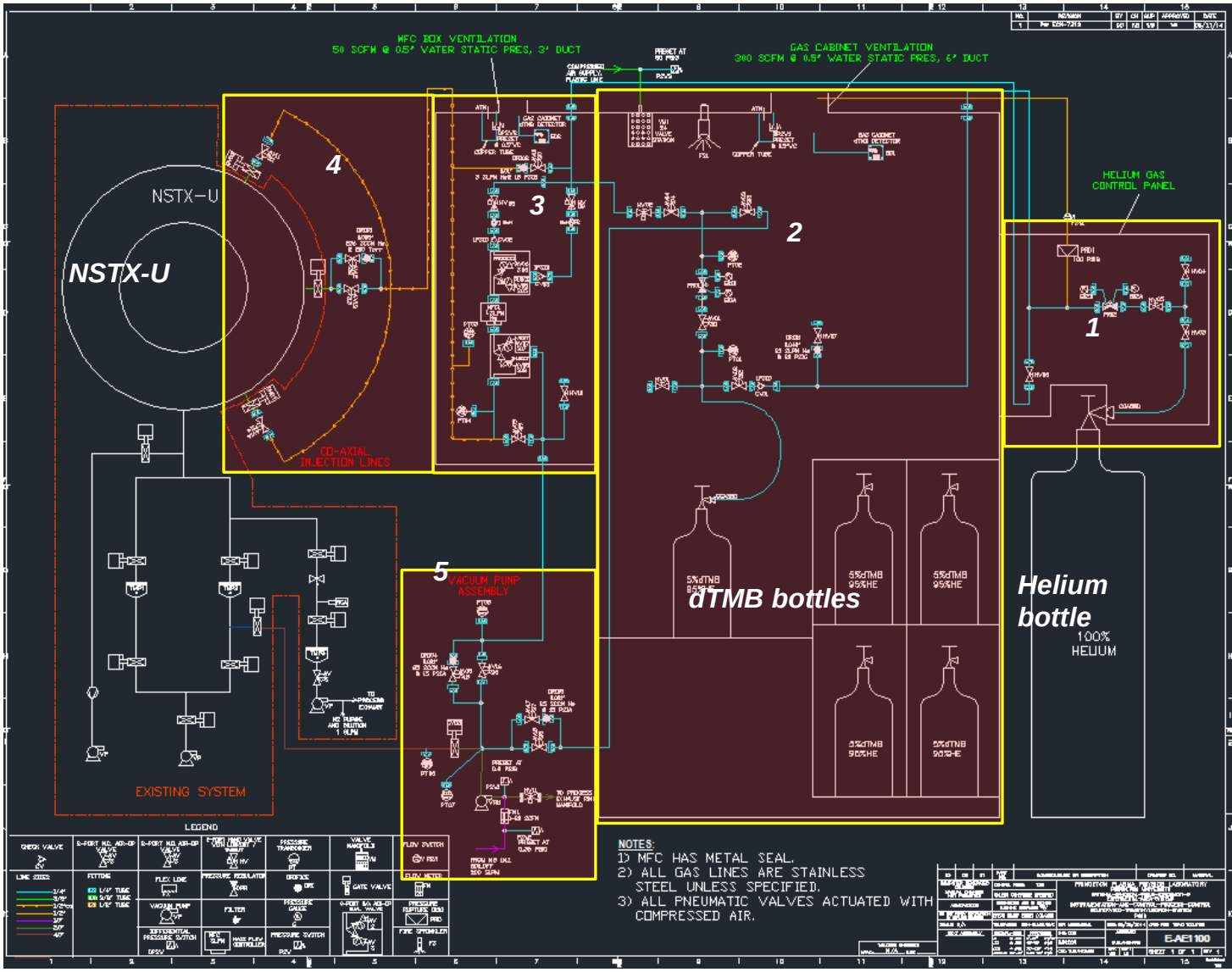
Boronization	• New engineer with extensive experience in hazardous gas handling completed design for trimethyl borane system • Components have been ordered with goal of availability of system for start of research operations
Lithium Evaporators (LITERs)	• Fume hood installation and other upgrades complete for laboratory for LITER filling and maintenance • Lithium handling procedures being updated – engineer responsible for boronization system involved
Granule Injectors for NSTX	• New injector expected to be available for plasma operations – new postdoc responsible for system • Lithium granules to be manufactured by UIUC

New boronization system being implemented
(Significantly enhanced due to industrial safety requirements)

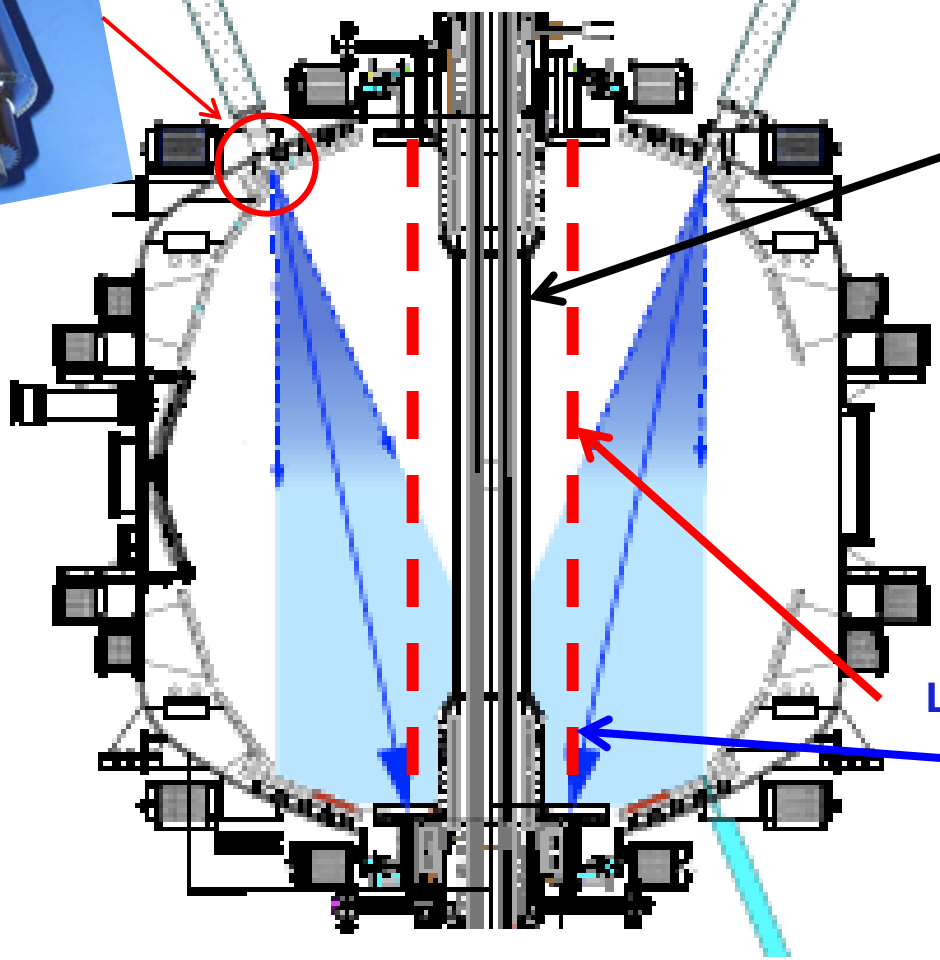
Five major sub-assemblies:

1. Helium control panel
2. dTMB gas cabinet
3. Master *Flow Control* (MFC) box
4. Coaxial injection lines
5. Vacuum pumping assemblies

To be available for research operation



LIThium EvaporatoRs – LITERS
Using same exit ducts as used on NSTX



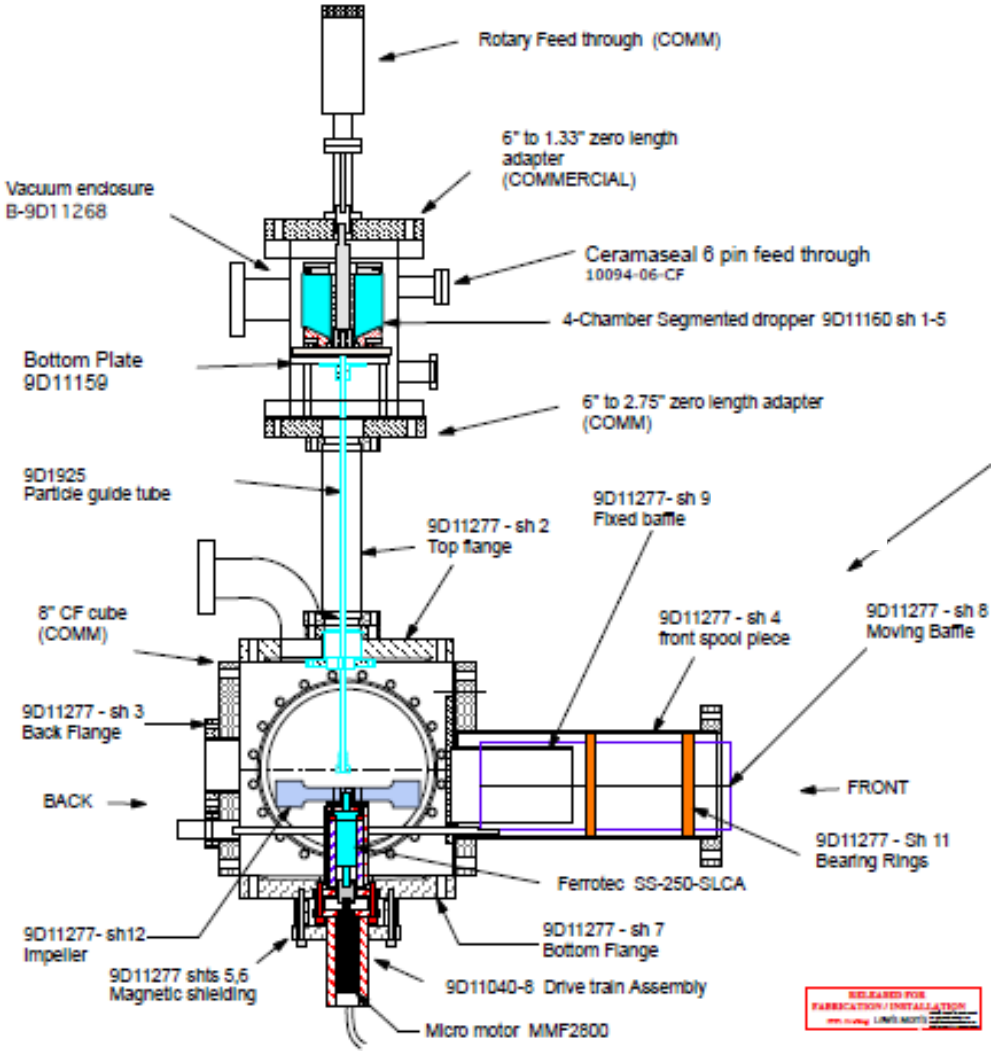
Orientation of exit tubes for lithium evaporators – LITERs – to remain unchanged for NSTX-U

Original NSTX center stack

Larger diameter of new center stack

More lithium coverage for "vertical" section of inboard divertor

Lithium Granule Injector – LGI – identical to system presently in use for inducing ELMs in EAST and DIII-D plasmas



Available pellet sizes (approximate)
900μm, 700μm

Proposed Pellet Composition
Lithium, Boron Carbide*, Graphite*

Pellet Injection Velocity
50 – 150 m/sec

Pellet to Pellet Injection Frequency
100 – 500 Hz

Granule supply arrangements being negotiated for fabrication at the University of Illinois

HHFW system commissioning schedule for Research Operations

Complete transmission and matching hookups:

- **Jan** Finish loops
- **Feb** Hookup to loops, set decouplers,
- **Mar** Match vacuum from RFE

Complete source assembly and testing

- **Feb - Mar** Complete source assembly and test into dummy load
- **March** Labview updates for power/phase, EPICs system control

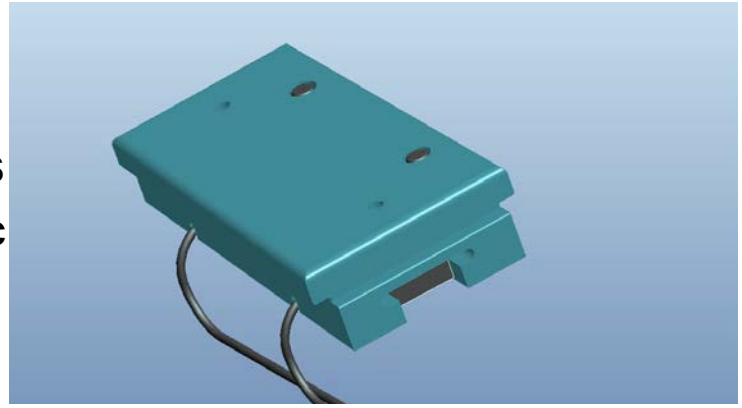
NSTX-U TC & RFE diagnostics re-commissioning

- **Feb - March** Into MDSplus

Prepare diagnostics for supporting HHFW studies

- **May** Complete coaxial Langmuir probe electronic hookups and connections to central computer (MDS plus)
- **May** IR camera commissioning
- **May** ORNL Reflectometer, probe, etc. reactivation
- **May** RF probes at Bay J installation, hookup, commissioning

Resonant loop connections to top/bottom antenna element feeds



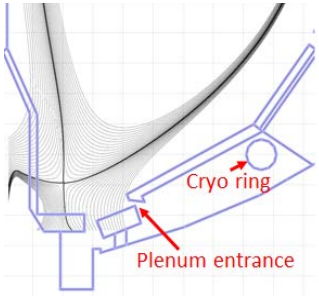
Coax connected Langmuir probes at Bay J top and bottom, Two probes per tile in rows 2, 3, and 4

NSTX-U facility enhancements proposed for 5 year plan support FESAC Tiers/Priorities

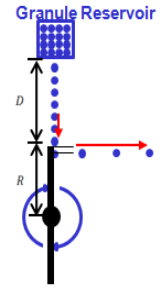
- Improved particle control tools
  - Control D inventory, rapidly trigger ELMs to expel impurities *(Transients, PMI)*
  - Low ν^* to understand ST confinement to support FNSF, validation *(FNSF, Predictive)*
- Disruption avoidance, mitigation *(Transients, Predictive)*
  - Massive gas injection, detect halos, disruptions, control v_ϕ, RWM, ELM
- ST start-up and ramp-up tools *(FNSF)*
  - ECH to raise start-up plasma T_e to enable FW + NBI + BS I_P ramp-up
  - Test EBW-CD start-up, sustainment
  - Start-up/ramp-up critical for ST-FNSF
- Begin transition to high-Z PFCs, assess flowing liquid metals *(PMI, FNSF)*
  - Plus divertor Thomson, spectroscopy

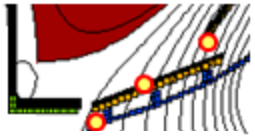
Upward Li evaporator

Divertor cryo-pump



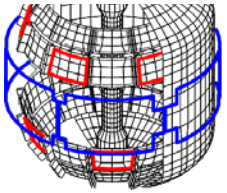
Li granule injector (LGI)

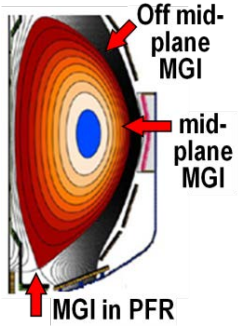




Extended low-f MHD sensor set

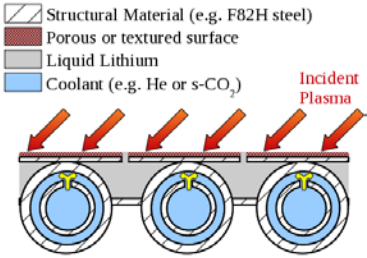
Midplane + off-midplane non-axisymmetric control coils (NCC)





1MW 28 GHz gyrotron

High-Z tiles



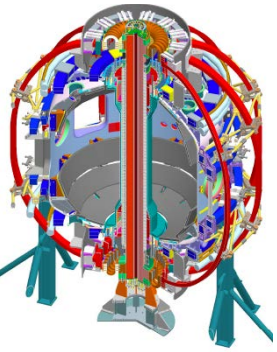
Actively-supplied, capillary-restrained, gas-cooled LM-PFC

Five Year Facility Enhancement Plan (green – ongoing)

ECH, Cryo-Pump and NCC system require resources starting in 2015 (red)

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Upgrade Outage	1.5 → 2 MA, 1s → 5s				Metallic PFCs, 5s → 10-20s				
Run Weeks:	12	5	10	12	12	22	6	18	22	22

New center-stack



2nd NBI

Start-up and Ramp-up
- Upgraded CHI for ~0.5MA
- 1 MW ECH/EBW
- 0.5-1 MA CHI
- up to 1 MA plasma gun
- 2 MW
- Extend NBI duration to 10-20s and/or implement 2-4 MW off-axis EBW H&CD

Boundary Physics
- Boronization
- Lower divertor cryo-pump
- Divertor Thomson
- Upper divertor cryo-pump

Materials and PFCs
- High-Z tile row on lower OBD
- High-Z PFC diagnostics
- All high-Z PFCs
- Hot high-Z FW PFCs using bake-out system

Liquid metals / lithium
- Li granule injector
- Upward LiTER
- LLD using bakeable cryo-baffle
- Flowing Li divertor or limiter module
- Full toroidal flowing Li lower OBD

MHD
- MGI disruption mitigation
- Partial NCC
- NCC SPA upgrade
- Full NCC
- Enhanced MHD sensors

Transport & Turbulence
- Pulse-burst MPTS Laser blow-off
- High k_θ
- δB polarimetry
- DBS, PCI, or other intermediate-k

Waves and Energetic Particles
- Charged fusion product
- 4 coil AE antenna
- HHFW limiter upgrade
- High-power AE antenna
- Neutron collimator

Scenarios and Control

Establish control of:
- Snowflake
- $\bar{n}_e$
- Rotation
- q_{min}
- Divertor P_{rad}
- Control integration, optimization
- Control integration, optimization with long-pulse and full metal wall

Inform choice of FNSF: aspect ratio, divertor, and PFCs

Update on High-Z Tile Status

Equilibrium simulations performed for NSTX-U coil set and capabilities

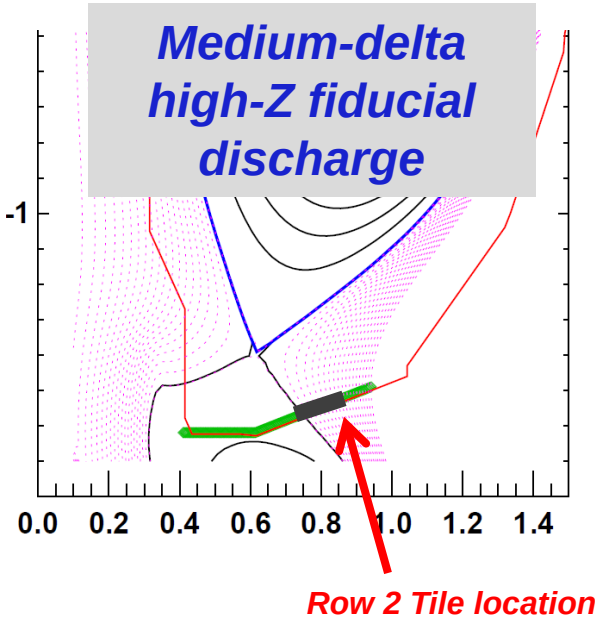
- 0-D estimates indicate comparable heat fluxes as high-performance discharges
- Enables high-Z PMI science studies

Castellated "macro-brush" design concept under development

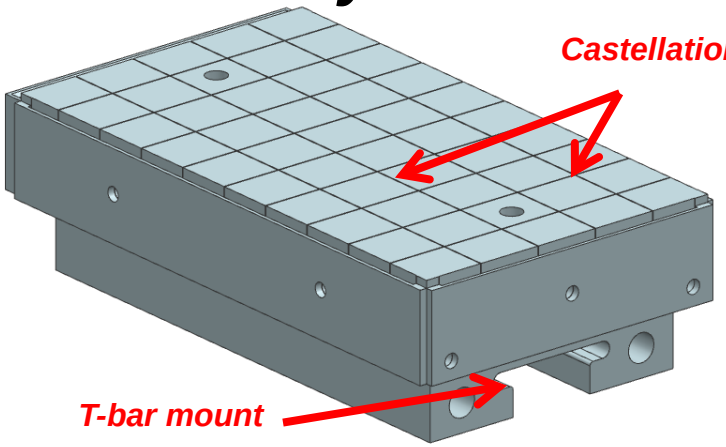
- Greatly reduces surface stresses while utilizing existing mounting system
- Minimizes divertor-floor geometric changes and diagnostic redesign

Alternatives for high-Z material under evaluation

- Comparison of TZM (molybdenum) vs. pure W underway
- Physics capabilities are similar, cost differences being evaluated



Preliminary tile variant



NSTX-U FY 2015 Budget Summary ($M)

Enables research operation while pursuing 5 year plan enhancements

	FY 2015 (FWP)		FY 2015
Budget Cases	**Base**	**Full/15%**	**BA**
Facility Ops	$33.40	$0.50	$33.00
Facility Enhancements	$1.00	$7.30	$6.03
CS & 2nd NBI	$3.30	$0.00	$3.47
Facility Total	**$37.70**	**$7.80**	**$42.50**
PPPL Research	$13.50	$0.90	$14.20
Collab Diag Interf	$1.20	$0.50	$2.20
Collaborations	$10.60	$0.60	$9.25
Science Total	**$25.30**	**$2.00**	**$25.65**
Reserve			**$1.84**
NSTX-U Total	**$63.00**	**$9.80**	**$69.99**

- Collaboration diagnostic interface requires enhancements due to increased collaboration diagnostic scopes including laser-blow-off system, charged fusion product, MGI disruption mitigation system
- Facility enhancements enables 5 year plan implementation including high-Z tiles, pulse-burst MPTS, engineering design activities for ECH, cryo-pump, and partial NCC

Summary of Preparation toward NSTX-U Operation

- NSTX Upgrade Project is nearly complete and it has entered the final phase. The vacuum pump-down occurred in December. The leak checking is in progress. Major leaks have been identified and repaired. Testing of various subsystems (PPT) are on-going.
- A Readiness for Operations review was held in December.
- Research operation schedule / commissioning – Presently planning to start research plasma operation in late May, 2014. Working toward minimizing the research prep time (~ 2 months) after CD-4.
- Diagnostic Enhancements / Commissioning are progressing well. All of the planned diagnostics should be available during the first year of plasma operations.
- Boundary Physics Enhancement / Preparation is going well (lithium and boronization).
- NSTX-U BA budget enables full research operation and 5 year plan facility/diagnostic enhancements activities

NSTX-U

Supported by

U.S. DEPARTMENT OF ENERGY | Office of Science

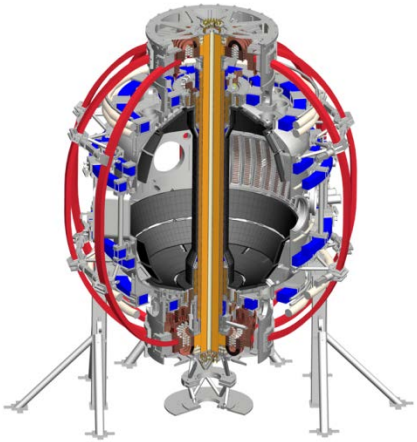
NSTX-U Program - FY2015 Q1 Report

Jon Menard, Masa Ono

For the NSTX-U Team

PPPL and FES

January 29, 2015



*This work supported by the US DOE Contract No. DE-AC02-09CH11466

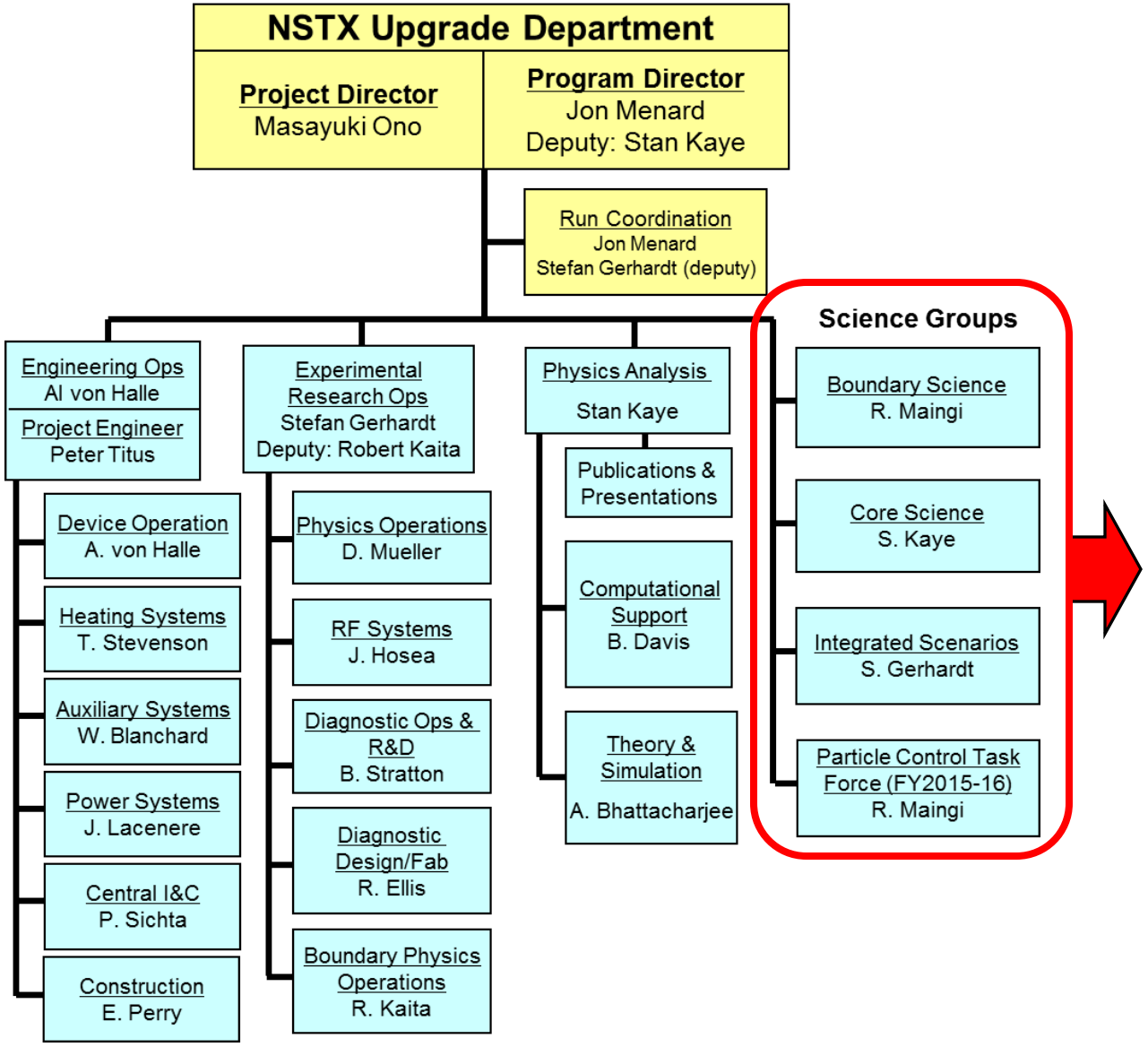
Coll of Wm & Mary
Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Lehigh U
Nova Photonics
Old Dominion
ORNL
PPPL
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Tennessee
U Tulsa
U Washington
U Wisconsin
X Science LLC

Culham Sci Ctr
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Inst for Nucl Res, Kiev
Ioffe Inst
TRINITI
Chonbuk Natl U
NFRI
KAIST
POSTECH
Seoul Natl U
ASIPP
CIEMAT
FOM Inst DIFFER
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

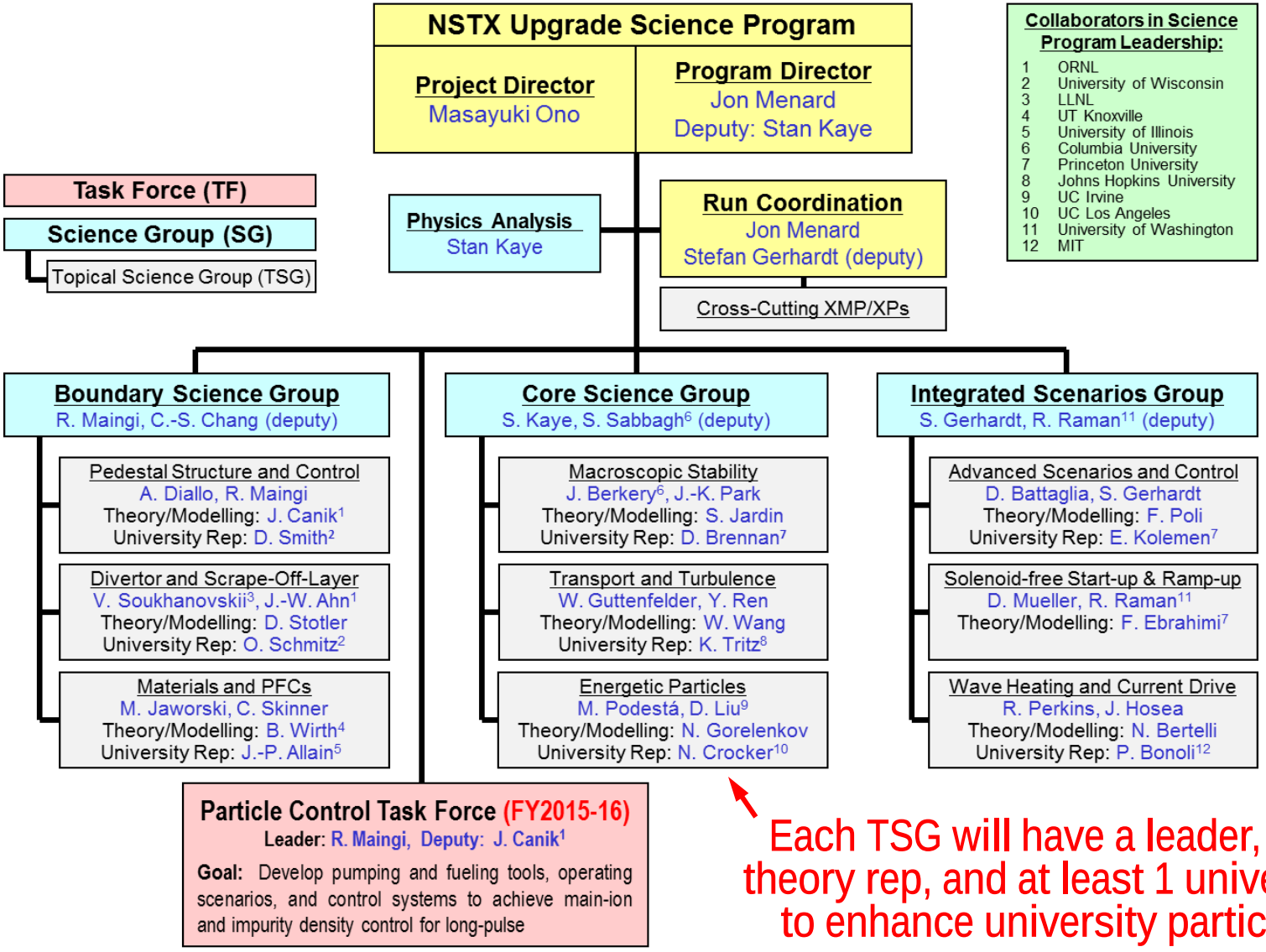
Outline

- Recap of new science organizational structure
- Roles, responsibilities, and charges of groups
- Status of planning for commissioning, shot development, and early physics experiments
- Research Forum preparation

NSTX-U Organization for FY2015



NSTX-U research program will be (re-)organized along 3 "Science Groups" starting with FY15 run



Each TSG will have a leader, deputy, theory rep, and at least 1 university rep to enhance university participation

Motivations for restructuring science program

- TSGs provide expertise in broad range of topics, but program would benefit from better coordination between TSGs
  - SG leader responsibility: Coordinate TSG physics research plans, experimental/shot plans, diagnostic coverage & usage
- Experiments that engage more than one TSG will receive increased priority for run-time
  - Example: experiment on 3D fields generating data for: plasma response, turbulence, energetic particle loss
- Efficient shot usage especially important during first run year (many systems need to be re-commissioned)
- Incorporate much wider set University researchers/PIs in planning + coordination of research program (FES/PPPL goal)
- NEW: Task-force for long-pulse particle control → cross-cutting goal supporting entire research program

Outline

- Recap of new science organizational structure
- Roles, responsibilities, and charges of groups
- Status of planning for commissioning, shot development, and early physics experiments
- Research Forum preparation

Roles / Responsibilities for Science Groups

- Work with Program/TSGs to set run-time allocation guidance
- Coordinate research of TSGs within the SG – promote experiments / plans that achieve multiple scientific goals
  - Critical to maximizing scientific output per shot
  - "Coordinated" XPs will receive higher priority / more run time
- Inform Run Coordinator when XP is ready for final review
- Provide summaries and highlights of scientific progress at/for NSTX-U team meetings, FES/quarterly reviews, other venues
- Aid dissemination of results with Physics Analysis Division
  - Journal publications, invited talks, seminars, colloquia, conferences, ITPA, BPO
- Coordinate / down-select milestone ideas from TSGs in SG
- Provide feedback / comment on annual Field Work Proposal
- Assist / report to the NSTX-U Program and Project directors

Roles / Responsibilities for Topical Science Groups

- Lead brainstorming, organization, writing of 5 year plan topics
- Determine and address highest priority scientific issues through discussion and consensus at open meetings
- Organize the NSTX-U Research Forum sessions for the TSG
- Draft scientific milestone ideas utilizing expertise of the TSG
- Propose and execute experiments to achieve milestones and address priorities
- With SG leaders, define facility and theory resources to achieve research goals
- Present TSG / SG results and plans at NSTX-U PAC meetings
- Assist / report to the NSTX-U Science Group leaders

Roles / Responsibilities for University Representatives

- Contribute to prioritization within TSGs
  - Help decide/draft milestones, XMP/XP prioritization
  - Help identify how your tools/codes/diagnostics/personnel can contribute to the group and the larger NSTX-U program
  - Advocate for your own research and for the needs of the larger NSTX-U research program
- Advocate for your TSG research *outside* of NSTX-U
  - Seek input/interest from those not funded by NSTX-U
    - Particularly from your own University and other universities
    - Includes giving seminars at other Universities / institutions describing NSTX-U and/or your research
- Help identify best tools for remote participation, and remote experimentation

Roles / Responsibilities for Task Forces

- Address specific operational and/or scientific goal that cuts across or impacts multiple SGs / TSGs
- Goal must be very high priority within research program
- Receives dedicated run-time, and has dedicated session at Research Forum
  - Similar to a TSG, but may not necessarily have theory/modelling or university representatives – depends on duration or scope
- Organizes experimental proposals to achieve goal
- Finite duration - nominally 1-2 years, renewable if necessary
- TF leadership should nominally have a leader and a deputy, and should include at least 1 collaborator if possible
- Reports directly to Program / Project

Particle Control Task Force (PC-TF)

- Leader/Deputy: Rajesh Maingi, John Canik
- Task force goal:
  - "Develop pumping and fueling tools, operating scenarios, and control systems to achieve main-ion and impurity density control for long-pulse"
- Scope includes XPs related to:
  - Main-ion fueling optimization via PCS and/or real-time control
  - Wall coating and preparation optimization for increased particle pumping
  - Reduction / control of impurity ion source rates
  - Natural and paced ELMs for impurity and main ion flushing
  - Real-time density measurements for density feed-back control
  - Physics design and performance characterization of divertor cryo-pump (if/as resources permit implementation of cryo-pump)
- Due date: ASAP, end of FY16 run for non-cryo elements

Roles / Responsibilities for Working Groups

- Responds to specific programmatic or technical charge from NSTX-U Program or Project
- Addresses issues that cross-cut more than one SG or TSG
- Nominal lifetime = 1-2 years, can be extended/renewed
- Provides points of contact between NSTX-U and other groups as necessary (e.g. PPPL theory, FESAC, ITPA)
- Does not have dedicated NSTX-U run time, but provides recommendations on XP prioritization, other resource needs
- WG leadership should nominally have a leader and a deputy, and should include at least 1 collaborator if possible

Non-axisymmetric Control Coil Specification Working Group (NCC-WG)

- Leader/Deputy: Jong-Kyu Park, John Canik
- Charges:
  - Specify required coil current, frequency, and location for NCC
    - Consider full set (24 coils) and partial set (12 coils)
    - Consider range of applications: NTV, EFC, RWM, RMP, ELM pacing, etc...
  - Specify required number of independent SPA channels vs. applications and requested capabilities
- Deliverables:
  - Organize summary presentation(s) on IPECOPT analysis results
  - Give presentation(s) making recommendations on NCC and SPA performance requirements, gather and incorporate team input
  - Generate written report (5-20pp Word file) documenting NCC and SPA requirements for use in developing engineering requirements document (GRD) to drive engineering design
- Due dates:
  - Initial written report April 2015 if possible (no later than May)
  - Consult with Project/engineers/designers as needed until implementation

Disruption Prediction/Avoidance/Mitigation Working Group (DPAM-WG)

- Leader/Deputy: Steve Sabbagh, Roger Raman
- Charges:
  1. How will NSTX-U interface to the upcoming FES workshops, and longer-term, address the FESAC/FES Tier 1 issue of “Transients" generally?
     a. In which disruption research areas can NSTX-U make leading contributions?
     b. What are the associated long-term resource needs from NSTX-U?
  2. What are the leading/highest priority NSTX-U contributions to JRT-16?
     a. What are the required resources during FY15-16 to support JRT-16?
  3. How can NSTX-U minimize disruptivity rates?
     a. What are leading causes of disruptions in NSTX & during initial NSTX-U ops?
     b. What prerequisites / tools are needed to prepare NSTX-U to operate a large # of sequential shot-seconds (say 1-5 shot minutes) without a disruption?
- Tasks: Organize meetings/reports to address above charges
- Due dates:
  - 1a – March/April 2015, 1b May/June 2015
  - 2a – April 2015, 3a – end of CY 2015, 3b – TBD/long-term

Outline

- Recap of new science organizational structure
- Roles, responsibilities, and charges of groups
- Status of planning for commissioning, shot development, and early physics experiments
- Research Forum preparation

Strategy / staging for achieving full NSTX-U parameters

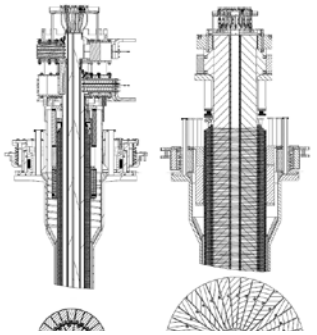
Parameter	NSTX (Max.)	FY 2015 NSTX-U Operations	FY 2016 NSTX-U Operations	FY 2017 NSTX-U Operations	Ultimate Goal
I_P [MA]	1.2	~1.6	2.0	2.0	2.0
B_T [T]	0.55	~0.8	1.0	1.0	1.0
Allowed TF I^2t [MA^2s]	7.3	80	120	160	160
Longest I_P Flat-Top at max. I^2t, I_P, and B_T [s]	~0.4	~3.5	~3	5	5

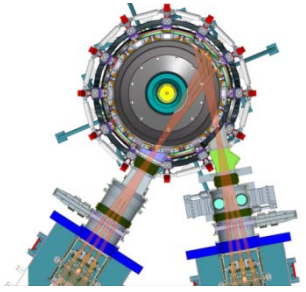
- 1st year goal: operating points with forces up to ½ the way between NSTX and NSTX-U, ½ the design-point heating of any coil
  - Will permit up to ~5 second operation at B_T~0.65
- 2nd year goal: Full field and current, but still limiting the coil heating
  - Will revisit year 2 parameters once year 1 data has been accumulated
- 3rd year goal: Full capability

FY2015-16 research milestones target exploitation of new capabilities, exploration of new regimes

Incremental (full ops)

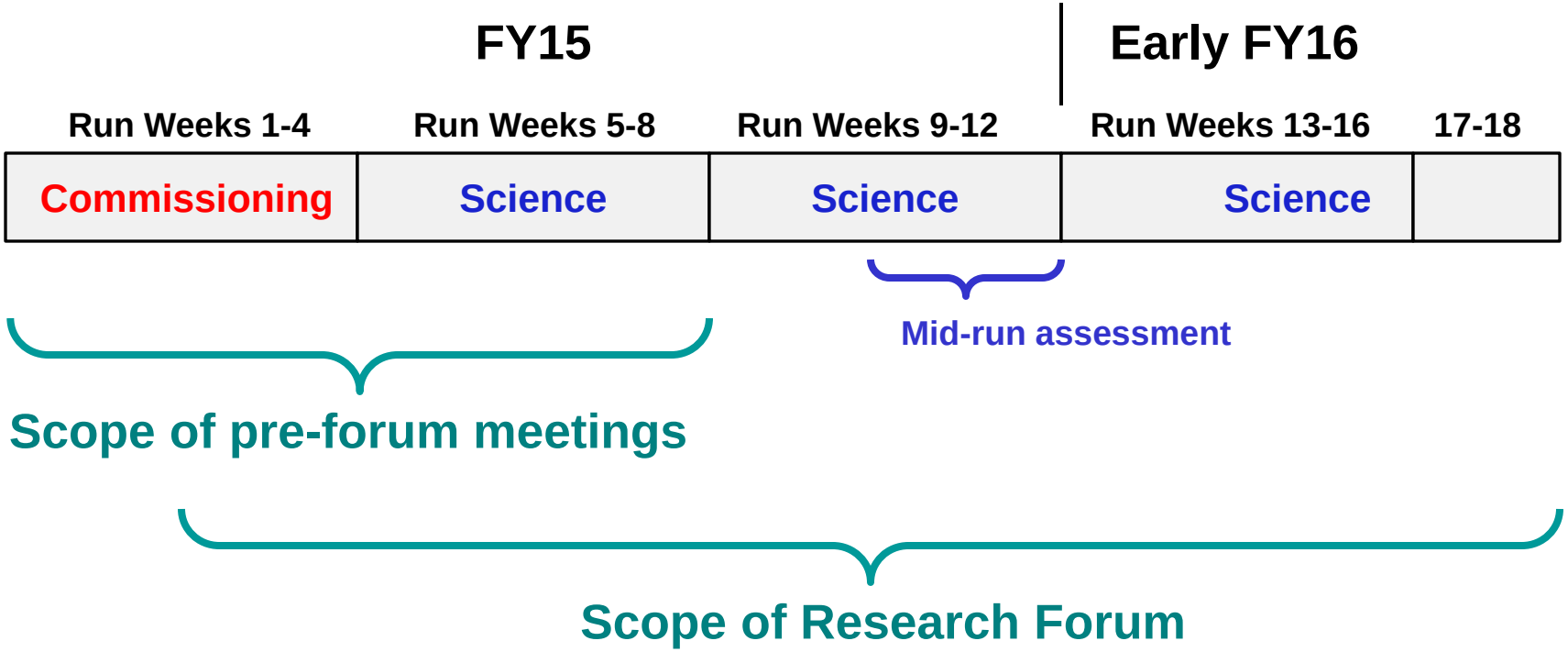
Expt. Run Weeks:





	FY2015	FY2016
	12 **14**	16 **20**
Boundary Science	R15-1: Assess H-mode confinement, pedestal, SOL characteristics at higher B_T, I_P, P_{NBI} Develop snowflake configuration, study edge and divertor properties	R16-1: Assess scaling, mitigation of steady-state, transient heat-fluxes w/ advanced divertor operation at high power density R16-2: Assess high-Z divertor PFC performance and impact on operating scenarios
Core Science	IR15-1 R15-2: Assess effects of NBI injection on fast-ion f(v) and NBI-CD profile	IR16-1: Assess confinement and local transport and turbulence at low ν^* with full range of B_T, I_P, and NBI power
Integrated Scenarios	R15-3: Develop physics + operational tools for high-performance discharges (κ, δ, β, EF/RWM)	R16-3: Assess fast-wave SOL losses, core thermal and fast ion interactions at increased B_T, I_P R16-4: Develop high-non-inductive fraction NBI H-modes for ramp-up & sustainment
FES 3 Facility Joint Research Target (JRT)	**NSTX-U leads JRT** Quantify impact of broadened J(r) and p(r) on tokamak confinement and stability	**C-Mod leads JRT** Assess disruption mitigation, initial tests of real-time warning and prediction techniques

Run schedule assumptions



- Pre-forum meetings emphasized XMP/XP title, goal, author identification to cover first 2 run months (Weeks 1-8)
- Forum will emphasize prioritization of XPs for weeks 3-18, but also document commissioning XMP/XP goals + run-time
- Mid-run (re-)assessment after first 6-8 Science run-weeks

Operations assumptions for first 2 run-months

- Machine Commissioning…assume 1 month (run weeks 1-4)
  - Develop basic breakdown, current ramp, shape/position control, diverted plasmas, H-mode access, basic fuelling optimizations.
  - Goal: 1 MA, 0.5 T, NBI-heated H-mode (i.e. ~NSTX fiducial levels)
  - Diagnostic commissioning
  - Boronized PFCs
  - Mostly XMPs
  - **What science (aka XPs) can be done during this phase?**
- 1st Month of Science Campaign (run weeks 5-8)
  - Boronized PFCs, possibly begin lithium coatings
  - Operations and basic profile diagnostics, neutron rate,…
  - Operation up to 1.4 MA and 0.65 T, 2 seconds
  - 6 beam sources up to 90 kV
  - HHFW available for commissioning
  - **What critical XPs can/should be done during this phase?**

First 4 weeks: Commissioning, fiducial development

- Magnetics calibration [1 day]
- Breakdown scenario development [1 day]
- I_p and R control on NSTX-U [3 days]
- Neutral beam checkout [1 day]
- L-mode development [2 days]
- H-mode entry at SOF [2 day]
- Increase H-mode flattop [3 days]
- Commission rtEFIT, ISOFLUX [2 days]
- XMPs to commission diagnostics and systems outside of control aspects (Phys Ops and RC must coordinate)

- Follow with additional ~1 week of H-mode fiducial development including additional control system optimization

Macroscopic Stability - Commissioning, early experiments

- Early commissioning activities
  - n > 0 magnetics calibration
  - Qualify MGI valves, controls, gas delivery, interlocks
  - Automated discharge shutdown method commissioning
  - Software test for n=1 RWM and EF control with 6 SPAs
  - Quantify vessel-generated EFs in AC vacuum shots
  - Dual sensor active RWM PID control checkout
  - RWM state-space controller (RWMSC) checkout
  - MHD spectroscopy checkout
- Early physics experiments
  - Low β, low density locked mode studies
  - High β n=1,2,3 compass scans
  - Optimization of PID Dynamic EF Correction
  - Establish dual field component n = 1 active control capability in new NSTX-U operational regime with 6 independent SPAs

Energetic Particles, Transport and Turbulence - Commissioning, early experiments

- Early EP commissioning activities
  - Neutron calibration: low P_{NB} discharges, E_{inj} = 40-50keV
    - Transfer calibration from pulse-counting to current mode
  - Commission new t-FIDA, ssNPA systems; checkout sFLIP & v-FIDA
- Early EP physics experiments
  - NUBEAM "sanity check" in MHD-quiescent plasmas, low PNB (NB blips)
  - On- vs. off-axis NB for "fiducial-like" H-mode, initial assessment of J_{NB} vs NBI
  - Dependence of fast ion distribution on NBI parameters
    - Systematic scans of tangency radii, NBI energy
    - Assess resulting F_{NB}; initial characterization of *AEs vs. F_{NB}
- Early Transport physics experiments
  - (R15-1) I_p, B_T scaling of τ_E, ped, SOL
  - Measure confinement, transport relation to GAE/CAE trends with P_{NBI}, R_{tan}
  - Measure perturbative particle transport (SGI+TS)
  - Inner wall limited, L-mode for validation study
  - Impurity transport (partially overlap L-mode above)
  - Measure perturbative momentum transport

Energetic Particles, Transport and Turbulence - Commissioning, early experiments

- Early EP commissioning activities
  - Neutron calibration: low P_{NB} discharges, E_{inj} = 40-50keV
    - Transfer calibration from pulse-counting to current mode
  - Commission new t-FIDA, ssNPA systems; checkout sFLIP & v-FIDA
- Early EP physics experiments
  - NUBEAM "sanity check" in MHD-quiescent plasmas, low PNB (NB blips)
  - On- vs. off-axis NB for "fiducial-like" H-mode, initial assessment of J_{NB} vs NBI
  - Dependence of fast ion distribution on NBI parameters
    - Systematic scans of tangency radii, NBI energy
    - Assess resulting F_{NB}; initial characterization of *AEs vs. F_{NB}
- Early Transport physics experiments
  - (R15-1) I_p, B_T scaling of τ_E, ped, SOL
  - Measure confinement, transport relation to GAE/CAE trends with P_{NBI}, R_{tan}
  - Measure perturbative particle transport (SGI+TS)
  - Inner wall limited, L-mode for validation study
  - Impurity transport (partially overlap L-mode above)
  - Measure perturbative momentum transport

High-harmonic fast wave - Commissioning, early experiments

- Early RF commissioning activities
  - Evaluate performance, condition antenna to max voltage:
    - Verify HHFW system controls (phase, amplitude, arcing, ect.)
    - Compare voltage limits across multiple plasma configurations
    - Monitor heating performance
  - Evaluate heat load of 2nd NB on HHFW limiter:
    - Both with and without applied HHFW power
    - Determine minimum acceptable plasma-limiter gap
  - Evaluate voltage standoff before/after boron → lithium

- Early RF physics experiments
  - RF heating in core vs. SOL both w/ & w/o NBI
  - HHFW absorption by ions in NBI-heated plasmas

Particle Control Task Force – Early Priorities

- Early 2015 run priorities:
  - Measure divertor profiles for cryopump physics design validation, under boronized (ELMy) conditions
  - Evaluate efficacy of naturally occurring ELMs for particle control, as basis for future cryo operation under boronized conditions
    - Important to get this for boronized walls in ELMy H-mode: proven density control technique in tokamaks, and a good basis for comparison with Li
    - Impurity sources; particle balance assessed
    - Optimized fueling (joint with ASC)
  - Evaluate LGI, 3D fields for ELM control with boronization
  - Deploy divertor gas puffing, and snowflake if available, with boronized walls, if impurity control an issue w/B
  - Group discussion: possible early I-mode evaluation?

Research Forum website now active

Form for XP idea submissions will open today

Summary

- The NSTX-U team will be ready for the run!