National Spherical Torus eXperiment Upgrade

NSTX-U Team Meeting

January 17, 2019

J. Menard, R. Feder, T. Stevenson, S. Kaye
and NSTX-U Recovery and Research Teams

PPPL PRINCETON PLASMA PHYSICS LABORATORY

PRINCETON UNIVERSITY

Agenda

- Updates since last meeting, prep for next reviews - Jon (15+10)
- Recovery technical progress, project management - Russ (15+10)
- Maintenance & run-prep technical progress, goals - Tim (15+10)
- Research program progress and plans - Stan (10+5)

National Spherical Torus eXperiment Upgrade

Updates, prep for next reviews

NSTX-U Team Meeting - January 17, 2019

J. Menard and the Recovery Project team

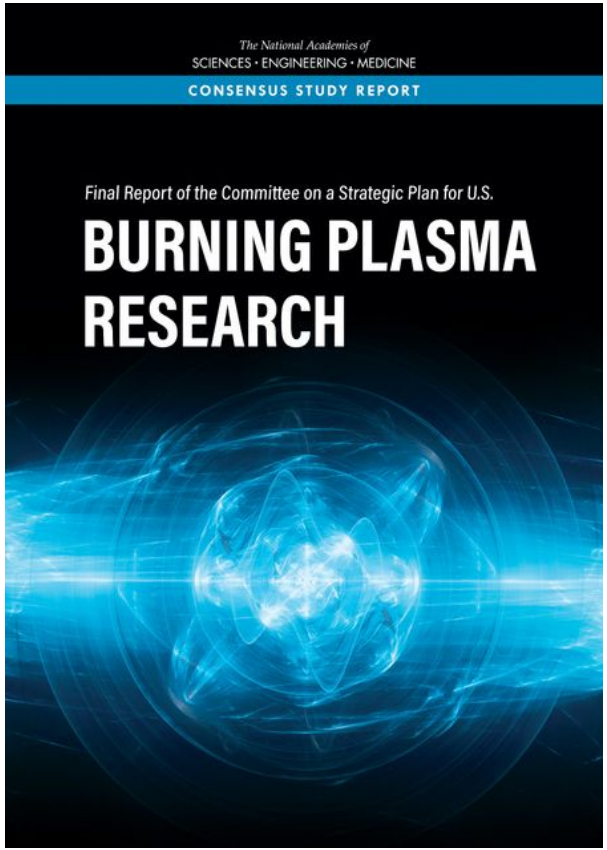
PPPL PRINCETON PLASMA PHYSICS LABORATORY

PRINCETON UNIVERSITY

Outline

- Continued importance of NSTX-U Recovery Mission
- Sample of Major Recovery accomplishments
- Recovery Notable Outcome status and prospects

NAS Strategic Plan Report Released

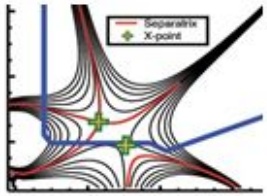


- "Final Report of the Committee on a Strategic Plan for U.S. Burning Plasma Research"
- Two main recommendations:
  - (1) The United States should remain an ITER partner as the most cost-effective way to gain experience with a burning plasma at the scale of a power plant.
  - (2) The United States should start a national program of accompanying research and technology leading to the construction of a compact pilot plant that produces electricity from fusion at the lowest possible capital cost.

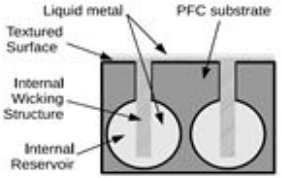
NSTX-U mission well aligned with NAS report

- Exploit unique Spherical Tokamak (ST) parameter regimes to advance predictive capability - for ITER and beyond
- Develop solutions for plasma-material interface (PMI) challenge
- Explore ST physics towards reactor relevant regimes (Fusion Nuclear Science Facility, low-A Pilot Plant)

ITER

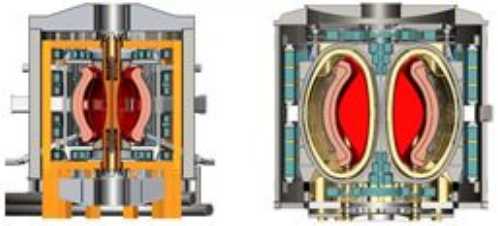


Advanced divertors



Liquid metals

ST-FNSF / Pilot-Plant



Report advocates Fusion Integrated Systems Engineering

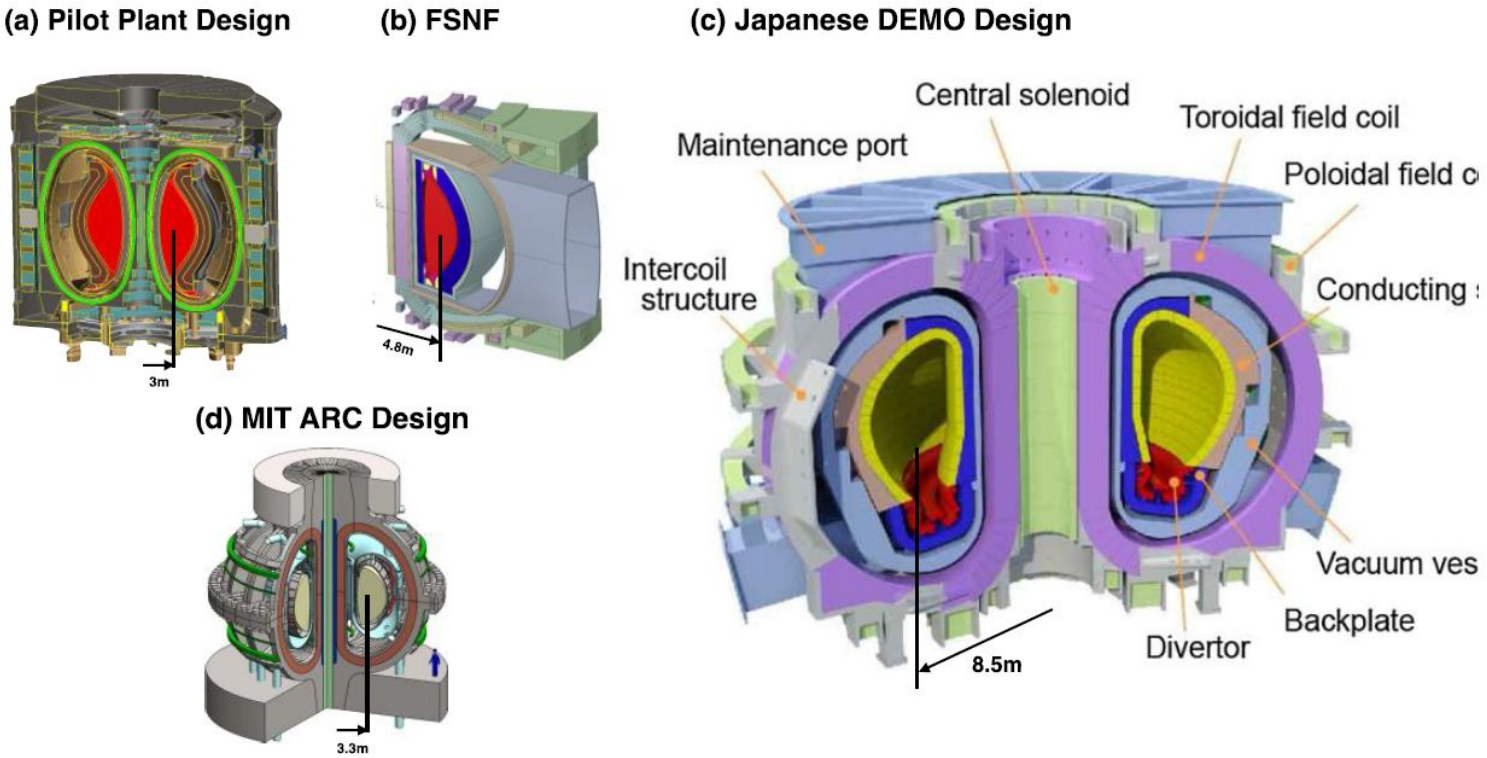


FIGURE 2.15 - Example next-step options resulting from integrated systems studies in the United States and in Japan. Each study combined burning plasma science with different engineering constraints and assumptions for large superconducting magnets. Integrated systems studies guide research and identify programs that can reduce cost and lower risk to the development of fusion power.

Low-A tokamak like NSTX-U important next-step option

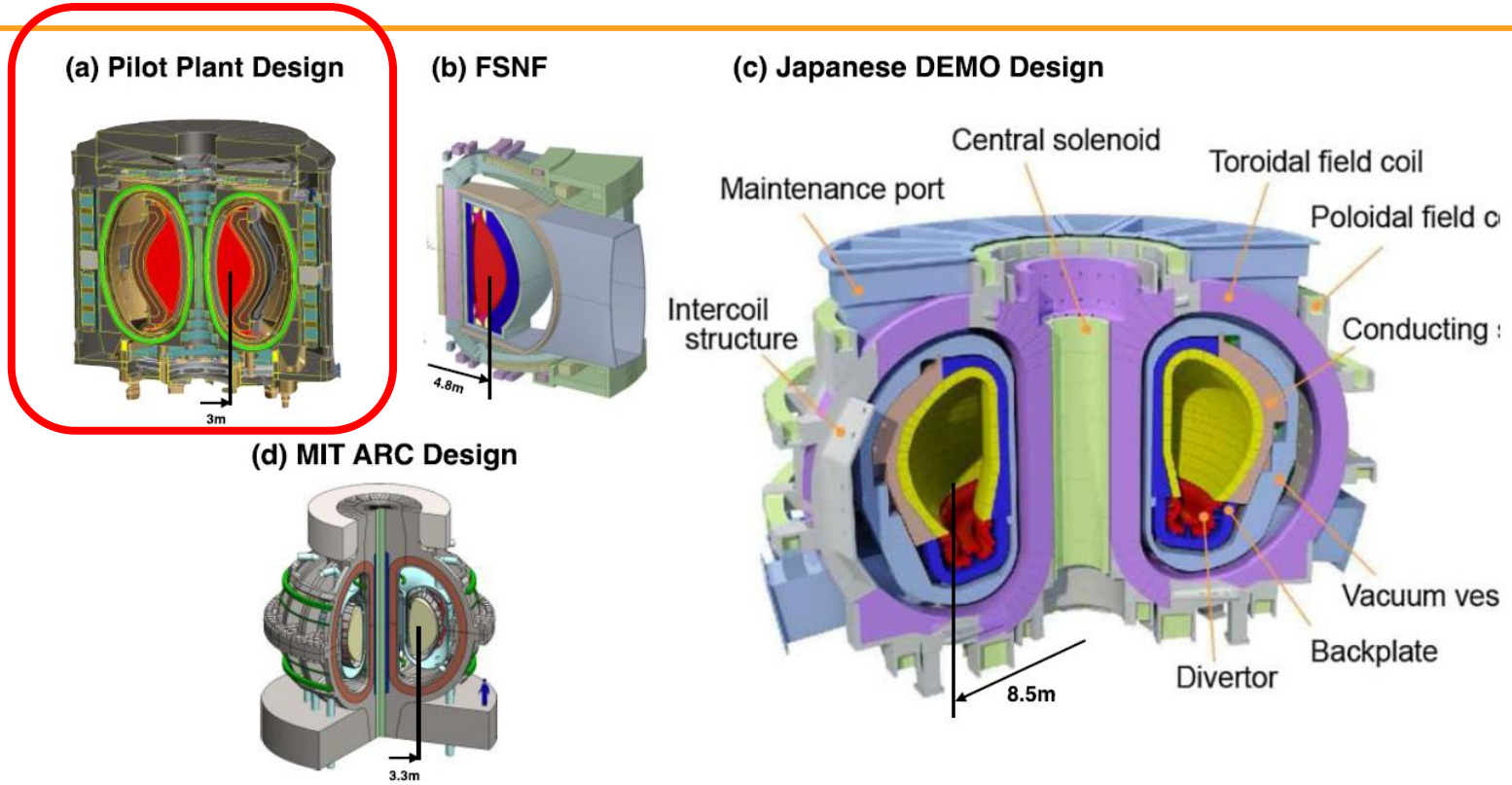
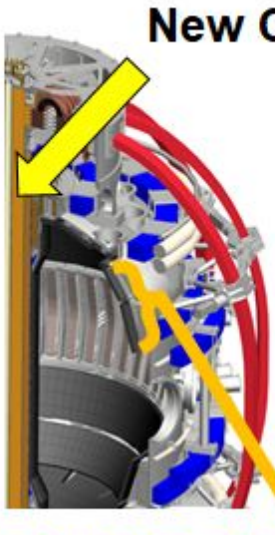


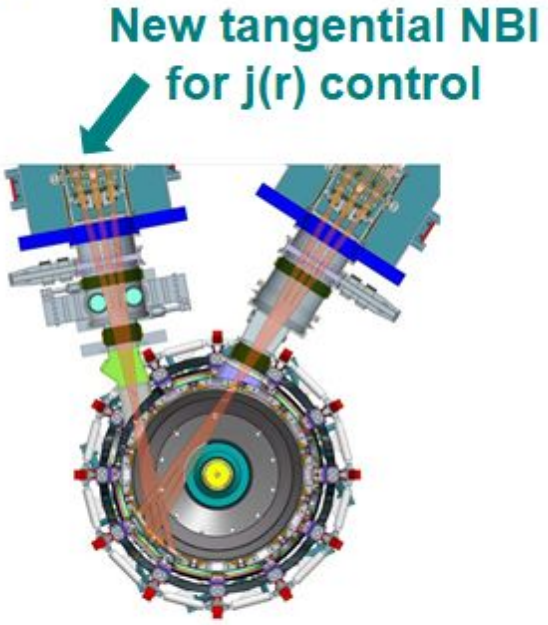
FIGURE 2.15 - Example next-step options resulting from integrated systems studies in the United States and in Japan. Each study combined burning plasma science with different engineering constraints and assumptions for large superconducting magnets. Integrated systems studies guide research and identify programs that can reduce cost and lower risk to the development of fusion power.

NSTX-U Recovery vital to access new fusion regimes

Maximum Parameters

		NSTX	NSTX-U
I_p	≤	1.4	2 MA
RB_T	≤	0.47	0.94 m-T
P_{NBI}	≤	6	15 MW
P_{RF}	≤	6	6 MW
τ_{pulse}	≤	1-2	5-10s





- Higher B_T (1 T at R_0) → projected largest range in β and (lower) ν_* in an ST
- Higher stability $\beta_N / l_i \leq 14$ + flexible NBI → high / full non-inductive current

Select recent Recovery accomplishments

- September: FDRs: PF1B power loop, new PFCs (PEMP Notable)
- October: CS Casing PDR showed new design of end flanges meets requirements, but original casing welds deficient
  - Weld expert + PPPL concur completely new casing most prudent approach
- November: FDR for CS Casing Heat Transfer Tubes and Plates
- Magnets: PF1A prototype coil evaluations completed
  - Nov/Dec: Corona testing completed on sectioned PF1A prototype coils
    - Paschen breakdown observed, but no evidence of insulation degradation
  - Conductor for new coils undergoing grit-blast-prime at ICAS Tratos, Italy
- December: Personnel Safety System (PSS) CDR
  - Major new scope resulting from ASO implementation + Director's Review
- Heroic team effort to complete new CSC FDR (PEMP Notable)
- January: Test cell shielding FDR with extensive MCNP neutronics

FY2019 Notable Outcomes for Recovery (1)

- **<u>FES Notable</u>: For the NSTX-U recovery project, complete a final design review(s) for the integrated casing assembly**, including the heat-transfer tubing and plates and associated attachment hardware, the vertical and angled sections of the center-stack casing, and the horizontal divertor end-flanges, bellows, collars, and organ pipes **by December 31, 2018**. **(Completed)**

- **<u>FES Notable</u>: For the NSTX-U recovery project, award a sub-contract(s) for the procurement of the integrated casing assembly,** including the heat-transfer tubing and plates and associated attachment hardware, the vertical and angled sections of the center-stack casing, and the horizontal divertor end-flanges, bellows, collars, and organ pipes **by March 31, 2019.**
  - CS Casing fabrication is critical path → good to prioritize this award
  - In progress - possible to achieve but very tight schedule

FY2019 Notable Outcomes for Recovery (2)

- September 2018 Director's Review response to charge question "Are the cost and schedule estimates credible and realistic to support establishment of the baseline?"

***Response: No**, the basis of estimate was not yet fully documented.*

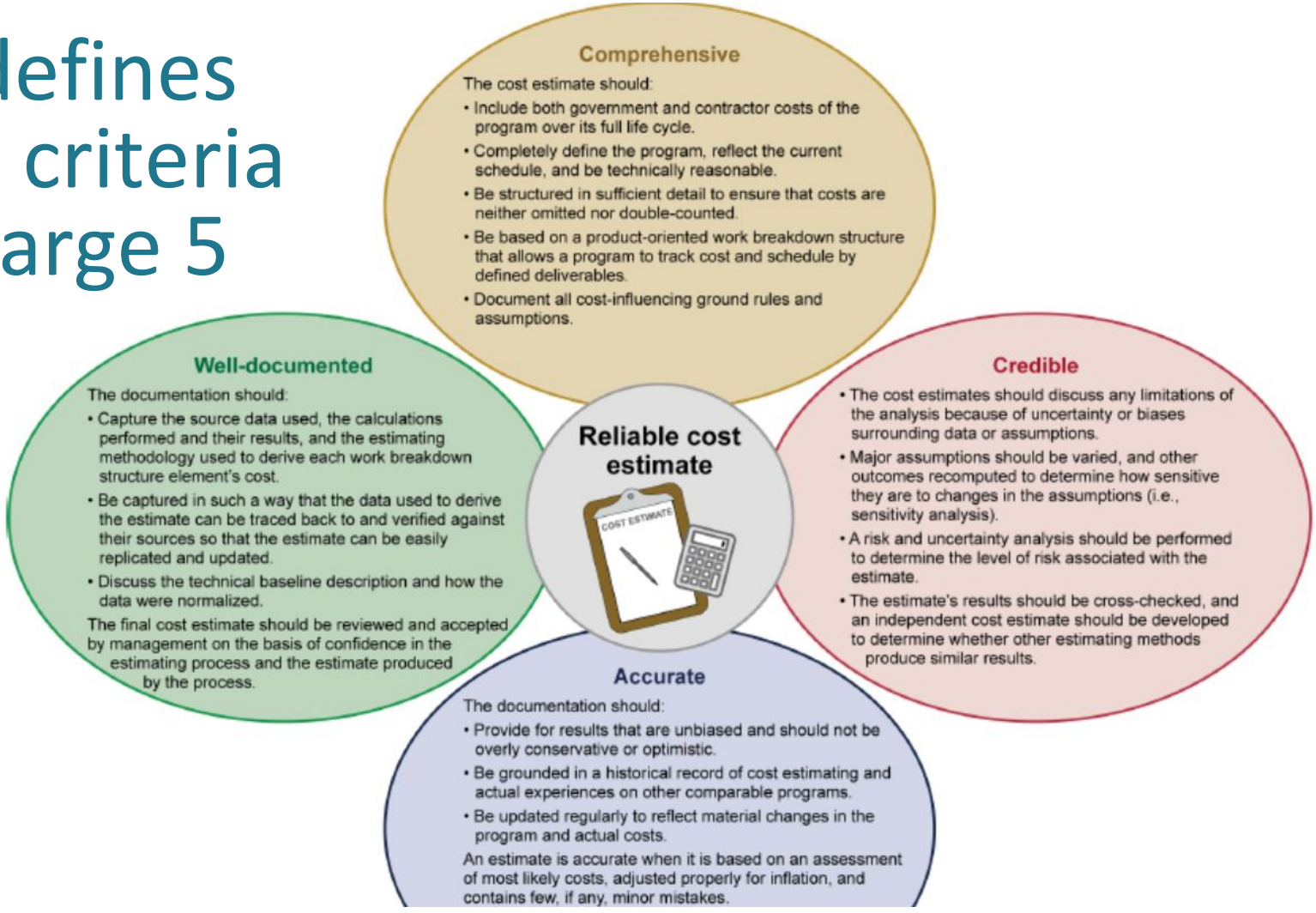
- **FES Notable:** Prepare an NSTX-U Recovery Project cost estimate that is deemed by external review to be well documented, comprehensive, accurate and credible, as defined by GAO-09-3SP and DOE Order 413.3B, by March 31, 2019.
  - Response being coordinated by Russ with strong input from PMO and entire Recovery team effort to support this.

Charge questions for Basis of Estimate Review (BoER)

1) Is there sufficient detailed information available and documented to support the cost estimates?
2) Are the estimates accurate, credible, comprehensive, and do they follow the GAO -12 Steps for Cost Estimating Best Practices?
3) Are project risks identified reasonable and included in project cost?
4) Is the schedule resource loaded, identify a critical path, and include sufficient details to successfully achieve CD-4 on time?

5) Can you positively affirm the NSTX-U Recovery Project cost estimate is ***well documented, comprehensive, accurate and credible*** as defined by GAO-09-3SP and DOE Order 413.3B?

GAO defines specific criteria for charge 5



Basis of Estimate Review (BoER) prep status

- Developed ~50 “Cost Books” with thousands of lines of estimate
- Previously planned to hold BoE review next week
- Preview of cost books with review committee in mid-December raised concerns about adequacy of backup documentation
  - Cannot rely on engineering judgement above some threshold (~30%)
  - Need to rely heavily on previous experience and quotes (we are doing this)
  - BUT need to provide sufficient evidence for previous experience
    - Project ~80+% labor, need to document labor items GE 1 person month
- Focusing on improving backup docs, will discuss with review committee next week to assess example improvements in docs
  - Aiming for BoER late Feb or in March - but seeking committee feedback first to gauge present approach/readiness and estimate time needed
- Successful BoE Review is pre-requisite for CDE-2/3A review

FY2019 Notable Outcomes for Recovery (3)

- **FES Notable:** For the NSTX-U recovery project, fabricate at least one production inner-poloidal magnetic field coil. Verify the quality of the coil through electrical testing and dimensional inspection by September 30, 2019. (Objective 2.2)
  - **Technically on track**
  - **But requires successful BoER → CDE-2/3A → ESAAB approval to wind**
  - Risk: Baseline not approved soon enough to achieve Notable on time
  - **NEED ALL HANDS ON DECK FOR COMPLETING BoE DOCUMENTATION**

- **PSO Notable:** Establish an effective and appropriately tailored Accelerator Safety Order Implementation Plan for the NSTX-U Recovery Project and obtain DOE's concurrence - **On Track**

National Spherical Torus eXperiment Upgrade

Recovery Project technical progress and project management

NSTX-U Team Meeting - January 17, 2019

Russell Feder and the Recovery Project team

PPPL PRINCETON PLASMA PHYSICS LABORATORY

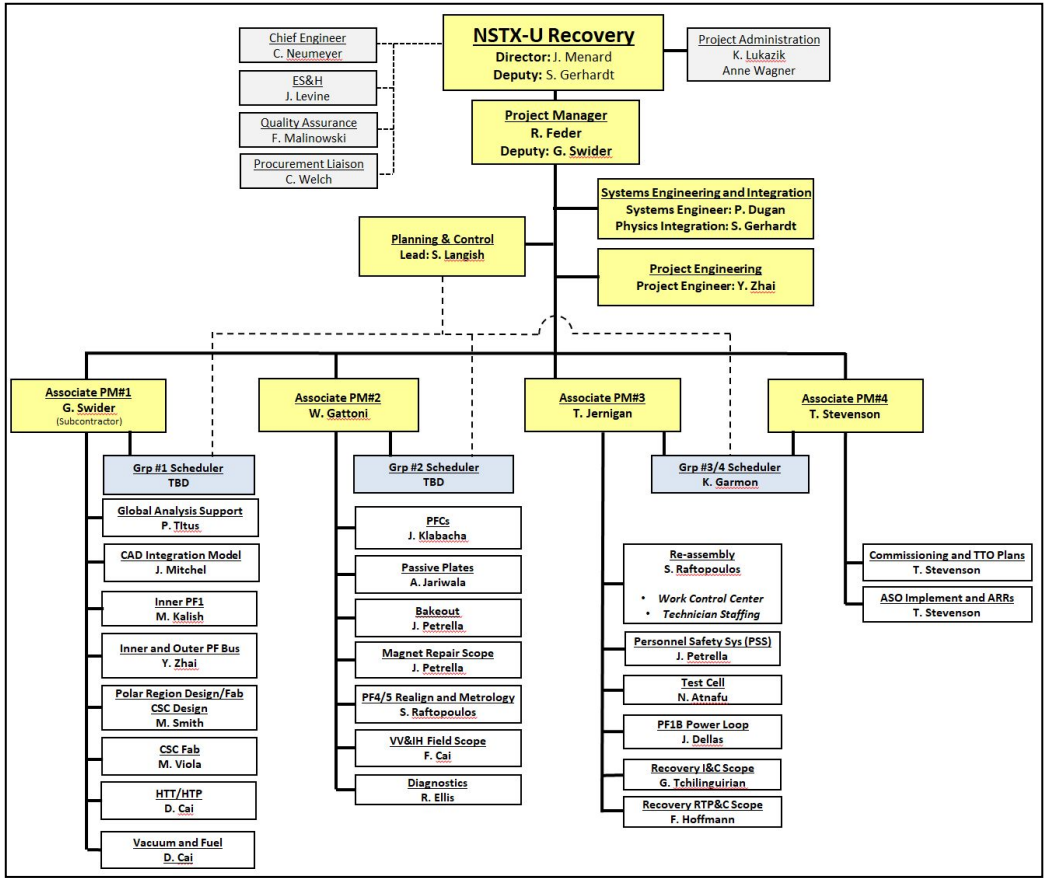
PRINCETON UNIVERSITY

Recovery Project Organization

- **Project-focused organization that improves work control, reporting and responsiveness**
- **Adding 4 new Associate Project Managers (APMs) and 3 new Schedulers**
- **APMs focus on project management**
- **Cognizant Engineers (COGs) have more time for engineering**
- **Mobilize preparations for CDE-2/3A review**

Key Changes

- **Associate Project Managers (APMs)** are the *CAM for their portfolio*
- **Cognizant Engineer** responsible for design, fabrication and deployment of technical scope
- Dedicated scheduler will support each APM
- Roles of Project Engineer and Systems Engineer unchanged



Design Review Status

33 of 44 Peer Reviews, CDRs and PDRs Complete

78% reviewable scope through PDR

PDRs	Schedule	Actual
1.1.1.1 Low Heat Flux PFCs	9/29/2017	9/29/2017
1.1.1.1 High Heat Flux PFCs	11/15/2017	11/15/2017
1.1.2.4 Cooling Tubes	11/30/2017	11/30/2017
1.3.1.1 Helium Bake Feedthrough	12/1/2017	12/1/2017
1.1.3.1 Inner PF Coils	12/14/2017	12/14/2017
PF1A Conductor Size Peer Review	12/19/2017	12/19/2017
1.3.3.3 Interspace Pumping	12/20/2017	12/20/2017
Turn-to-Turn Testing Peer Review	12/21/2017	12/21/2017
1.4.1.2 PFC Diagnostics	1/4/2018	1/4/2018
1.3.1.1 Helium Bake System - Gas Piping	1/11/2018	1/11/2018
Alignment I Peer Review	1/18/2018	1/18/2018
Alignment II Peer Review	2/1/2018	2/1/2018
1.3.1.2 exVessel Heating System	2/1/2018	2/1/2018
1.1.3.4 Cooling Water Controls	2/20/2018	2/20/2018
1.1.2.3 VVHW Field Scope - Part I	2/23/2018	2/23/2018
1.5.1.3 PF1B Bipolar Circuit	2/27/2018	2/27/2018
1.1.3.4 Inspect Outer PF Coils/Repair	3/13/2018	3/13/2018
1.4.1.1 Vessel/Coil Instrumentation	3/22/2018	3/22/2018
1.1.2.1 Polar Region #1	3/27/2018	3/27/2018
1.1.3.4 TF/OH Bundle Reliability	4/3/2018	4/3/2018
1.3.1.5 DC Current to Top NSTXU	4/5/2018	4/5/2018
1.8.1.1 NTC Shielding	4/10/2018	4/10/2018
1.1.2.2 Passive Plates	7/31/2018	7/26/2018
1.8.1.3 NSTXU Reassembly	7/31/2018	8/1/2018
1.1.2.1 Polar Region #2	6/21/2018	8/2/2018
1.8.1.1 NTC Shielding PDR #2	8/6/2018	8/6/2018
1.8.1.2 NTC O2 Monitor	8/14/2018	8/14/2018
1.8.1.3 NTC Door Rad Monitor	8/14/2018	8/14/2018
1.1.0.1 Integration Scope (Project PDR)	8/1/2018	8/15/2018
1.1.2.6 CSC PDR	10/16/2018	10/16/2018
1.1.3.6. PF4/5 Realignment CDR	10/25/2018	10/25/2018
1.1.3.2 PF Bus Support PDR #1 Inner PF Bus	1/30/2019	
1.8.2 PSS CDR	12/13/2018	12/13/2018
1.7.2.1 Turn-to-Turn Fault Monitoring CDR	*3/8/2019*	
1.1.3.2 PF Bus PDR#2	*3/26/2019*	---
1.1.3.6 PF 4/5 Realignment PDR	*12/19/2018*	---
1.4.1.3 Aerodag and Bay-K Armor	*2/25/2019*	---
1.4.1.5 Field Seal Repairs PDR	*2/25/2019*	---
1.4.1.7 BES Shutter PDR	*3/22/2019*	---
1.4.1.6 Halo/Flux Loops PDR	*4/16/2019*	---
1.1.2.3 VVHW Field Scope - Part II PDR	*12/14/2018*	---
1.3.3.5 Private Flux Region Fuelling PDR	*12/8/2018*	---
1.8.2 Personnel Saftey System PDR	*5/2/2019*	---
1.7.2.1 Turn-to-Turn Fault Monitoring PDR	*6/11/2019*	---

PPEP Aug 18'

10 of 32 FDRs Complete

52% reviewable scope through FDR

FDRs	Schedule	Actual
1.6.1.2 NSTXU Camera Surv	4/18/17	4/18/2017
1.1.3.1 Inner PF Coils	3/30/18	3/30/2018
CS Casing Trial Fit	4/17/18	4/17/2018
1.5.1.2 Inner PF Coil Power Test	5/9/18	5/9/2018
1.5.1.3 PF1B Bipolar Circuit	9/20/18	9/20/2018
1.1.1 Plasma Facing Components	9/26/18	9/28/2018
1.1.2.4 Cooling Tubes (HTT/HTP)	11/1/18	11/1/2018
1.1.2.1 Center Stack Casing (MCS #1)	12/28/18	12/28/18
1.8.1.1 NTC Shielding	1/14/18	1/14/18
1.4.1.2 PFCs Diags + Ip Rogowski	1/31/19	1/31/18
1.1.2.2 Passive Plates	*3/1/2019*	
1.1.2.1 Machine Core Struc #2	*4/1/2019*	
1.1.3.6 PF 4/5 Realignment FDR	*2/12/2019*	
1.3.1.1 Helium Bake Scope	*3/1/2019*	
1.4.1.3 Aerodag and Bay-K Beam Armor	*6/5/2019*	
1.1.3.3 PF Bus Support FDR #1	*5/20/2019*	
1.1.3.3 PF Bus Support FDR #2	*7/14/2019*	
1.3.1.5 DC Current to Top NSTXU	*8/13/2019*	
1.4.1.5 Field Seal Repairs	*4/16/2019*	
1.4.1.6 Halo/Flux Loops	*6/30/2019*	
1.4.1.1 Vessel/Coil Instrumentation	*8/19/2019*	
1.4.1.7 BES Shutter	*5/11/2019*	
1.3.3.5 Private Flux Region Fuelling	*3/1/2019*	
1.8.2 Personnel Safety System FDR	*7/1/2019*	
1.1.2.3 VVHW Field Scope	*2/1/2019*	
1.3.1.2 exVessel Heating System	*6/19/2019*	
1.1.3.4 Magnet RP Scope FDR (if needed)	*5/1/2019*	
1.8.1.2 NTC O2 and Rad Monitor	*2/26/2019*	
1.7.2.1 Turn-to-Turn Fault Monitoring	*8/5/2019*	
1.8.1.3 NSTXU Reassembly	*5/1/2019*	
1.1.0.1 Integration Scope, Project FDR	*6/1/2019*	
1.3.3.3 Interspace Pumping	*???*	

PPEP Aug 18'

Major FDRs completed

- Inner PF Magnets
- PFCs
- CSC rebuild
- HTT/HTP
- NTC Shielding
- PF1B Power

FDRs carrying cost risk

- Passive Plates
- MCS
- PF4/5 Alignment
- PSS

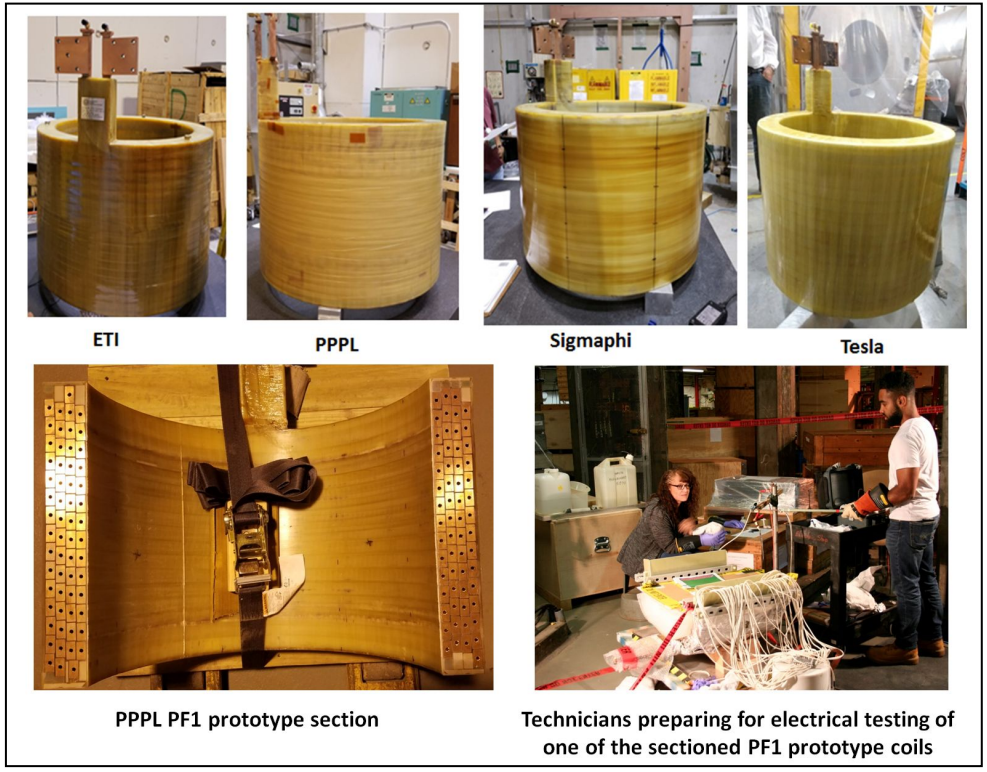
74% of scope by TEC $$ is "design reviewable"

- Exclude
  - Project Management
  - ASO
  - Commissioning
  - Integration / Analysis

Replacement Inner PF Coils

Grit blasting and priming of copper conductor at ICAS/TRATOS facility in Italy.

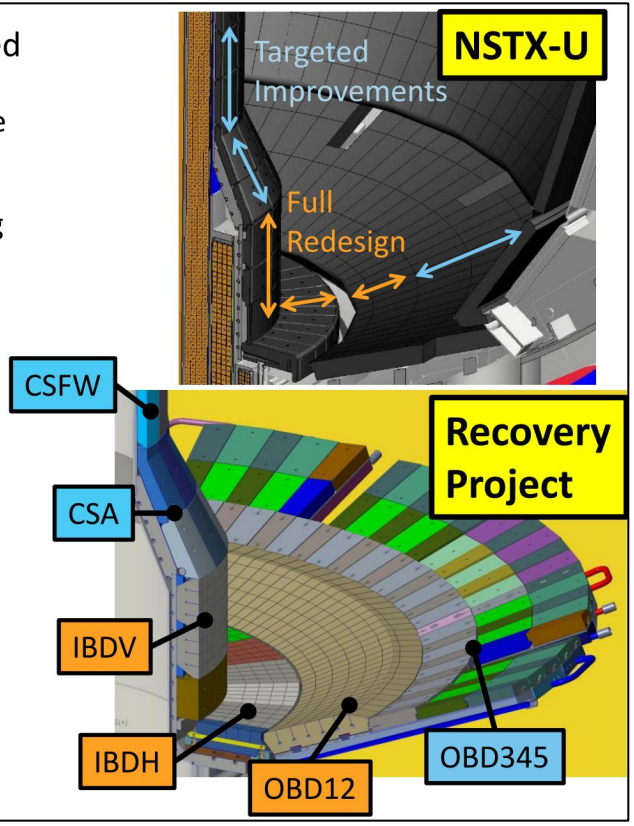
Prototype testing was completed in 2018. Production coil vendor selection is based on the results of the prototype program.



Plasma Facing Components (PFCs)

The PFCs FDR was completed in Sept 2018. Bulk graphite procurement is underway.

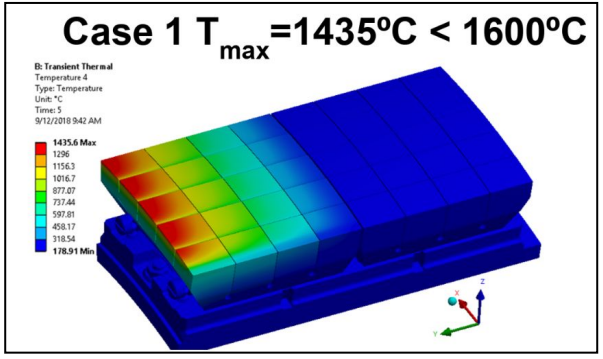
- Emphasis on reliable operation resulted in PFC Recovery effort
  - Updated EM loads and re-analysis more challenging than expected
  - More conservative approach to heat-exhaust solutions emphasized requiring improved PFC performance
  - New PFCs to be qualified for full-power and full-load operations on day 1
- Seven major sections of PFC effort
  - Targeted Improvements: Center Stack First Wall, Outboard Divertor-345, Center Stack Angled **[WBS 1.1.1.1, 1.1.1.5, 1.1.1.7]**
  - Full Redesign: Inboard Divertor-Horizontal, Inboard Divertor-Vertical, Outboard Divertor-12 **[WBS 1.1.1.2, 1.1.1.3, 1.1.1.4]**
  - Team Integration **[WBS 1.1.1.6]**



Next steps

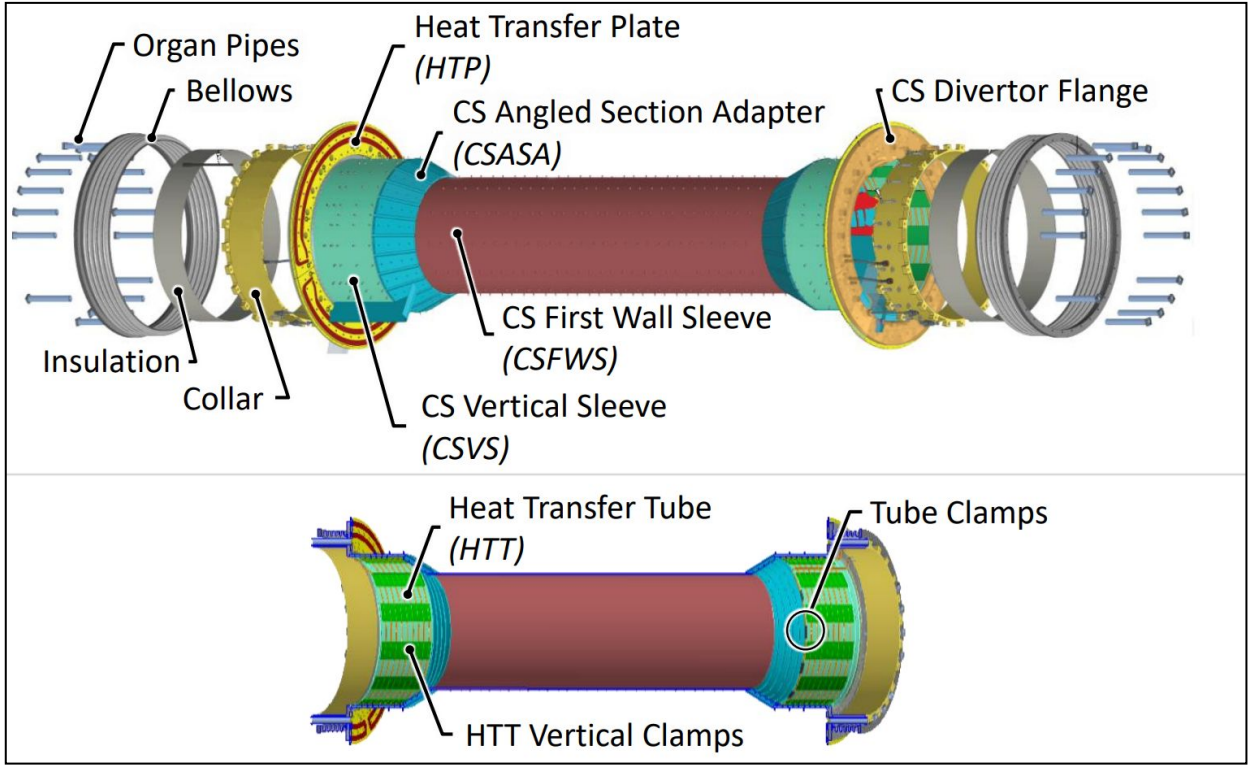
1. Purchase bulk graphite and CFC
2. Fabrication subcontracts for metal and graphite parts

Team with ORNL for PFCs design and FEA



Center Stack Casing Rebuild

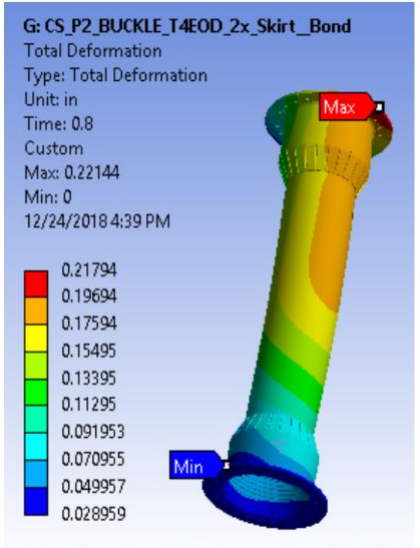
Rebuild CSC → adequate welds and other structural upgrades
FDR completed December 28th, 2018



Next steps

1. PEMP Notable → place subcontract by 3/31/19

Team with ORNL for CSC analysis

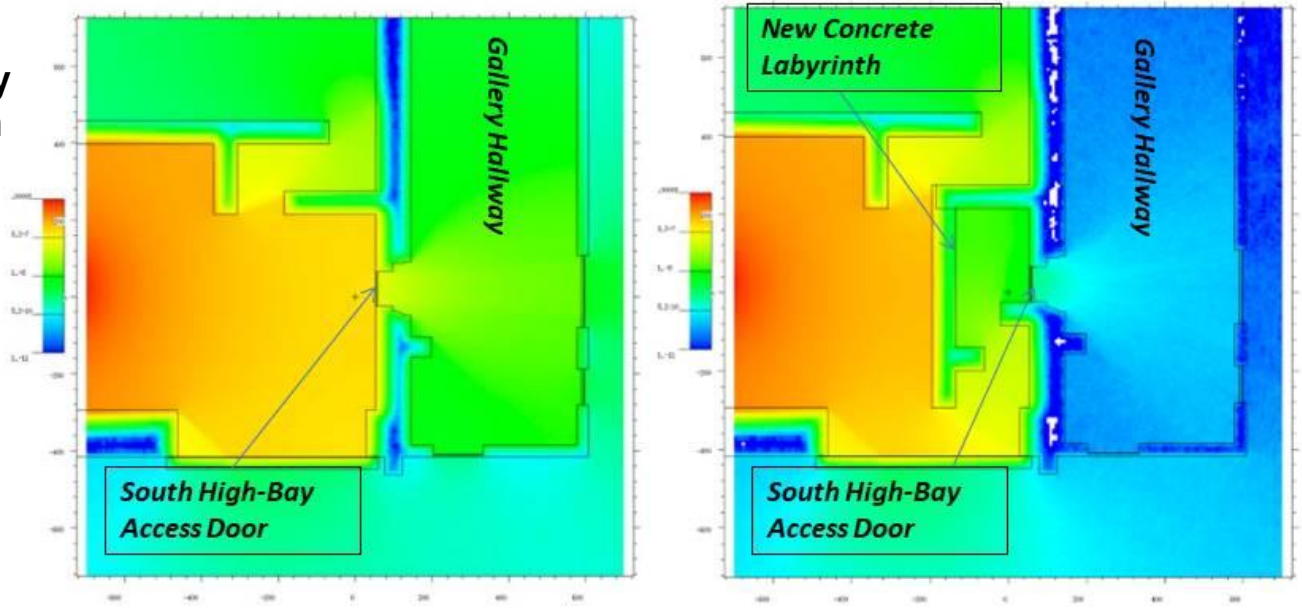


Buckling Load Deformation @ 200%
Combined Halo/Eddy/PFC

Test Cell Shielding Upgrades

FDR completed 1/14/2019. Authorized to start some of the work in the test cell after the FDR.

Without south high-bay door labyrinth



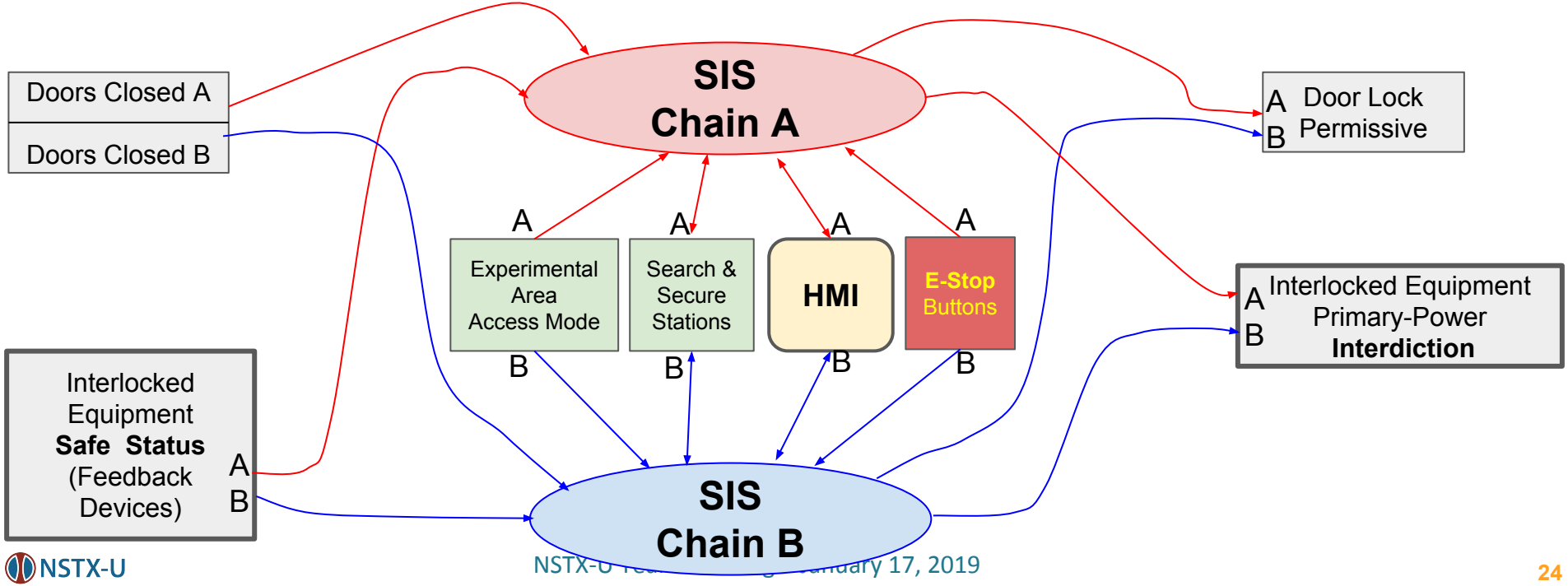
With new south high-bay door labyrinth

The neutronics code MCNP was used to evaluate improvements to NSTX-U test cell shielding. This is an overhead view of a parametric study of the effectiveness of a new concrete labyrinth for the South High-Bay access door to minimize neutron radiation in the Gallery hallway. The contour colors show much lower neutron flux levels with the new labyrinth.

Personnel Safety System (PSS) Scope

Install Dual Chain "shell" over updated Centralized Control System

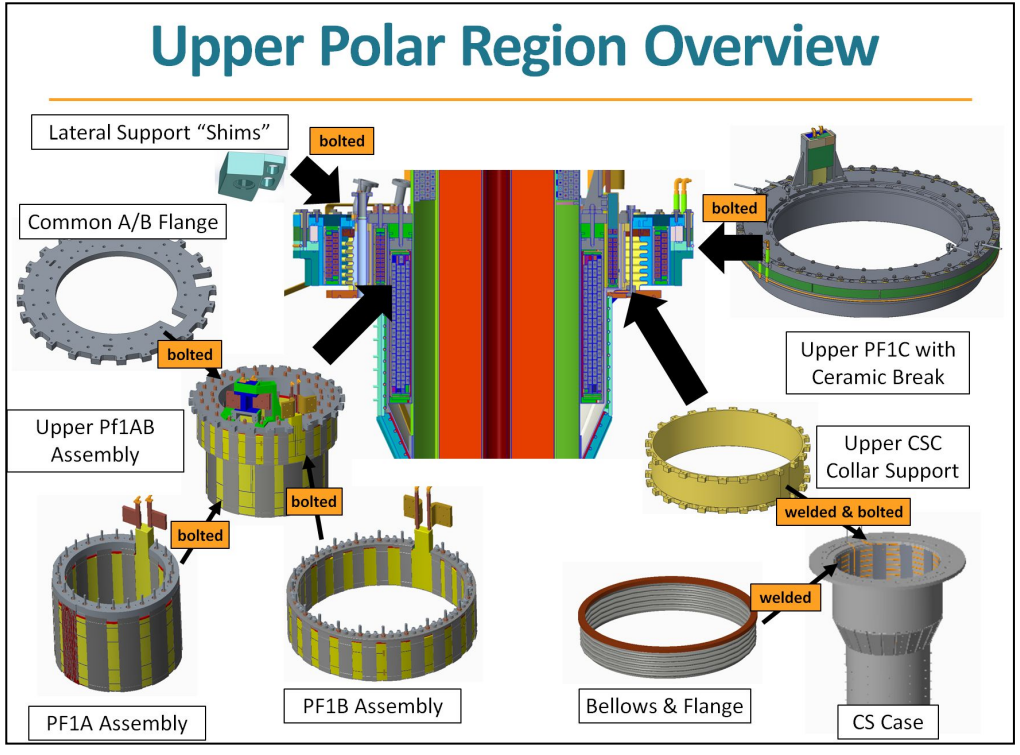
- New Dual Chain SIL-capable Logic Solvers
- New SIL-capable Instruments
- New SIL-capable Output Hazard Control Devices (interrupt existing control wiring)
- New PSS-Specific Trapped Key system



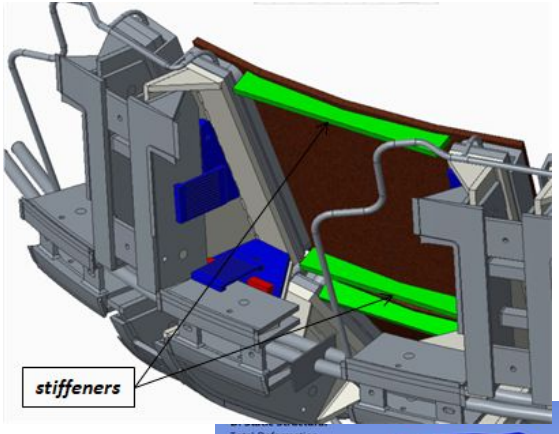
Next Priority: MCS and Passive Plates

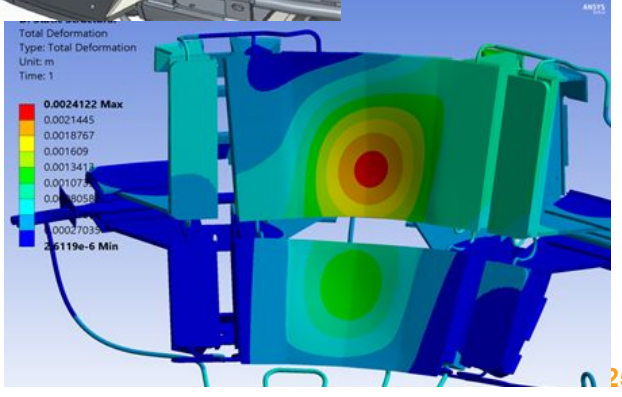
Goal → Complete MCS and Passive Plate FDRs in late May, 2019

Machine Core Structures (MCS) was previously known as Polar Region



Stiffeners will be added to the passive plates to limit deflections under disruption loads.





NSTX-U Recovery FY19 PEMP Notables

	FY2019 PEMP Notable Key NSTX-U Recovery Project Event *(paraphrased from full PEMP text)*	Finish By Date	Status
A	Complete Basis of Estimate documentation for baseline review. Hold Basis of Estimate Review (BOER) to verify CDE-2 readiness.	3/31/2019	The highest priority of the Recovery project team. Will be completed no later than the week of March 18th.
B	Complete the Center Stack Casing Rebuild FDR	12/31/18	Completed 12/28/18
C	Award the fabrication subcontract for the Center Stack Casing Rebuild	3/31/2019	All drawings and procurement documents are complete. Procurement actions will start week of Jan 21.
D	Fabricate and test a production PF1 coil via electrical testing and dimensional inspection	9/30/2019	The procurement package is under review with DOE. The team is aiming to place subcontracts by mid-March.
E	Develop ASO Implementation Plan and obtain DOE concurrence	9/30/2019	The ASO Implementation Plan draft is complete and is in review with DOE.

Recovery Project Status

1. The Recovery Project has achieved important technical milestones and we are ready to fabricate
   a. Magnets
   b. Center Stack Casing
   c. HTT/HTP components
   d. Plasma Facing Components
   e. Test Cell Shielding
   f. PF1B Power Loop

2. The Recovery Project has authorization from DOE to
   a. Place Inner PF subcontracts and start coil winding prep. *Can't start winding until CDE-2/3A* approval
   b. Build a new Center Stack Casing
   c. Build the HTT/HTP parts
   d. Order all PFCs bulk material but *can't start PFCs fabrication* until CDE-2/3A approval
   e. Start some aspects of Test Cell Shielding work. Start labyrinth fab/filling penetrations after CDE-2/3A
   f. Complete install of the PF1B Power Loop

3. To achieve CDE-2/3A approval the project first needs to pass the Basis of Estimate Review (BOER)

National Spherical Torus eXperiment Upgrade

Maintenance & Run Prep: progress & goals

NSTX-U Team Meeting - January 17, 2019

Tim Stevenson and the NSTX-U team

PPPL PRINCETON PLASMA PHYSICS LABORATORY

PRINCETON UNIVERSITY

M&RP Ops - Goals and Cost Drivers

- Maintain and prepare to operate NSTX-U for Recovery KPPS and Research
  - Maintain equipment and systems (NB, RF, MG, FCPC, BAKE, CWS, VAC, CI&C, RC&P)
  - Maintain areas (D site, NTC, RF) and safety (MSW, etc.)
  - Maintain operating staff and core knowledge
  - Maintain procedures and training
  - Maintain Work Planning and Control as well as Conduct of Operations
- Prepare for operations with high reliability and availability
  - Manage down obsolescence
  - Build spare NB sources; perform RF dummy load testing; test ECH-PI
  - Perform periodic MG and FCPC testing and spares; maintain switches
  - Perform CI&C testing, manage down CAMAC; build spares, attend to software, clean up control pages
  - RC&P spares
- Cover minimum Operations LOE, DSSS, electricity, HP and ERWM allocations

M&RP Ops - Goals and Cost Drivers

- All M&RP jobs revisited for FY19 and updated per historical need and as spent accuracy
- All M&RP jobs being tracked monthly for status, plans, and KPIs
- M&RP keeps the NTC open
- M&RP keeps D site functioning safely
- M&RP keeps the lights on
- M&RP addresses housekeeping, facility upkeep, and DSSS coverage for work control
- Deferred scope now in the process of being estimated in additional WAFs
- New weekly M&RP Status meeting Tuesdays 0845 H. in CRA (after 8:30 meeting)
- Recovery jobs only charged for Recovery scope; all else charges to M&RP jobs

Technical Scope and LOE Defined in M&RP WAFs following NSTX-U WBS

- Torus Systems
- Plasma Heating and Current Drive (RF & NBI)
- Auxiliary Systems
  - Bakeout
  - Cooling
  - Vacuum and Fueling
- Power Systems (MG & FCPC); New WAFs for MG#2 welding and CCV upgrade generated
- Central Instrumentation and Control (CI&C); New WAFs generated
- Project Management and Support
  - Real Time Protection and Control
- NSTX-U Test Cell Radiation Annunciation and ODH monitor
- Procedures and Training

M&RP Ops - Status and Plans

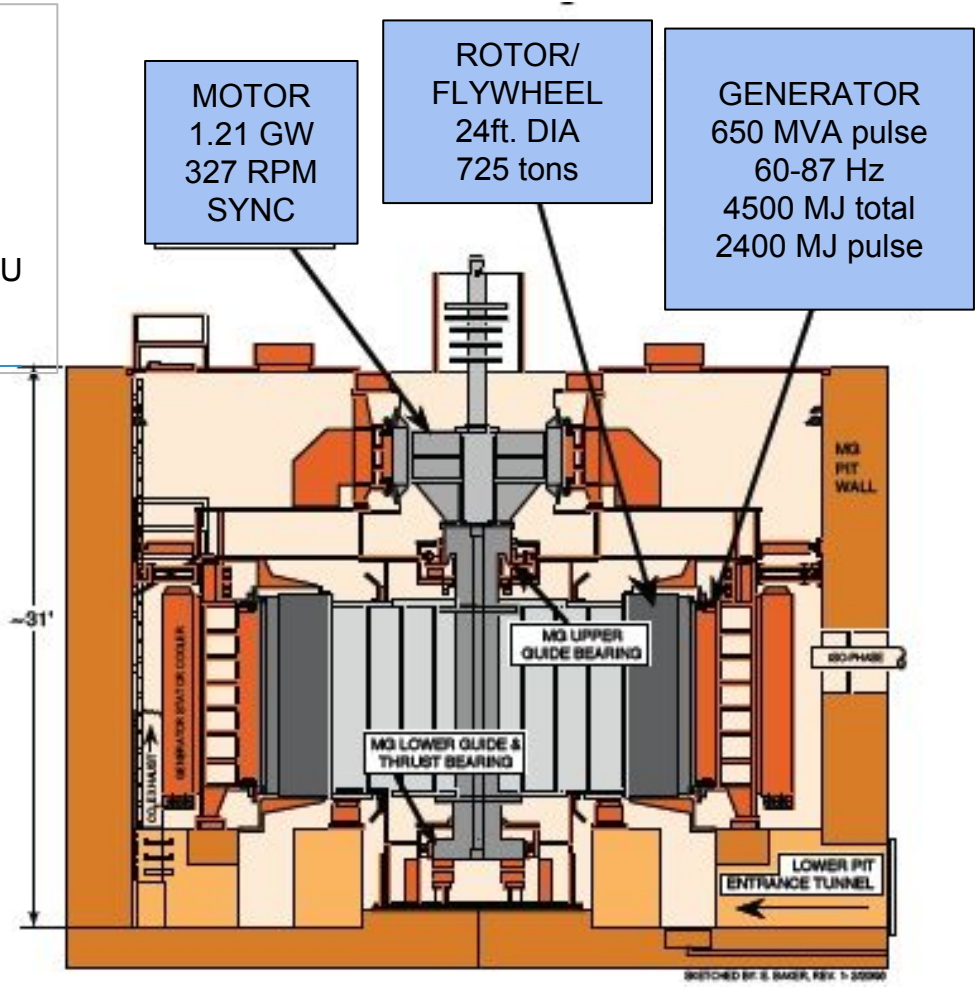
- MG#1 in service
  - including pole, brake cylinder, and guide bearing maintenance
  - Need MG#1 to test production coils, commissioning, Recovery KPPs
- MG#2 weld repairs and CCV upgrades estimated
- FCPC rectifiers and switch maintenance in progress
  - Pringle switches completed, Ground switches planned
  - FCPC needed to test production coils, commissioning, Recovery KPPs
- CI&C and RC&P maintained; recent SAD2 FDR successful
  - recent tests brought online the real time FPDP system and software
  - DCPS will require extensive testing as part of commissioning; PTP planned
  - Managing down and redeployment of CAMAC in progress
  - Some new scope estimated
  - Managing high staff turn over with training and cross-training
- CWS in service supporting ops, testing; minor maintenance needed.

NSTX-U Motor Generators (2)

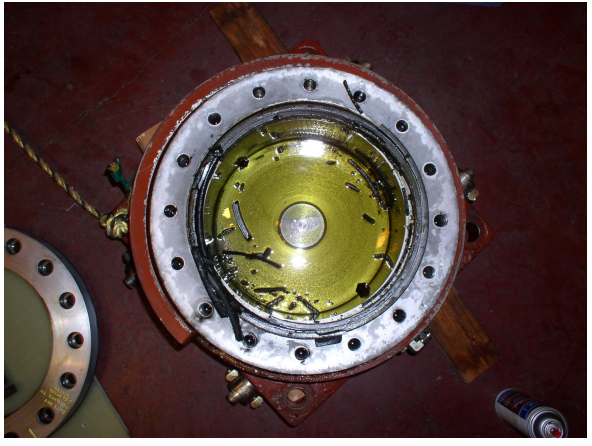
MG#1 Maintenance

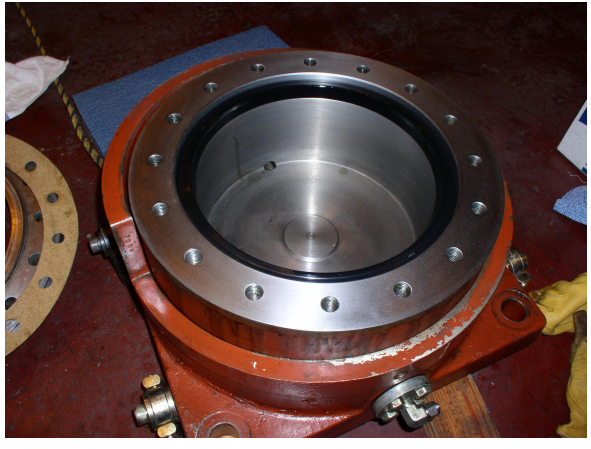
MG#2 Out of service derated due to weld cracks

Need 1 MG for NSTX-U Ops



NSTX-U Motor Generators (2)

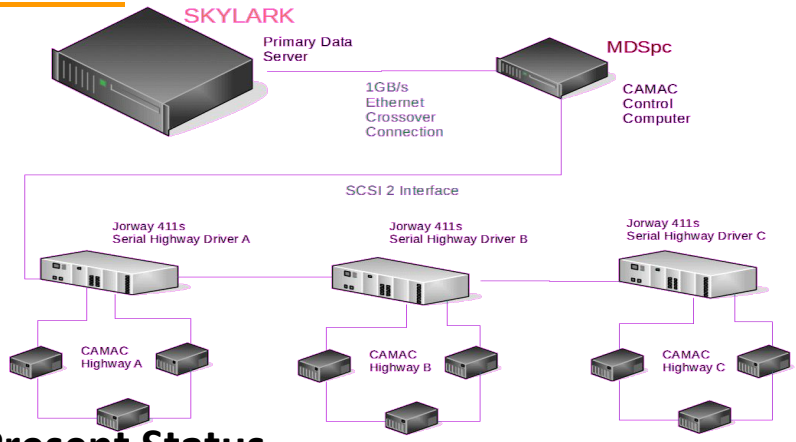




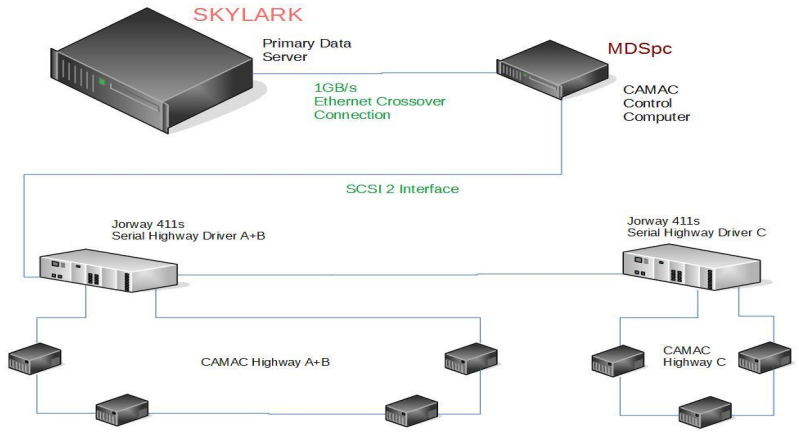
Central Instrumentation and Control

11.3.1: CAMAC Spares, Improvements and Modernization (WBS 1.6.1.1) (continued)

Before:



After:



Present Status

- WAF has been developed and approved
- Preliminary testing effort have been executed.
- Prototype replacement system has been procured for testing
- Design Requirements completed
- FDRs complete; in progress

Additional C&IC and Real Time Control & Protection scope in backup slides

M&RP Ops - Status and Plans

- NBI progress
  - one ion source rebuilt, one nearing readiness for test, next one on deck
  - calorimeter repairs
  - armor quadrant refurbishment in FY19
  - telemetry refurbishment
  - ModReg electronics, etc.
  - Cryogenics refurbishment complete and tested; turbine controller
- RF ECH-PI tested last year; more tests planned this year
- RF HHFW maintained
  - with some minor repairs needed
  - Periodic dummy load tests are planned and being prepared for next month/quarterly
- Vacuum system off with minor refurbishments done
- TVPS CWS in progress
- Bake PLC upgrade planned
- ES-MECH-15 Pressure Systems compliance in scope and in progress

Major Heating Systems Tasks Required for Start-up

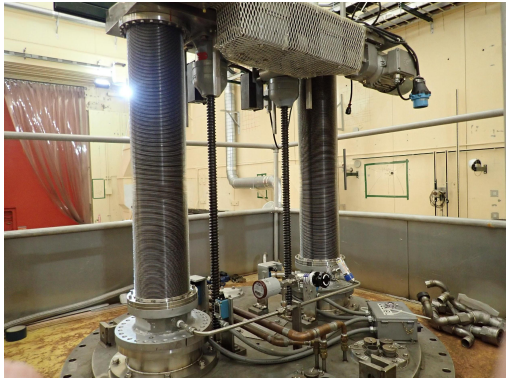
- High Harmonic Fast Wave (HHFW)
  - ~~ECH-PI Maintenance and Calibration.~~
  - Antenna Boron Nitride Shield replacement.
  - Antenna Thermal & Mechanical Analysis (disruption loads).
  - Installation of Antenna Thermocouples and Electronics.
- Neutral Beam (NB)
  - ~~Repair of NBL-1 Ion Source Isolation Valves.~~
  - Repair of both calorimeters.
  - Refurbishment of Ion Sources.
  - ~~Inspection of Beamline internals.~~
  - ~~Replacement of LHe cold box temperature sensors.~~
  - ~~Refurbishment of the three 500 hp compressors.~~
  - Upgrade of telemetry.
  - Mod/Reg Chassis repairs/upgrades.
  - Design & fabricate new turbine controllers.
  - Repair of Neutral Beam Armor.
  - Redesign & fabrication of NB Armor thermocouple boards.
  - Miscellaneous repairs.

Refurbishment of NBI Ion Sources

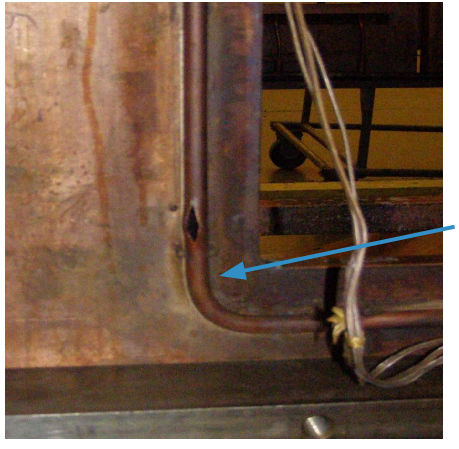
- Need to rebuild four more sources to support restart
  - One source needed to replace NBI-2C failed source (external water leak discovered)
    - Replacement source completed and tested; ready to be installed prior to start-up
  - One source NBI-1C due to come off for end of life on hoses; a replacement source is assembled
  - Three spares for operations in progress in Source Shop

Repair of both calorimeters nears completion

Calorimeter Lift (Both out for repair)
Both need to be re-installed after CS moves out of SHB



BL1 & BL2 Calorimeter External Bellows & Drive: repair and re-alignment completed

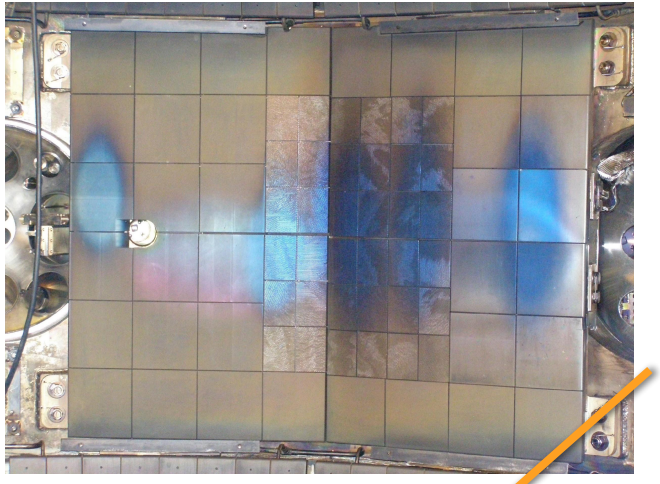


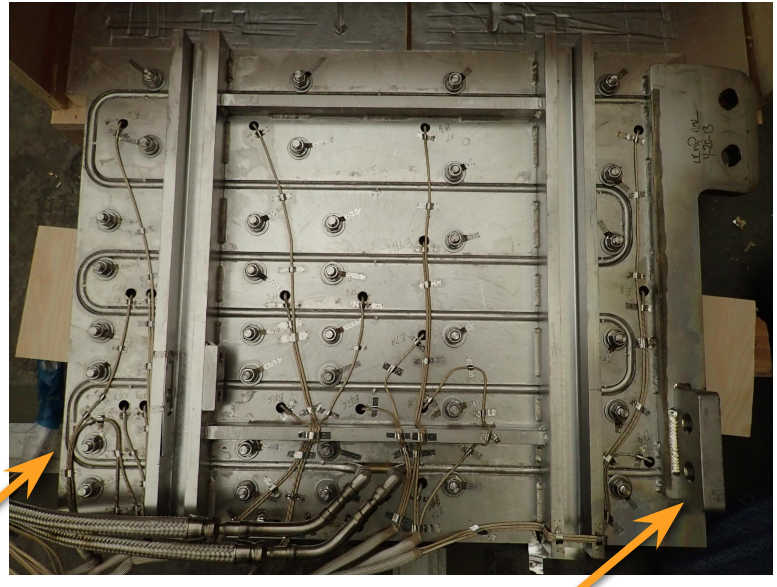
NBL-1 Calorimeter Scraper Water Leak Repaired in progress; Final welding in progress

BL1 & BL2 Internal Bellows replacement completed

BL2 Cal ready to install

Repair of Neutral Beam Armor in Progress



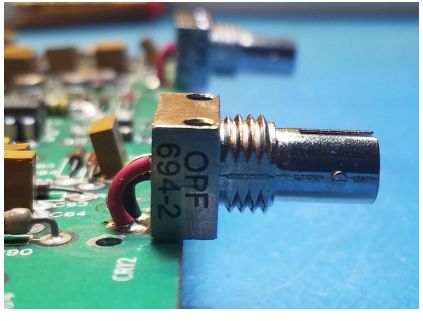


Leak in tube under mounting plate;
New plate fabrication effort in progress

NBI Electrical and Electronics

Upgrade of Telemetry and Fault Detection

- Transmitters and receivers are reaching EOL
  - Have been obsolete for 30+ years
  - Not enough spares to maintain system past a few years
- Will be replaced with standard ST style terminations and receptacles
- Parts have been selected and changes have been mocked up
  - Retermination of approximately 11 bundles of 8 fibers per source
  - Modifications to electronics
  - Replacement of HVE feedthroughs



New LED Mounted to Transmitter PC Board

Front Panel of Upgraded Transmitter

ST Fiber Optic Connector

M&RP Ops - Procedures and Training

- New job added for Procedure updates to support OP-NSTX-02 restart
  - changes required due to QAPD, ENG, ASO, Technical scope
  - approximately 100+ procedures
- New job added for Training
  - New training packages needed for operators and instructors
  - Capture core knowledge; establish a sustainable training program
  - Retraining operators for testing and commissioning
- Both support safe operations, testing now
  - Supports the ASO Accelerator Readiness Review and commissioning

M&RP Ops - Summary

- M&RP covers NSTX-U, D site, and some RF at C site
- M&RP in progress to support Ops and testing now
- M&RP will provide solid foundation for safe operation to perform commissioning and Recovery KPPs
- M&RP will address some obsolescence and reliability issues
- M&RP will establish appropriate and sustainable processes to support future research operations
- Questions?

NSTX-U RESEARCH UPDATE

S.M. Kaye

NSTX-U Team Meeting

17 Jan. 2019

Updating Publication List for ‘18 & ‘19

- 2018
  - 52 peer-reviewed papers published by NSTX-U researchers
  - 1 additional accepted (not yet published)
  - 15 submitted and in review
- 2019
  - 4 published in print
  - 3 accepted

Please send me input on publications - Omissions, modifications, etc.

Collaborations

- MAST-U collaboration
  - First plasma July 2019
  - Physics ops Sept. 2019 ($I_p \leq 1$ MA, $B_T \leq 0.65$ T)
  - Can still propose experiments for first campaign (but has to be within ~ one week)
    - XP form sent around: fill out and send back to Andrew Kirk (cc me)
  - Post-docs being interviewed for PPPL-CCFE post-doc exchange initiative
    - Energetic particles (Podesta)
    - Pedestal stability (Diallo and Ferraro)
    - Microturbulence-driven transport - gyrokinetic modeling (Guttenfelder)
    - Discharge scenario development (Boyer)

Collaborations

- ST40 collaboration (Tokamak Energy Ltd, UK)
  - High TF ST (3 T)
  - Goals developed under business model of demonstrate and upgrade - limited, but beneficial collaboration opportunities
    - Strong support by FES to establish collaborations, TE enthusiastic and desires these
  - Three operational phases
    - P1: Q2 – Q3 2019 (establish startup)
    - P2: Q4 2019 – Q2 2020 (establish control and configurations)
    - P3: Q3 – Q4 2020 and somewhat beyond (most physics in this phase)
  - Have held discussions and videoconferences with TE in a number of topical areas
    - Core (T&C, macrostablity, EP, startup and control, RF modeling for startup, heating & CD, preliminary discussions on transient CHI for P4)
    - Boundary (divertor/SOL physics, wall conditioning)

Collaborations - continuned

- ST40 collaboration (Tokamak Energy Ltd, UK)
  - Need to start detailing workscope and actual proposal to FES
    - Have to ”name names” and commit (envision fractions of FTE)
    - Develop work plan and deliverables for each phase
    - Solidify hardware estimates (divertor, PBLS,…)
  - Plan to call meeting among interested parties within ~1 week to start to flesh out
  - PPPL/ORNL/UC Irvine/Columbia U interest
    - PPPL/ORNL CRADA? Univ. subcontracts?

Research Milestones

- **R(19-1):** Validate transport models for high-beta ST H-mode plasmas and assessing the importance of multi-scale effects in NSTX/NSTX-U turbulent transport (W. Guttenfelder)
  - EM transport models (MTM, KBM/EPM) and multi-scale effects
  - Validate ion-scale/electron scale nonlinear L and H-mode sims
  - Consider reduced models (MMM, TGLF)
  - Validate CGYRO wrt GYRO
- Will call meeting within 1 – 2 weeks to discuss

Research Milestones

- **R(19-2):** Develop optimized ramp-up scenarios in spherical tokamaks (D. Battaglia)
  - Multi-machine effort, including KSTAR, MAST-U
  - Some of work in conjunction with I&T efforts
  - Develop more physics-model based control algorithms within TOKSYS framework (simple plasma model)
    - Expand into control of fast ion pressure, q, n, T
    - Test robustness against ramp-up transients
  - Integrate TRANSP as plasma proxy
    - Evolution of T, n based on flux-driven or data-based transport model
    - Pedestal confinement study to be done to develop model for predictive simulations

Research Milestones

- **R(19-3):** Validate tearing mode physics for tearing avoidance in high-performance scenarios (J.-K. Park)
  - Multi-machine effort, including KSTAR
  - Integrate existing tearing mode simulation codes with TRANSP
    - Including the reduced model for islands based on MRE coupled to rotation, beam torque and radiative effects to simulate NTM evolutions
    - Including resistive DCON to provide tearing mode index Δ' in toroidal geometry
    - Will validate the TM/NTM models in high performance NSTX(-U) scenarios
    - Will couple DECAF to identify TM/NTM stable trajectories in ITER scenarios
  - Validate predicted tearing mode instabilities in existing devices (KSTAR)
  - Develop and test toroidal inner-layer model beyond GGJ
    - Improve layer models in asymptotic matching codes such as PEST-III and DCON
    - Verify models with full MHD codes such as M3D-C1
  - Will convene meeting within 1 – 2 weeks

Research Milestones

- **R(19-4):** Assess energetic particle transport by sub-TAE instabilities and develop reduced EP transport modeling tools (M. Podesta)
  - Multi-machine effort, including MAST-U
  - Kick model development
    - Completed initial development for NTMs; NF paper submitted
    - Developed procedure for fishbone-induced EP transport, validation ongoing
    - Extended previous work on sawtooth-induced EP redistribution
  - Plans
    - Extend kick model to MAST for fishbone/kink modes
    - Develop reduced parallel version for ORBIT for quick computation of probability matrix
    - Implement internal to TRANSP

Research Activities

- **RA(19-1):** Expand disruption prediction and avoidance capability for tokamaks - DECAF (S. Sabbagh)
  - Disruption event chains and prediction capability expanded by automated MHD event decomposition code, density limit physics model, etc.
  - DECAF database expanded to five tokamaks (NSTX, KSTAR, MAST, DIII-D, TCV) with 10's of thousands of discharges
  - Now provides early disruption forecast on transport time scales
    - Performance: 91.2% true positives, 8.7% false negatives (no warning)
- **RA(19-2):**Assess impact and importance of H species in HHFW-heated NSTX-U full-field plasmas (N. Bertelli)
  - Work completed (NF paper submitted)
  - Considering extending work to take into account non-Maxwellian tails