



U.S. DEPARTMENT OF  
**ENERGY**

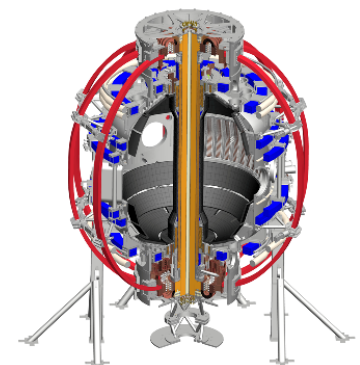
Office of  
Science



## NSTX-U Team Meeting

Masa Ono

September 15, 2016



# NSTX-U Team Meeting Agenda

Time: 1:30 ~ 3:00, September 15 (Friday), 2016

Place: M.B. Gottlieb Auditorium, PPPL

- General Items and Facility Update (45 minutes) M.O.
- Program Update (45 minutes) J.M.

# Safely, Safely, Safely

- With extended outage, please be safe in performing the outage tasks!
- Just a moment of lapse could lead to a serious accident and injury.
- The safe way is the fastest way to get the job done!

Jerry Levine: a video of safety incident at a factory where something went very very wrong in a routine line clean up activity. Humans make mistakes so we need safety tools (including procedures, regulations, and safe practice!) to help us we make less mistakes and in the event of mistake, it will not lead to serious incident.

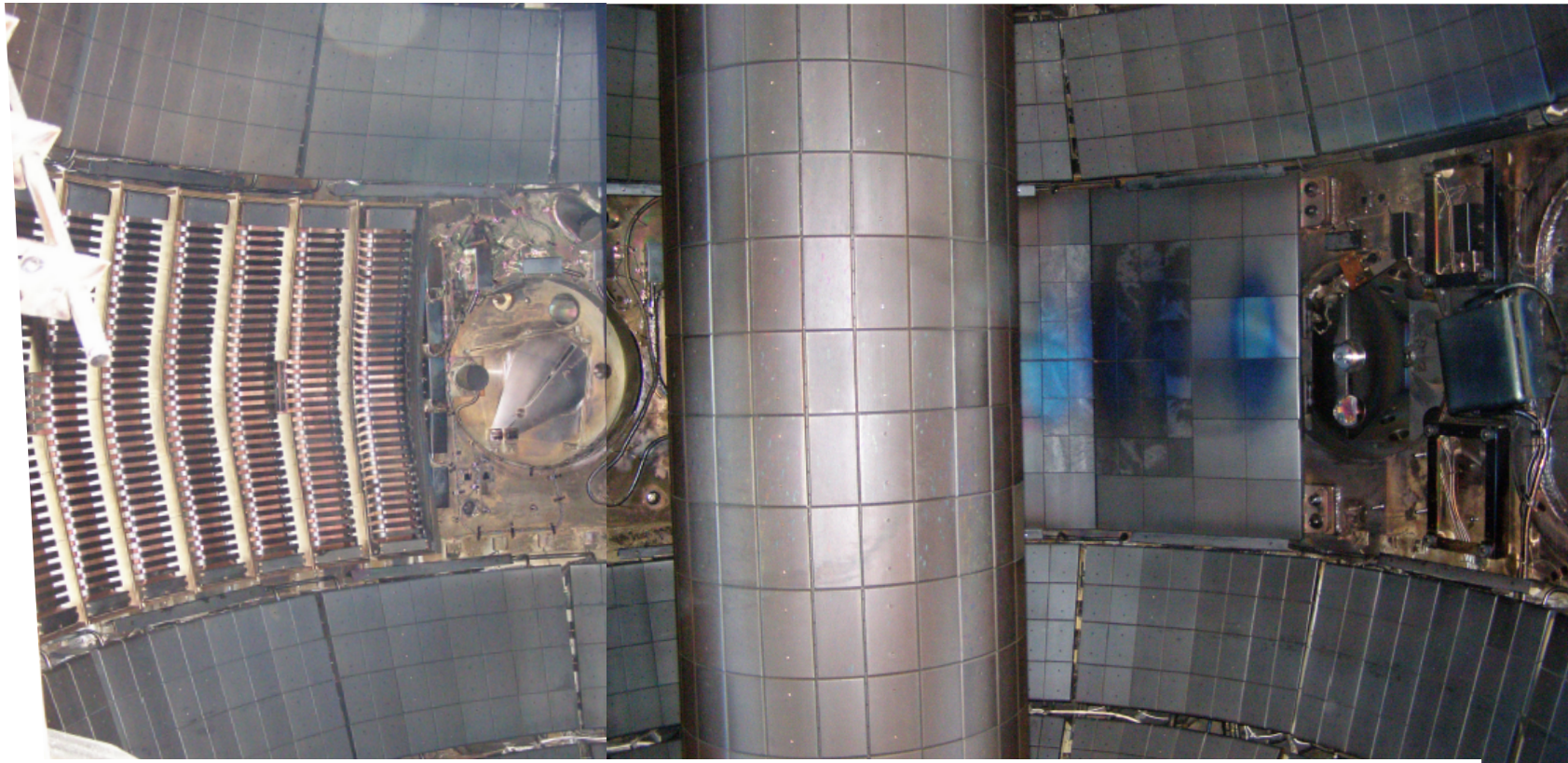
# NSTX-U Update Since Last Team Meeting on July 29

## NSTX-U outage schedule became much clearer

- PF-1AU was removed on August 24, 2016 ahead of schedule.
- PF-1AU forensic team was formed headed by Irv Zatz. The kick-off meeting was held with external participation (GA and MIT) on August 29.
- PF-1AU was sent for x-ray radiography to look for internal short location. The radiography is complete and the coil is now back to the lab. for further.
- New PF-1AU redesign and fabrication activities started. Four design improvements identified. Replacing PF-1AL became a logical option.
- With PF-1AU removed, on August 25, severe damage was reported in the copper cooling tube in the upper center-stack divertor wall. Damage was likely to be caused by induced currents by OH. The copper tube must be replaced with ss tube (as in NSTX). This requires Center-Stack removal.
- After consultation with FES and the laboratory management, it was decided to take out the CS and repair the cooling tubes and also replace both PF-1AU and PF-1AL. Will also enable us to examine every components.
- While the repair will take much of FY 2017, a proper repair would enable us to reach full parameter operation of NSTX-U in a shortest time.



# Initial Look of NSTX-U Vacuum Vessel Interior Taken on September 14 by Mark Cropper

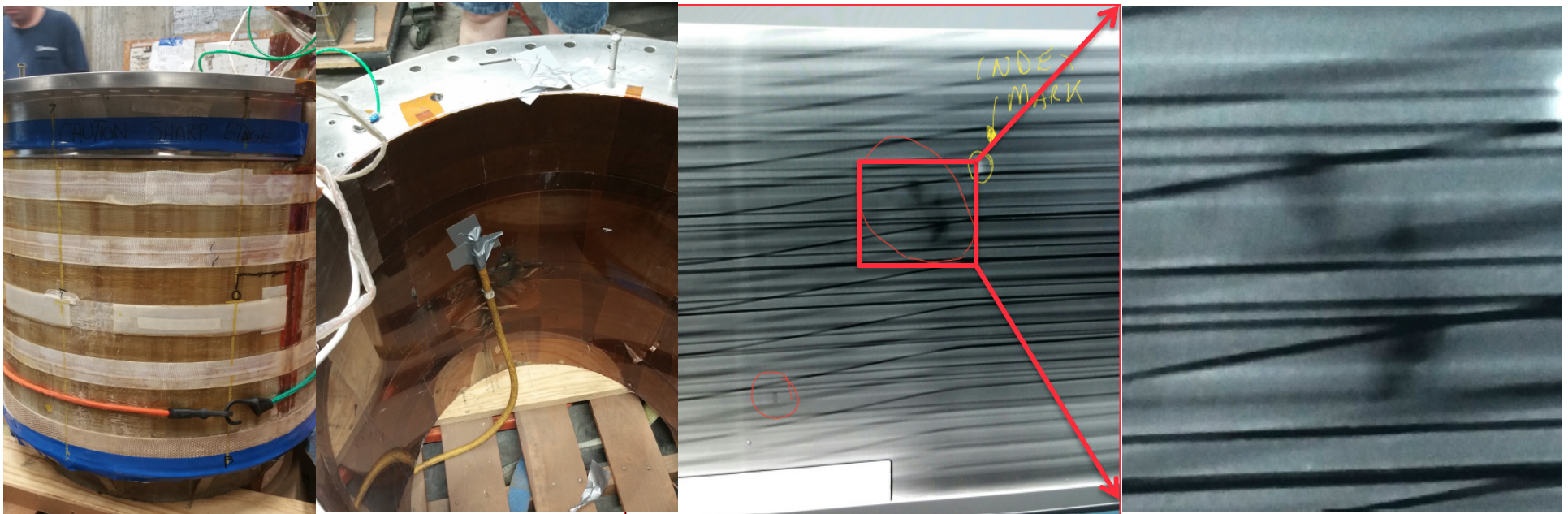


The VV interior appears to be in a good condition

# PF-1AU coil forensics

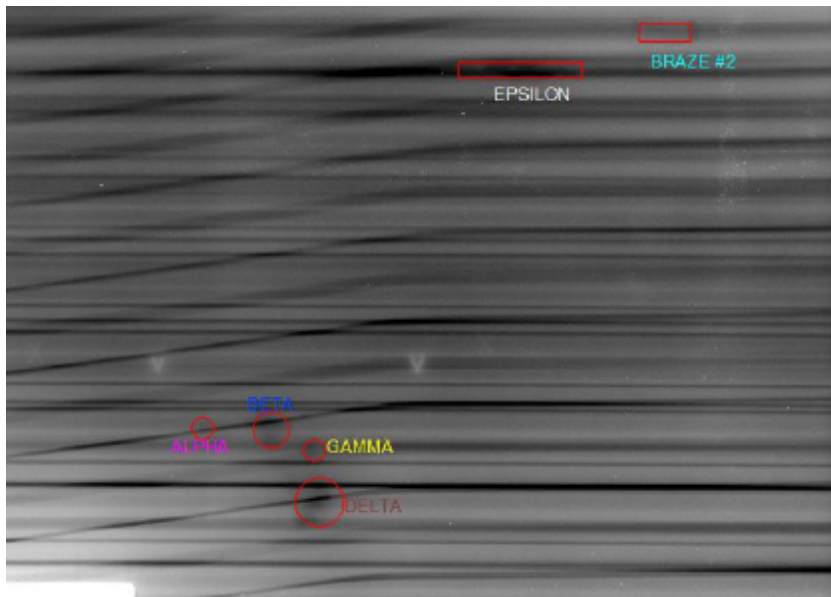
(Thanks to Joe Petrella and Irv Zatz)

- Preliminary images showed potential copper voids near the “joggle” transition.
- Additional coil radiography for the void area completed last week and the coil is returned to the lab this week for dissection and borescope inspections
- Second peer review of PF1AU forensic analysis planned this week to review the radiography results and review the dissection and borescope inspection plan.



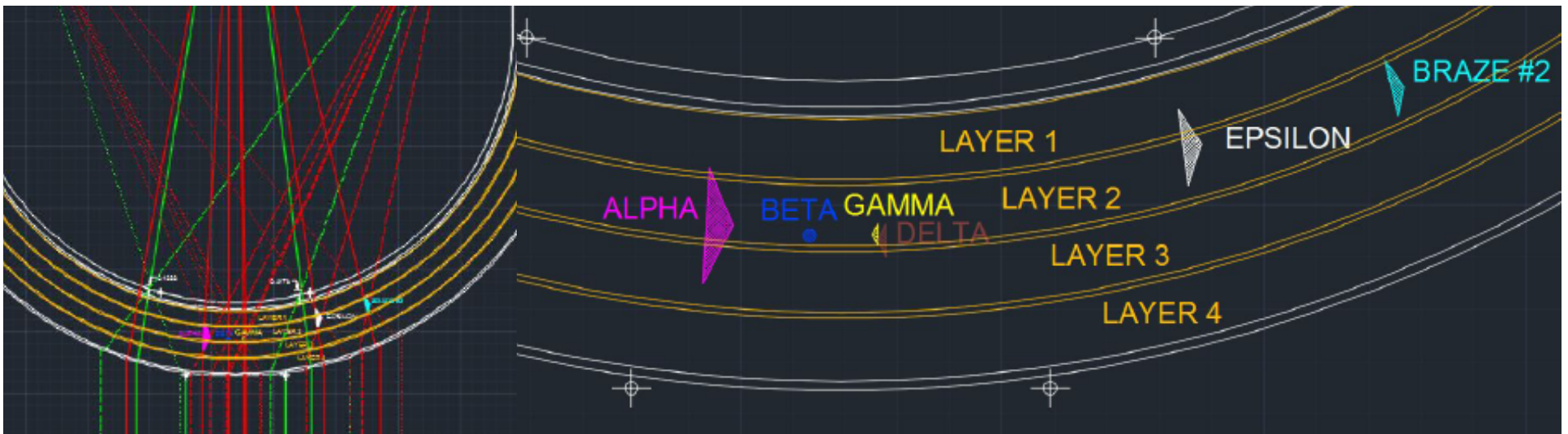


# Additional Radiography Provided Radial Localization Information Performed



The Alpha, Beta, Gamma, and Delta areas are proximal to Layer 2: Rows 8 and 9.

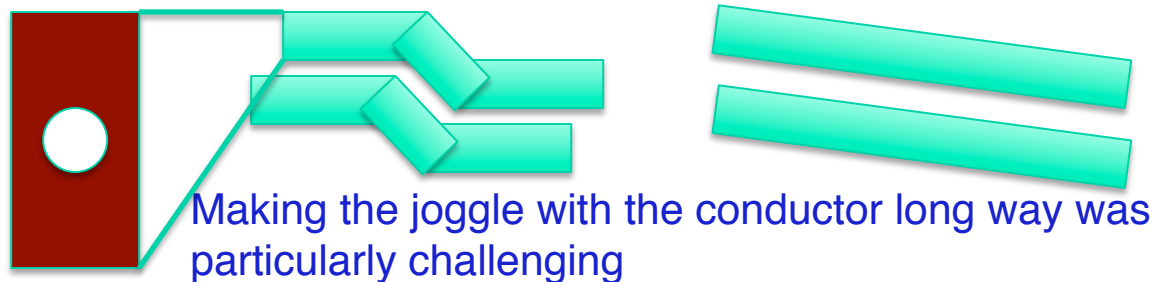
- The Epsilon area is proximal to Layer 2: Row 3
- Braze Joint #1 is proximal to Layer 1: Row 15
- Braze Joint #2 is proximal to Layer 2: Row 3
- Braze Joint #3 is proximal to Layer 3: Row 13
- Braze Joint #4 is proximal to Row 6 (9/1/16 imaging)



# PF-1AU coil fabrication status

## (Thanks to the PF-1AU Coil Team)

- 2 upper mandrels being fabricated at vendor.
- 1 lower mandrel being fabricated at PPPL. We can decide to fabricate another lower mandrel.
- A partial order (enough for three coils) for Cu conductor with sufficient length placed. An order with another vendor being placed enough for the another three coils.
- A coil shop is being set up at PPPL where the NSTX-U TF and OH coils were fabricated.
- Four design improvements were identified :
  - Eliminate joggles (ease winding and reduce stresses during cool down )
  - Double insulation thickness (increase insulation margin)
  - Use softer copper and control hardness (ease winding)
  - Use continuous conductor, eliminate in-line joints (avoid potential leaks)



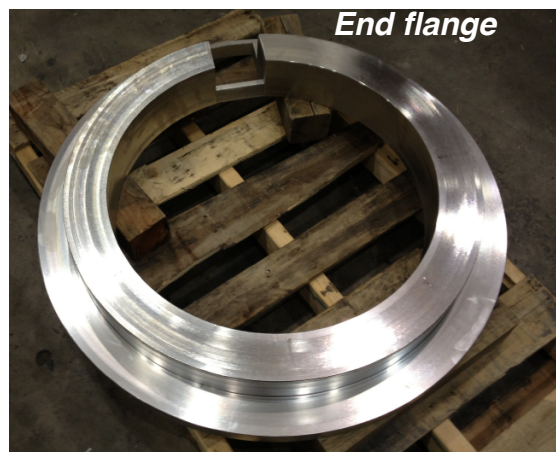
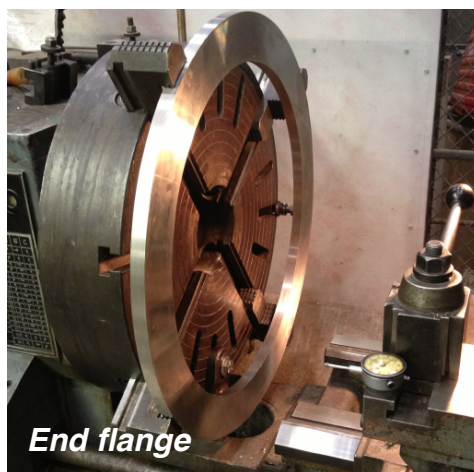


# PF-1AL coil shop is being set up and the mandrel fabrication is on-going at PPPL

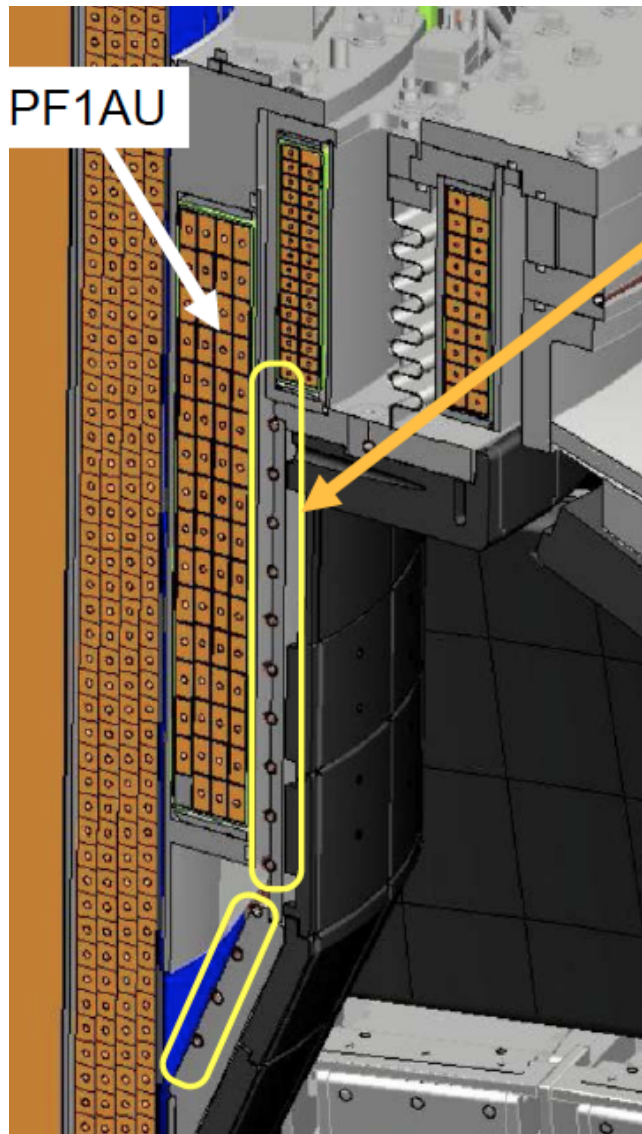
## Coil shop preparation



## Mandrel fabrication



# NSTX-U CS Divertor Cooling Tube Issues



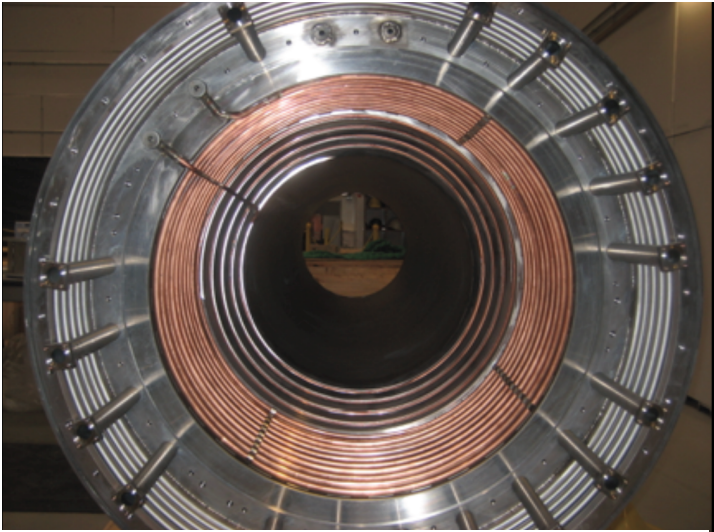
- NSTX-U has spiral cooling tubes on airside ID of center-stack casing ends to cool divertor region.
- Another set of vacuum side cooling tubes on the horizontal CS flanges (horizontal inboard divertor).
- Installed to cool PFCs between pulses to avoid thermal ratcheting over multiple high-power shots.
  - This cooling capability has not been needed or used yet but we need it in the future.
- Similar tubing on bottom of CS casing near PF1AL coil.



# Divertor CS Cooling Tubes Severely Damaged

## Induced currents in copper tube likely cause

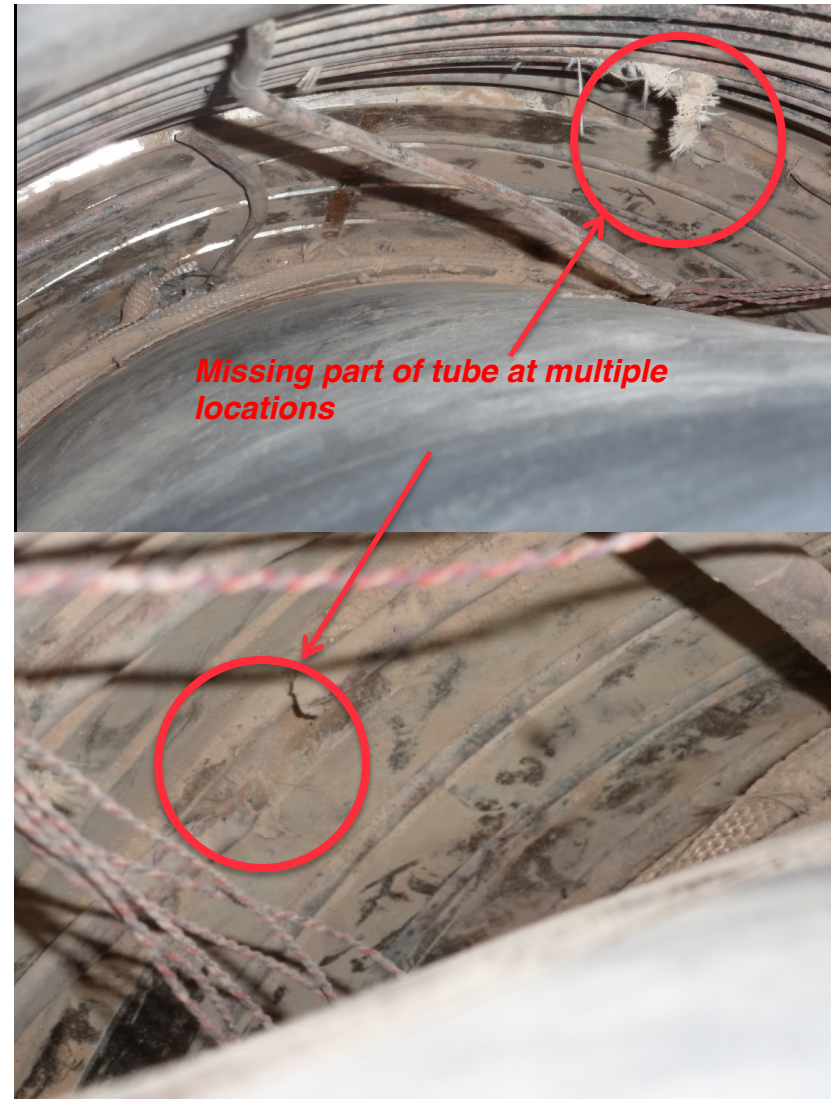
Divertor CS cooling tube before installation



Divertor CS SS cooling tubes in NSTX, look pristine after 10 years



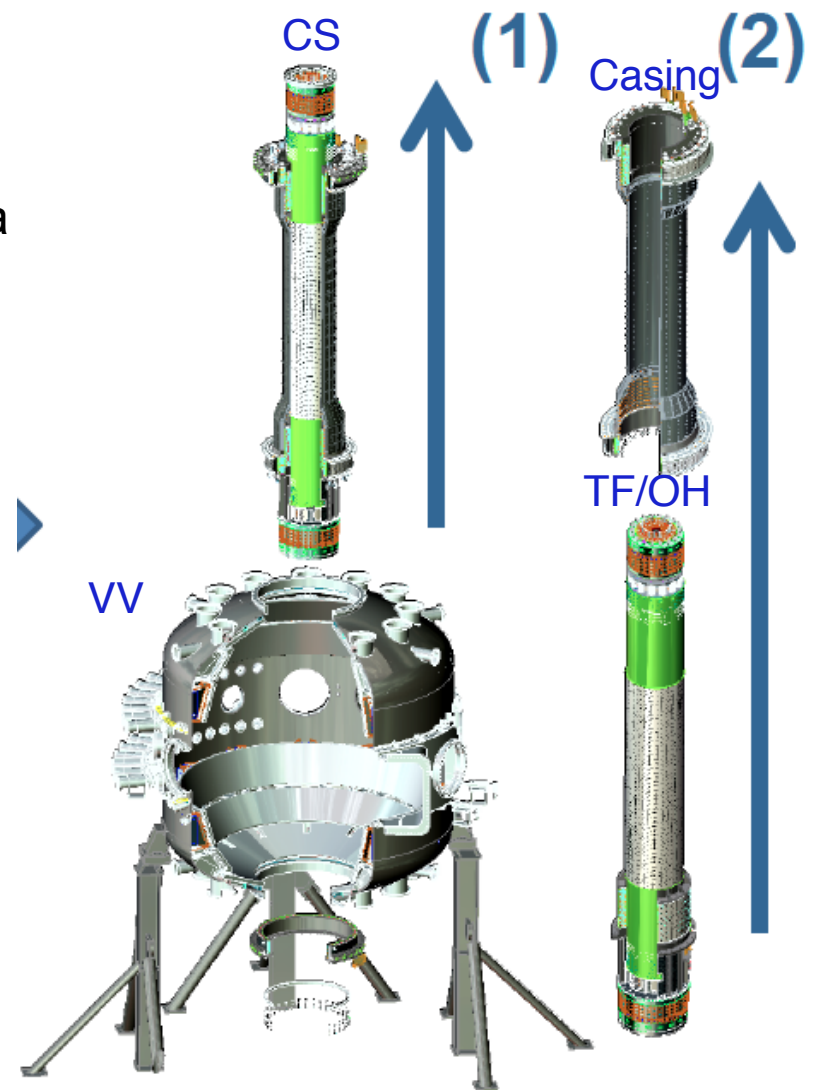
Severe damage in divertor CS cooling tubes



# Recent findings motivate decision to remove center-stack

## With cooling tubing replacement, the critical path is now defined

- Due to up-down symmetry, we expect similar cooling tube damage in the lower divertor area. Lower cooling tube does not hold any air pressure.
- With damaged cooling tubes, the divertor area cannot be cooled between long-pulse higher power NSTX-U operations.
- Copper tubes if left in CS maybe degraded further. They should be replaced with SS tubes at this time.
- Tubes can be only accessed by:
  1. Removing CS from VV.
  2. Pulling CS casing from OH-TF bundle
- The damaged cooling The cooling tubing installation schedule is similar to the new PF-1AL and -U installation schedule so they can be performed in parallel with no significant schedule hit.

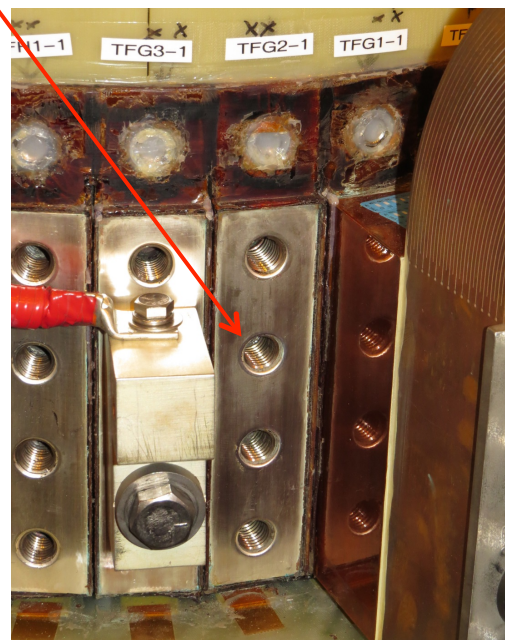
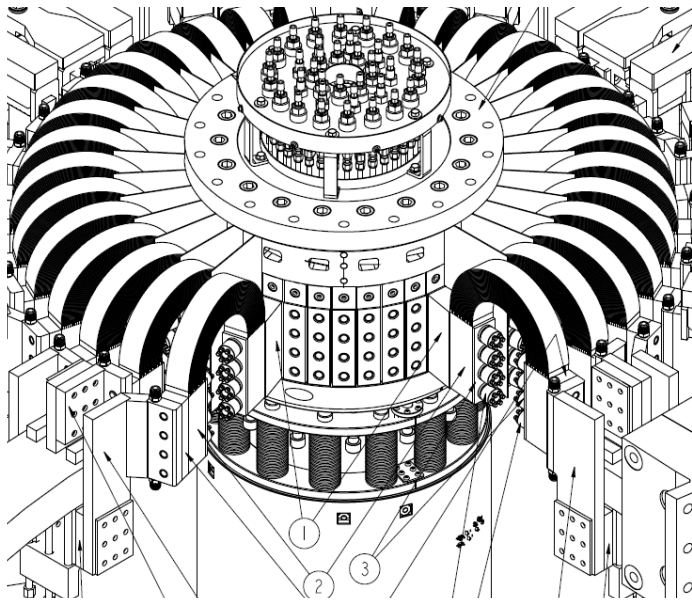




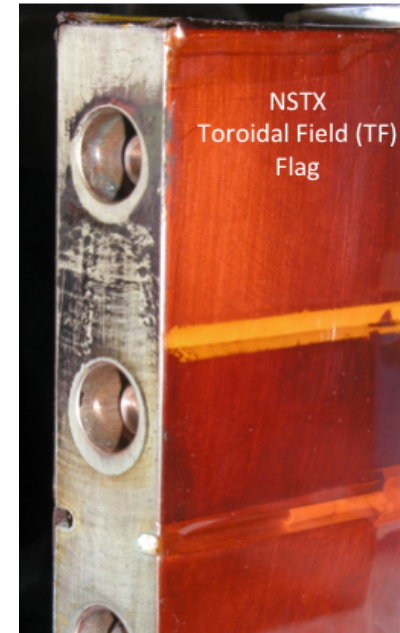
# Good news from the joint measurement and examination

## Thanks to Hans Schneider and the team!

- In FY 2016, NSTX-U operated mostly at  $B_T \sim 6.5$  kG up to  $\sim 2.2$  s flat top for well over 1000 shots.
- The TF joint measurement were performed as the TF joints were disassembled.
- All measured joints are nominal based on design, installation procedure, modeling data, bench measurements, and in-situ measurements.
- Joint surfaces look very good.

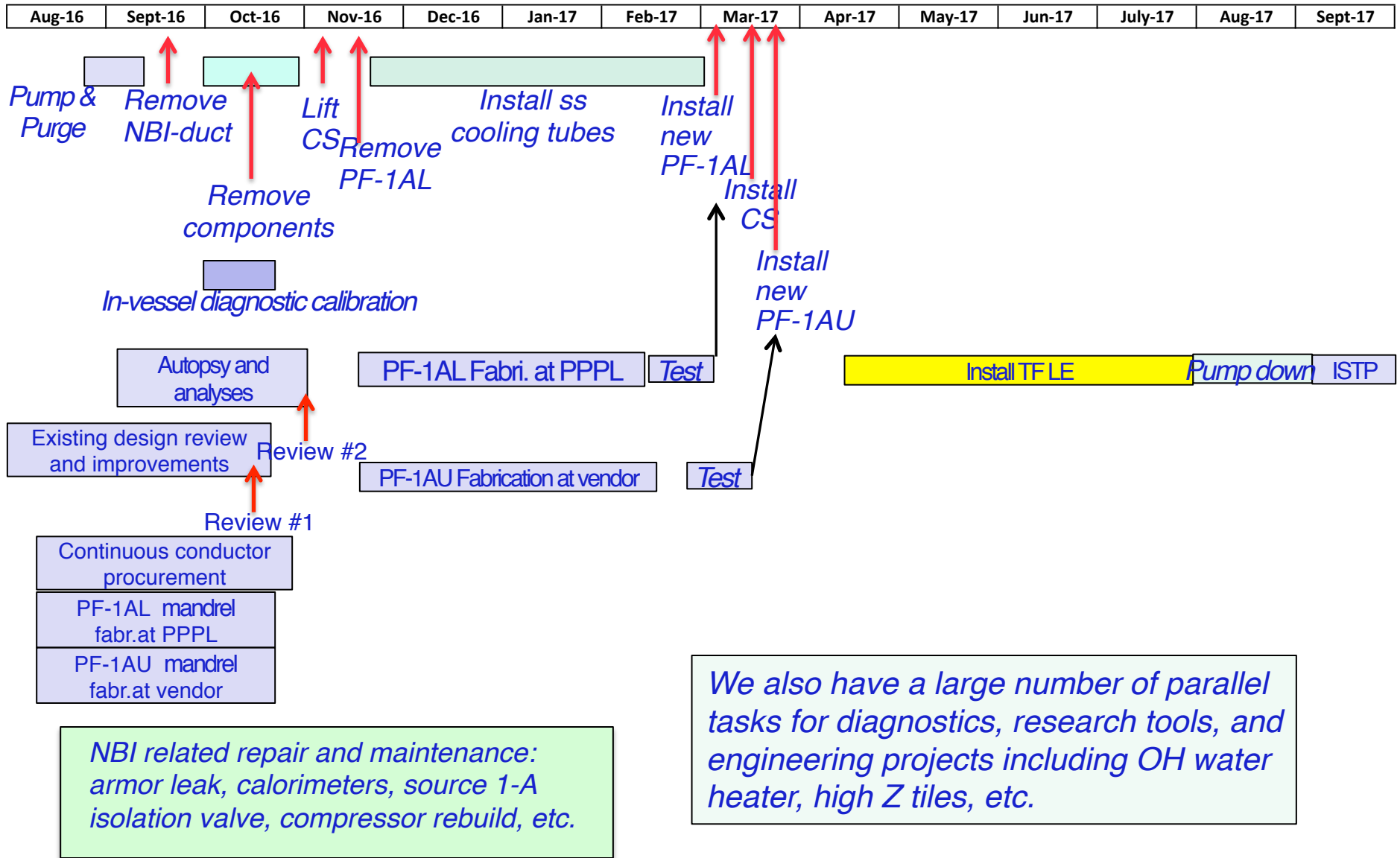


*Joint surfaces degraded in NSTX due to lift-off*



# Most Recent Draft Schedule

Cooling tube replacement can be done in parallel with PF-1A fabrication



# NSTX-U device performance progression plan

## Will utilize this outage to prepare for full capability

- FY 2016: Limit forces to ½ way between NSTX and NSTX-U, and ½ of the design-point heating of any coil
  - Operated at  $B_T \sim 0.65T$  for  $\sim 2$  sec for over 1000 shots. All joints came out clean and nominal.
- FY 2017 goal: Implement repair/enhancements needed to achieve full capability
  - Replace TF joint lead extension pieces
  - Replace poloidal CHERs passive plates and enhance passive plates as needed
  - PF-1C to be available and in-board divertor tiles will be thermally insulated for bake-out
  - Install and test instrumentation to monitor coils and passive plates to full capability
- FY 2018 goal: Full capability

Parameter	NSTX (Max.)	FY 2016 NSTX-U Operations <b>Achieved</b>	FY 2017 NSTX-U Preparation for	Year 3 NSTX-U Operations	NSTX-U Ultimate Goal
$I_p$ [MA]	1.2	<b>~1.1</b>	2.0	2.0	2.0
$B_T$ [T]	0.55	<b>~0.65</b>	1.0	1.0	1.0
Allowed TF $I^2t$ [MA <sup>2</sup> s]	7.3	<b>80</b>	160	160	160

# Five Year Facility Enhancement Plan (green – ongoing)

*Incremental enables 5 year plan enhancements including DCP, NCC, ECH*

