



NSTX-U Recovery Project Review, Status and Plans

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Presented at FESAC

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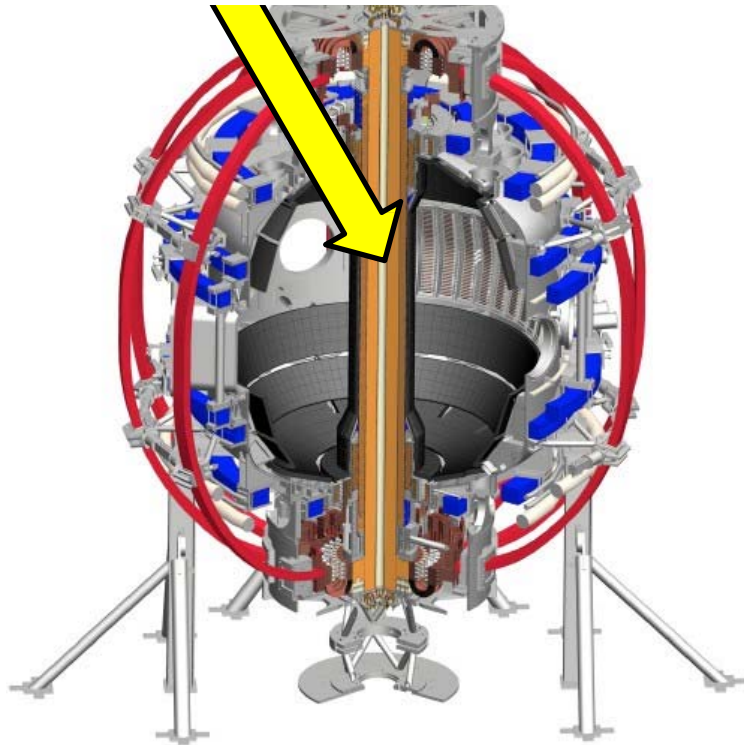


Outline

- Background
- Machine Disassembly
- Extent of Condition Review
- Plans

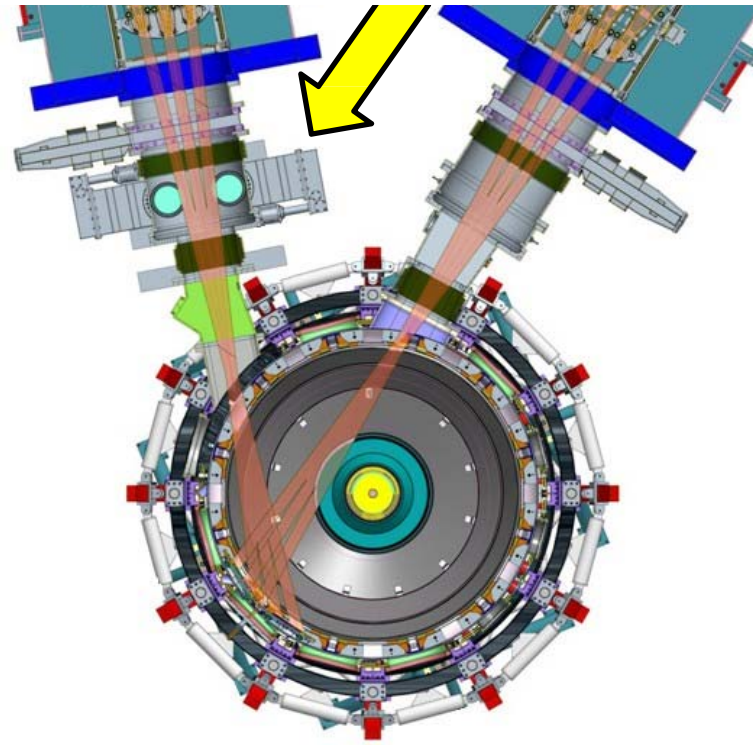
NSTX-U will Access New Physics with 2 Major New Tools:

1. New Central Magnet



Higher T, low v^* from low to high β
→ Unique regime, study new transport and stability physics

2. Tangential 2nd Neutral Beam



Full non-inductive current drive
→ Not obtained in high- β_T low- v^* ST essential for any future steady-state ST

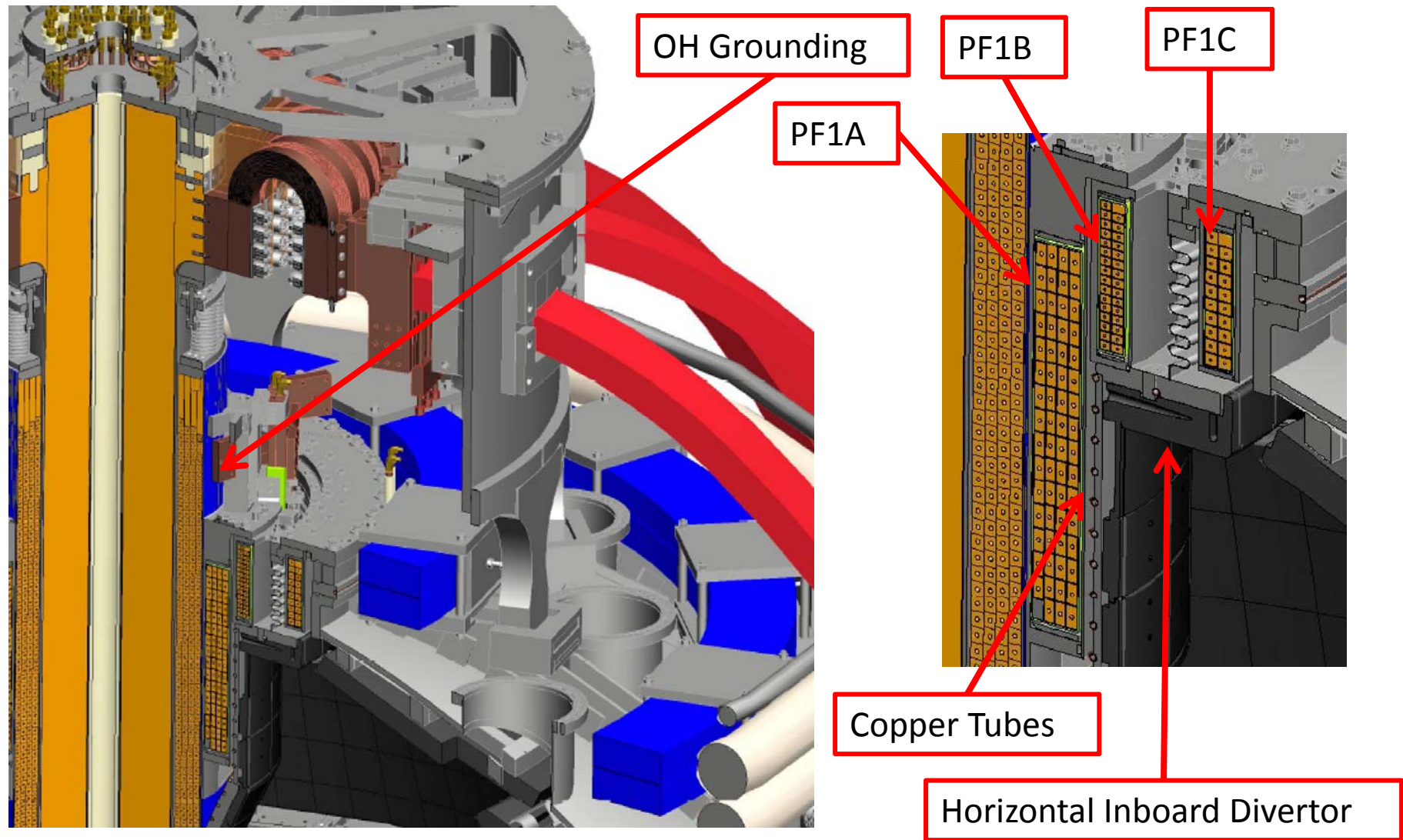
NSTX-U Science and Engineering Accomplishments

- Achieved H-mode on 8th day of 10 weeks of operation
- Surpassed magnetic field and pulse-duration of NSTX
- Identified and corrected dominant error fields
- Matched best NSTX H-mode performance at ~1MA
- Commissioned all magnetic and kinetic profile diagnostics
- Initiated turbulent transport studies using BES in L-mode
- New 2nd NBI suppresses Global Alfvén Eigenmodes (GAE)
- Evidence of hollow fast-ion profiles from off-axis NBI
- Implemented techniques for controlled plasma shut down, disruption detection, commissioned new tools for mitigation
- **Run ended prematurely due to divertor field coil failure**

Prior Issues

- NSTX-U has experienced a series of problems
 - OH “Arc Flash” incident – April 2015
 - Unable to bake inboard divertor PFCs at 350C – Sept 2015
 - PF1A Upper Bus Bar incident – May 2016
 - Center Stack Passive Structure Issues– May 2016
 - Failure of PF1A Upper coil – June 2016
- Each event can be attributed to a variety of Technical and Procedural Causes
- PPPL is conducting a broad investigation
 - Extent of Condition
 - Extent of Cause

Region Where Problems Have Occurred



Removal of PF1A Upper Coil

PF1A
Upper
Coil

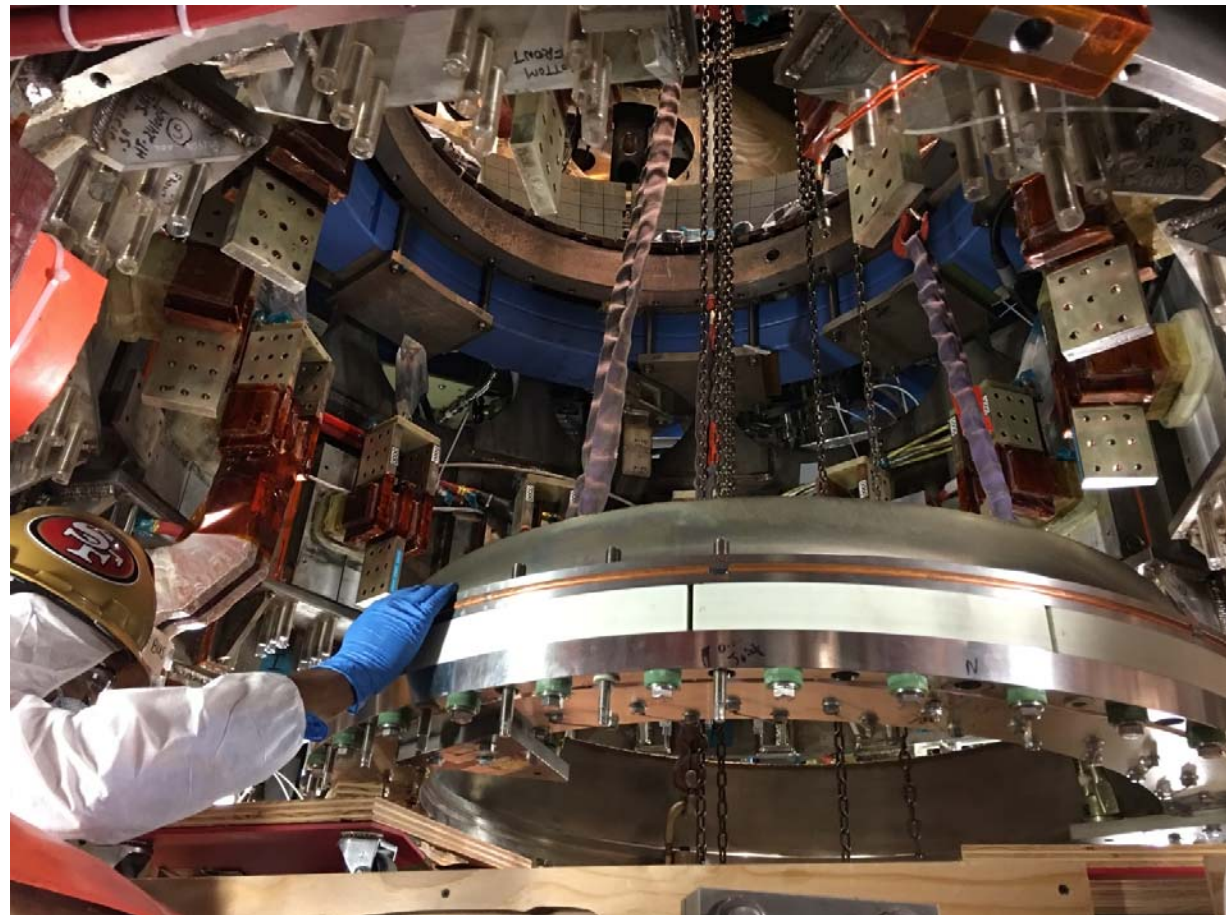


Centerstack Removed then Casing Separated from TF bundle



Lower Ceramic Break Removed

Machine disassembly completed enabling detailed inspection and repair



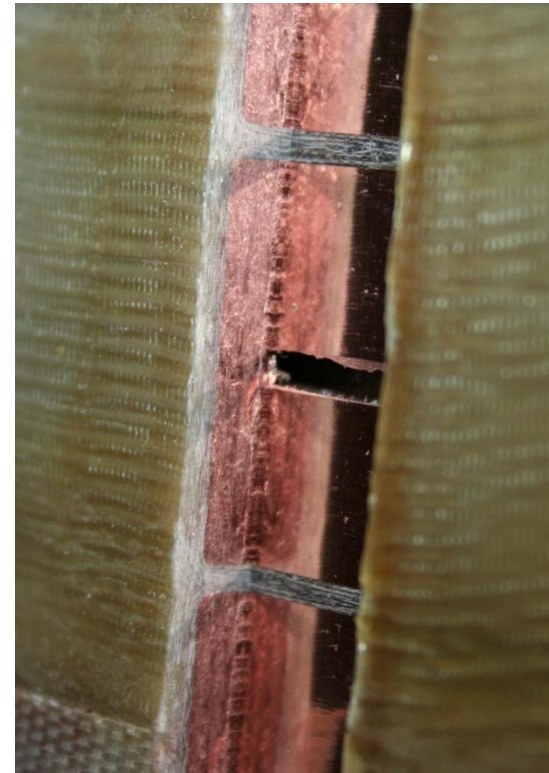
PF1AU Forensic Analysis Overview

- Identify locations with issues
- Section the coil in ways that do not destroy regions of interest
- Do visual, electrical, pressure, and vacuum testing on the sections.
- Followed by inspection of the turn-to-turn fault

Coil Was Sectioned Using a Milling Machine



Section Planes Chosen to Avoid
Any Regions of Interest



Detail of an Initial Cut

A Battery of Tests Was Performed on the Three Sections

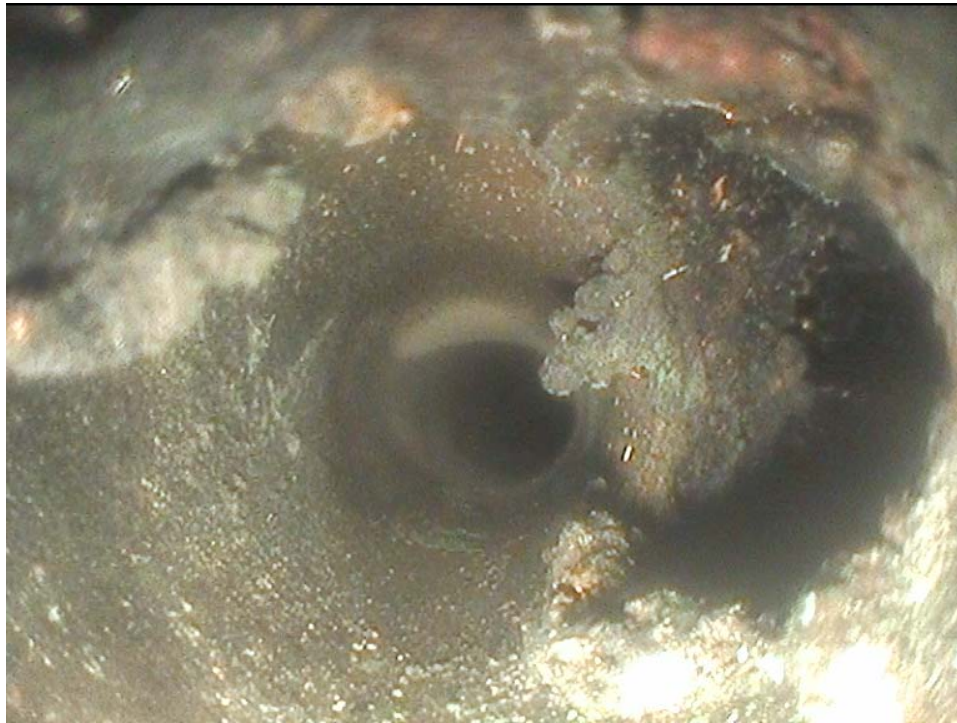
Electrical Tests



Also vacuum & pressure testing of individual channels

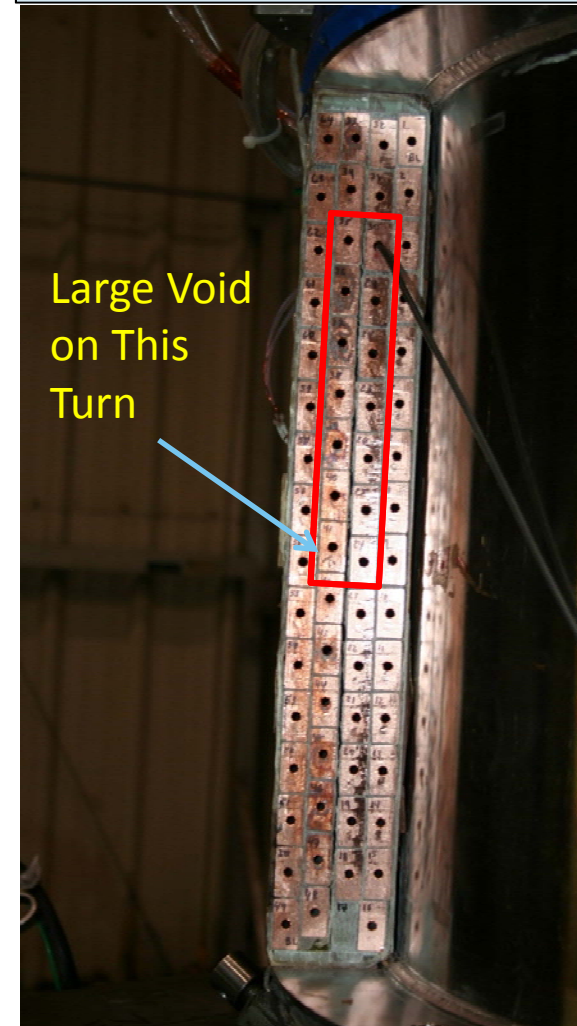
Videoscope Shows Breach in Cooling Channel

Section A-B, Layer 3, Row 9 Void Anomaly

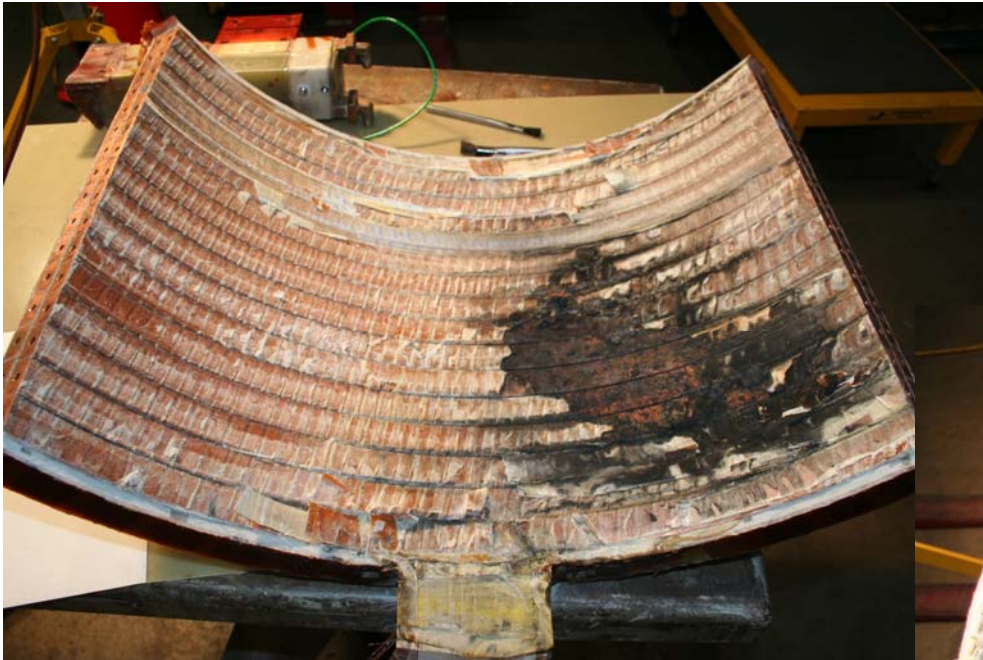


- Dry glass found – not impregnated

Region of Shorted Turns



Coil Section with Fault Was Split Between Layers



Concave Side

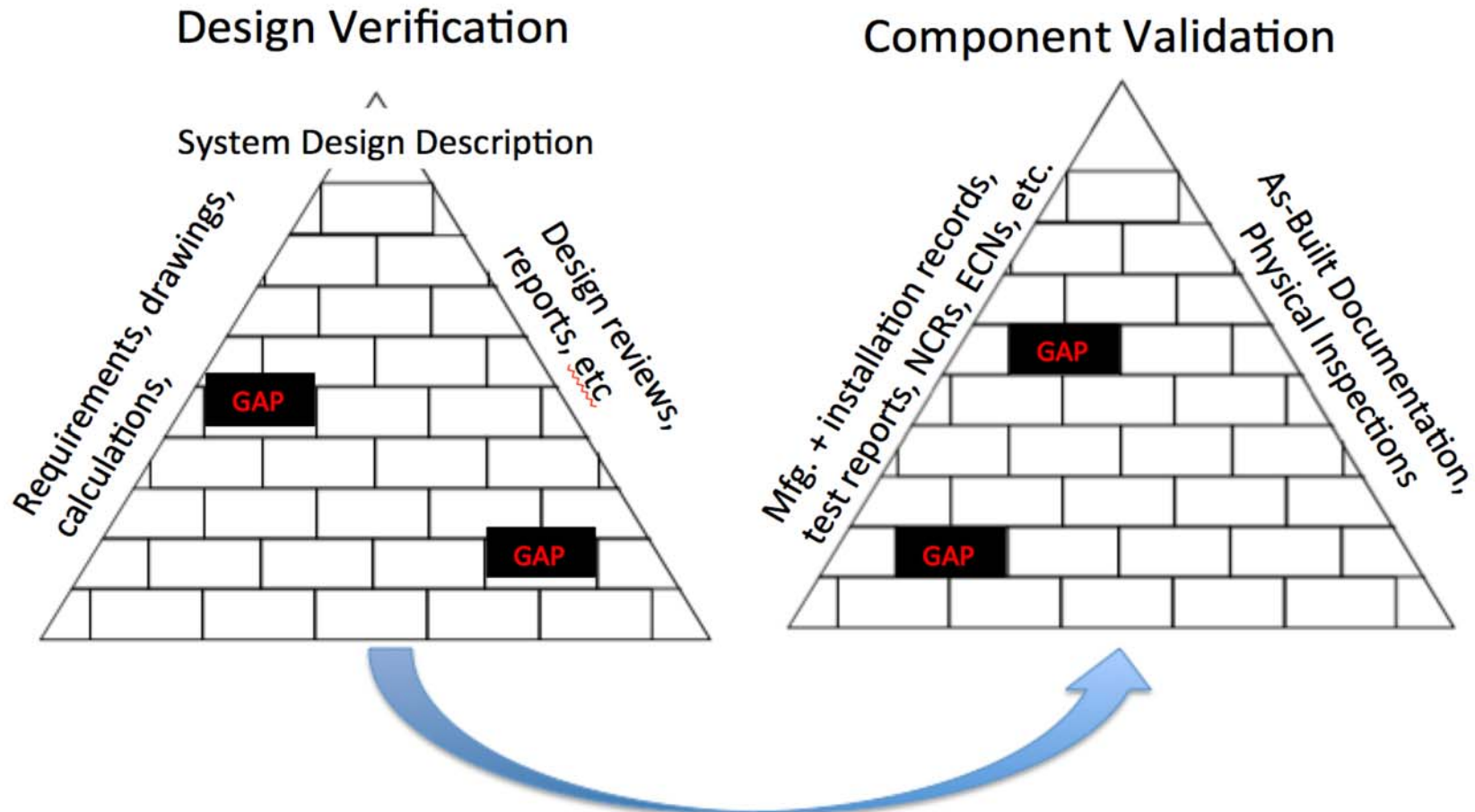


Convex Side

Failure of PF1A Upper Coil

- Technical Cause
 - Turn-to-Turn fault, most likely due to poor Vacuum Pressure Impregnation (VPI) plus other quality factors leading to turn-to-turn insulation breakdown
- Procedural Issues
 - Manufacturability of coil design
 - Inadequate QA and QC surveillance of manufacturing process at factory
- On-going investigations currently under way:
 - Reviewing VPI with experts in the field
 - Checking integrity of the conductor

Design Verification & Validation Review System Design Description (SDD) is Key Element



- DVVR looks for potential gaps in design basis or as-built configuration
- Corrective Action Plan (CAP), derived from the DVVRs, determines path forward



Design Verification and Validation Reviews Have Started

<u>System</u>	<u>Date</u>
Central I&C	18-Jan
Integrated Project Design	24-Jan
Heating Systems:	
HHFW	30-Jan
NBI	31-Jan
Magnets	7-Feb
VV & Int. Hdwe.	14-Feb
Cooling	week of 20-Feb
Power Systems	week of 27-Feb
Test Cell	week of 13-Mar
Vacuum & Fueling	week of 20-Mar
Diagnostics	week of 27-Mar
Bakeout	week of 3-Apr
Realtime Control & Protection	week of 10-Apr

- Dates are preliminary and dependent on reviewer availability



Develop Corrective Action Plan Based on the Issues Identified in DVVR for the Components

	Use	Maintain or Modernize	Rebuild	Test/ Analyze	Redesign
Design Acceptable	Y	Y	Y	Y	N
Fit for Function	Y	Y	N	?	-
Remaining Life	Y	N	-	-	-

- The Corrective Action Plan will be reviewed by the external Extent of Condition Committee.



Extent of Condition Review Committee to Review Corrective Action Plan

Tom Todd (chair)	CCFE (retired)
Heinrich Boenig	LANL (retired)
Richard Callis	GA (retired)
Frank Casella	US ITER
Ursel Fantz	IPP
Rem Haange	ITER Deputy Director General (retired)
Michel Huguet	Head of Naka site, ITER-EDA (retired)
Dave Humphreys	GA
B. La Bombard	MIT
Arnie Kellman	GA
Graeme Murdoch	US ITER
Ron Parker	MIT (retired)
John Smith	GA
D. Youchinson	ORNL



First Extent of Condition Review in March

- First Extent of Condition Review will occur during the week of March 6th, depending on reviewer availability
 - Include the results from the magnet and vacuum vessel and internal hardware DVVRs as well as Integrated Project Design, Central I&C and Heating Systems.
- Interim report will be submitted to FES end of March
- Second Extent of Condition Review upon completion of the DVVRs and Corrective Action Plan



Redesign of Failed Coil is Underway

- The design of the PF1-A coil is nearing completion.
 - PDR within the next two months
 - FDR within the next three months
- Evaluating different options for coil manufacturing:
 - PPPL
 - Industry
 - Other national laboratory
- Evaluating whether other coils should also be rebuilt.



NSTX-U Recovery is Moving Forward

- To ensure reliable and predictable operation in the future:
 - Addressing the issues comprehensively
 - Taking a deep dive into all systems
 - Applying a rigorous systems engineering approach
- Developing the corrective action plan to define the scope of the recovery project is the immediate priority.
 - Interim report March 31
 - Final report September 30
- Plan will enable reliable and predictable operations!