

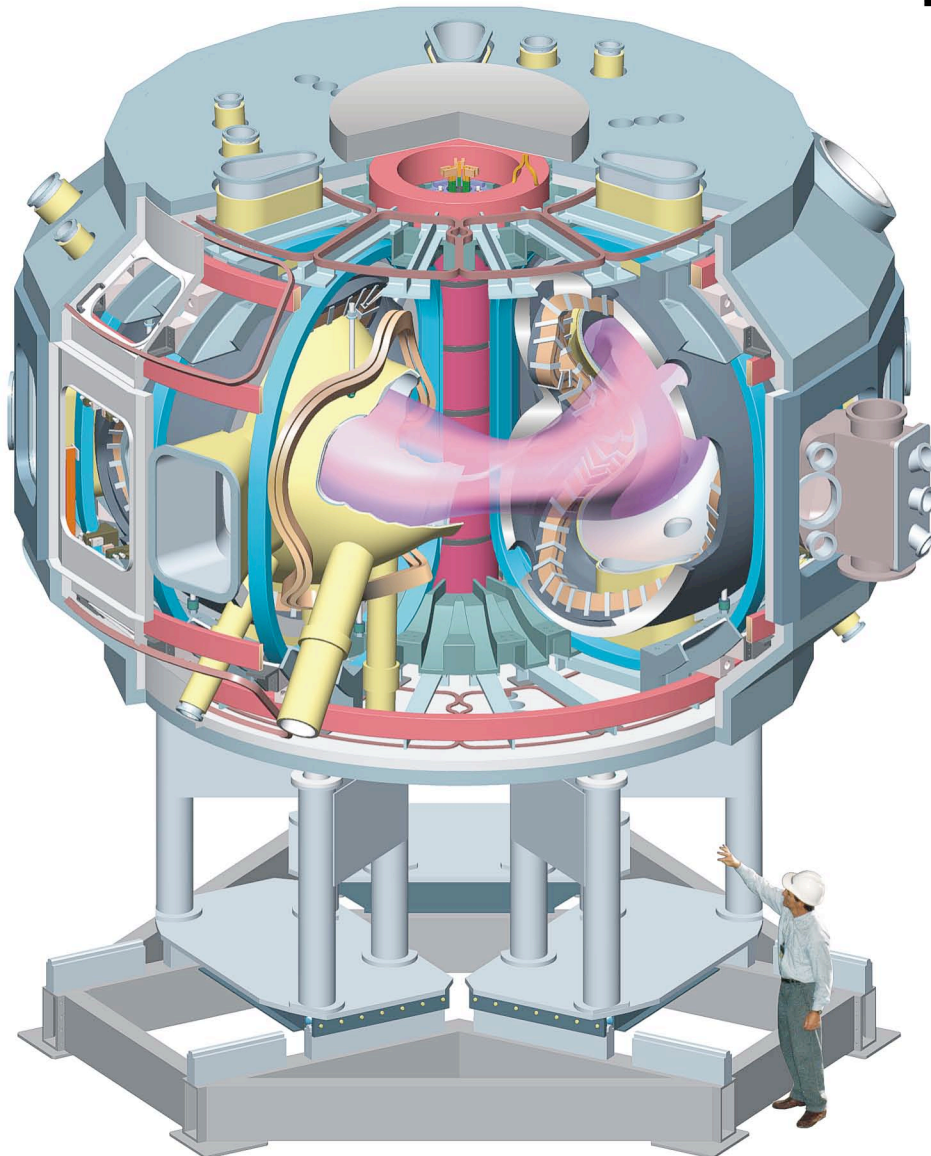
Progress in NCSX Construction

Wayne Reiersen
on behalf of the NCSX Team

SOFE07

- Introduction to NCSX
- Procurement of major components
- Modular coil fabrication
- Assembly of vacuum vessel mounted components
- Assembly of modular coils
- Assembly sequence for field period and final assembly

NCSX is a compact stellarator being constructed at PPPL



- 3 period, quasi-axisymmetric stellarator
- Major radius: 1.4 m
- Magnetic field strength
 - @ 0.2 s pulse: 2.0 T
 - @ 1.7 s pulse: 1.2 T
- Coils cooled to LN2 temperature
- Vacuum vessel bakeable to 350 C

Field error requirements

- Field error requirements have driven the NCSX design and assembly
- The overarching requirement is that toroidal flux in island regions shall not exceed 10% of the toroidal flux in the plasma
- Derived required include...
 - Low permeability materials used throughout
 - Insulating breaks added to break up eddy currents
 - Trim coils to suppress islands
 - Tight tolerances on coil winding centers: +/- 60 mils (1.5mm) on modular coils, +/- 120 mils (3mm) on all other coils

NCSX has progressed from design and procurement to construction

- The design and procurement of the most difficult stellarator core components (VV subassemblies and modular coil winding forms) have been completed

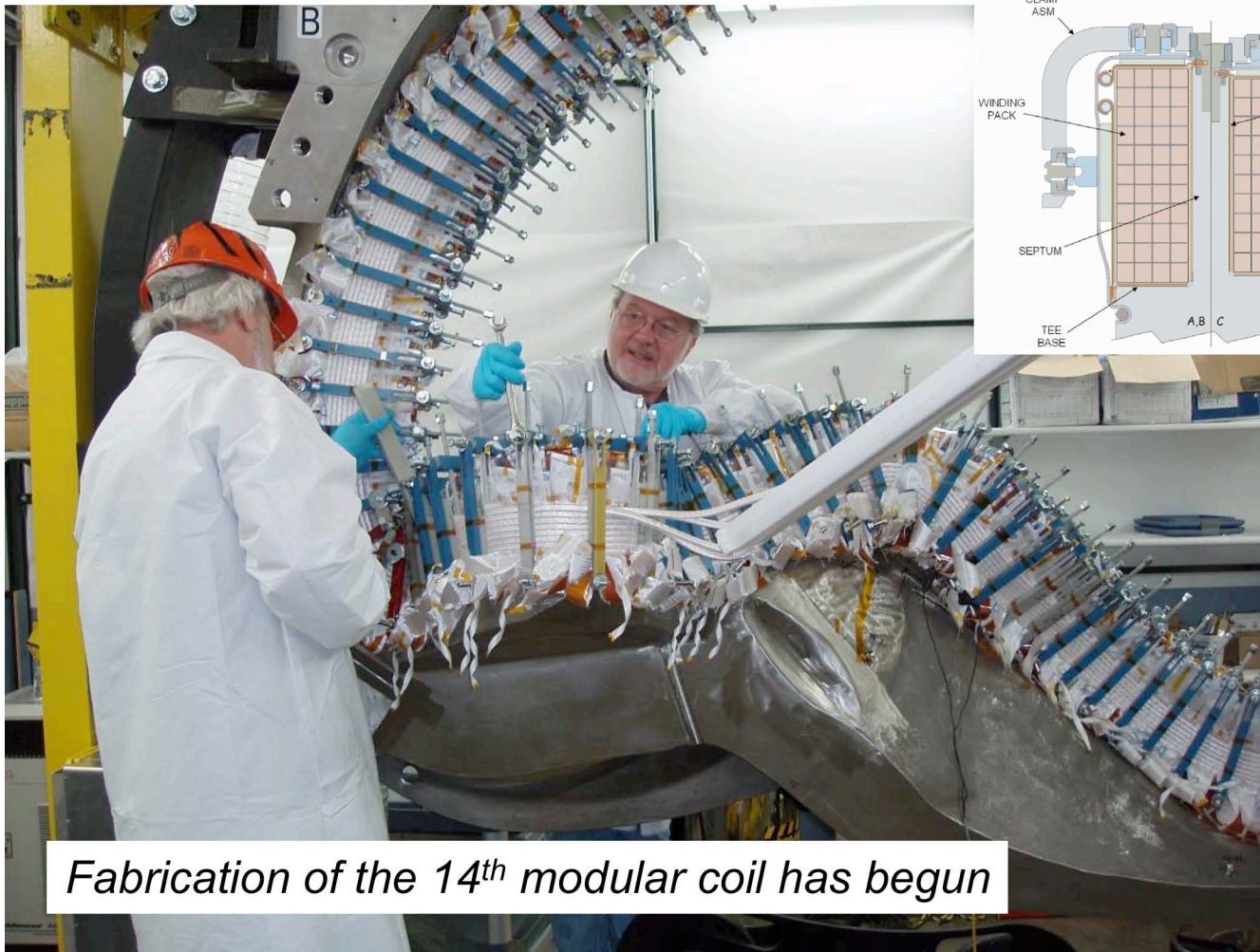


All 3 VVSAs have been delivered



All 18 MCWFs have been delivered

Winding operations have been optimized and are progressing well

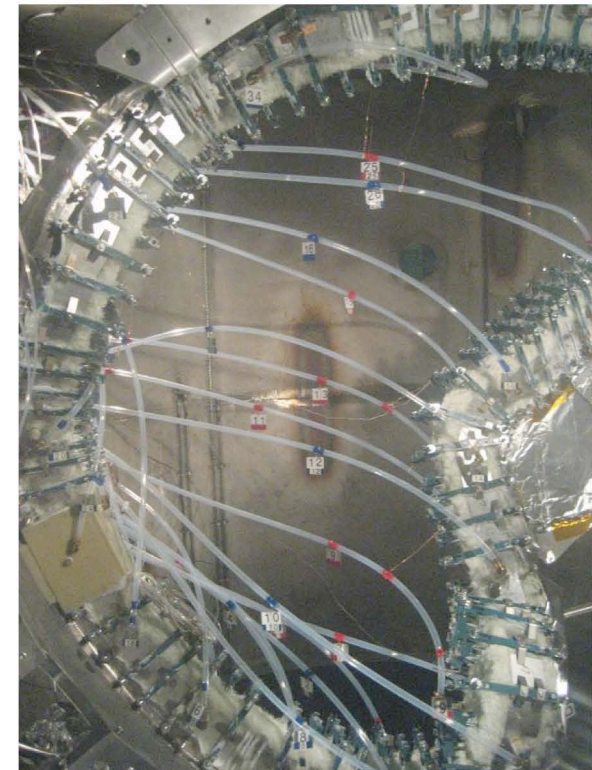


Fabrication of the 14th modular coil has begun

12 of 18 modular coils have been epoxy impregnated



Epoxy manifold



Epoxy feeds to coil in autoclave

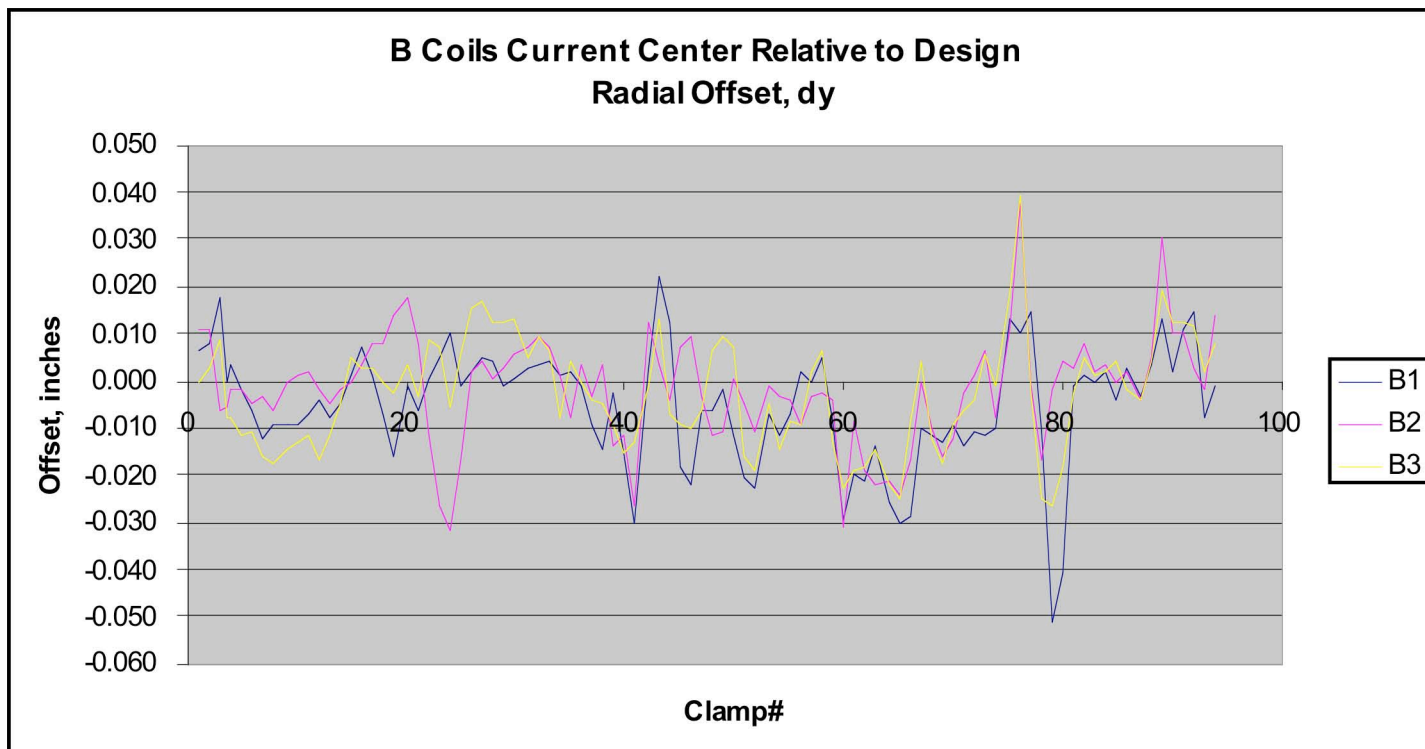
Coil tolerances are being met

- MC fabrication allocated +/- 20mils (0.5mm) of the overall +/- 60mils (1.5mm) tolerance budget
- Current center is controlled by adjusting the clamp positions during winding
- Goal of +/- 20 mils (0.5mm) achieved over most of the coils but not everywhere
- Coils wound to match current center achieved on prior wound coils to minimize symmetry breaking field errors



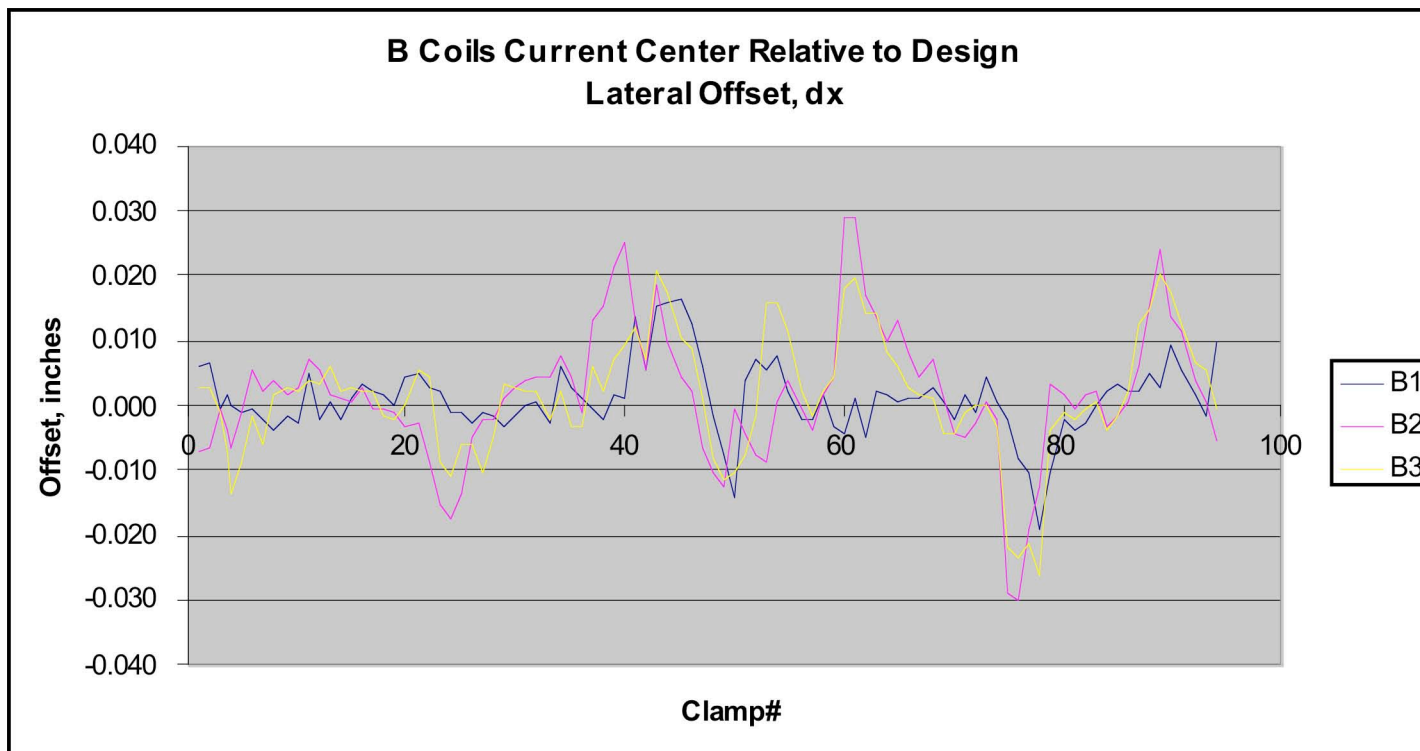
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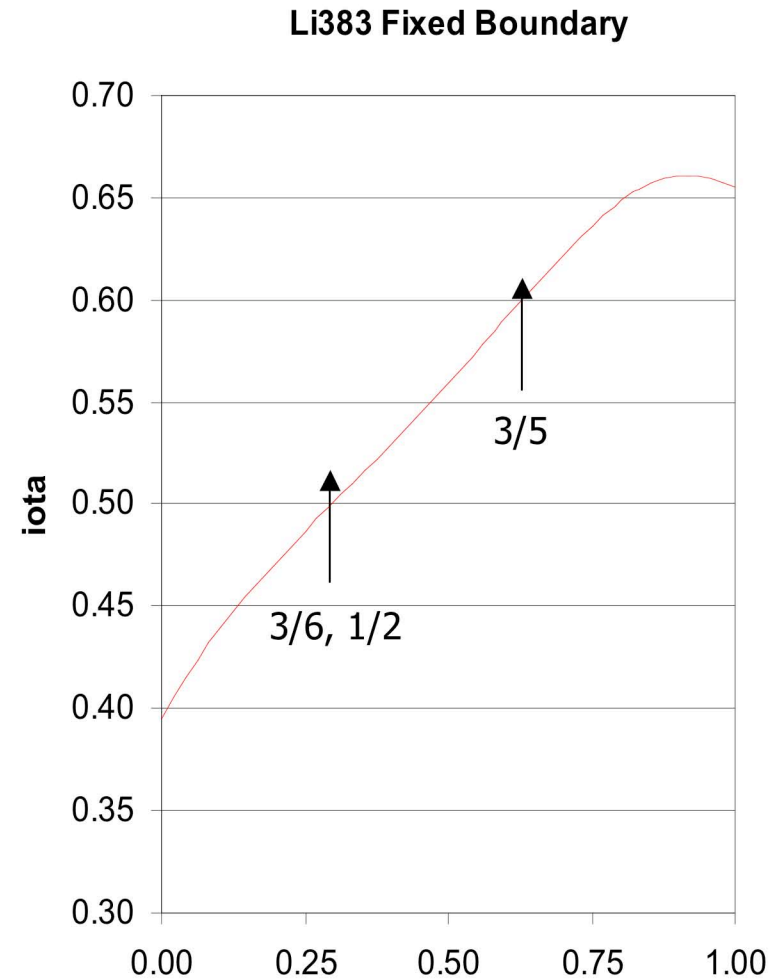
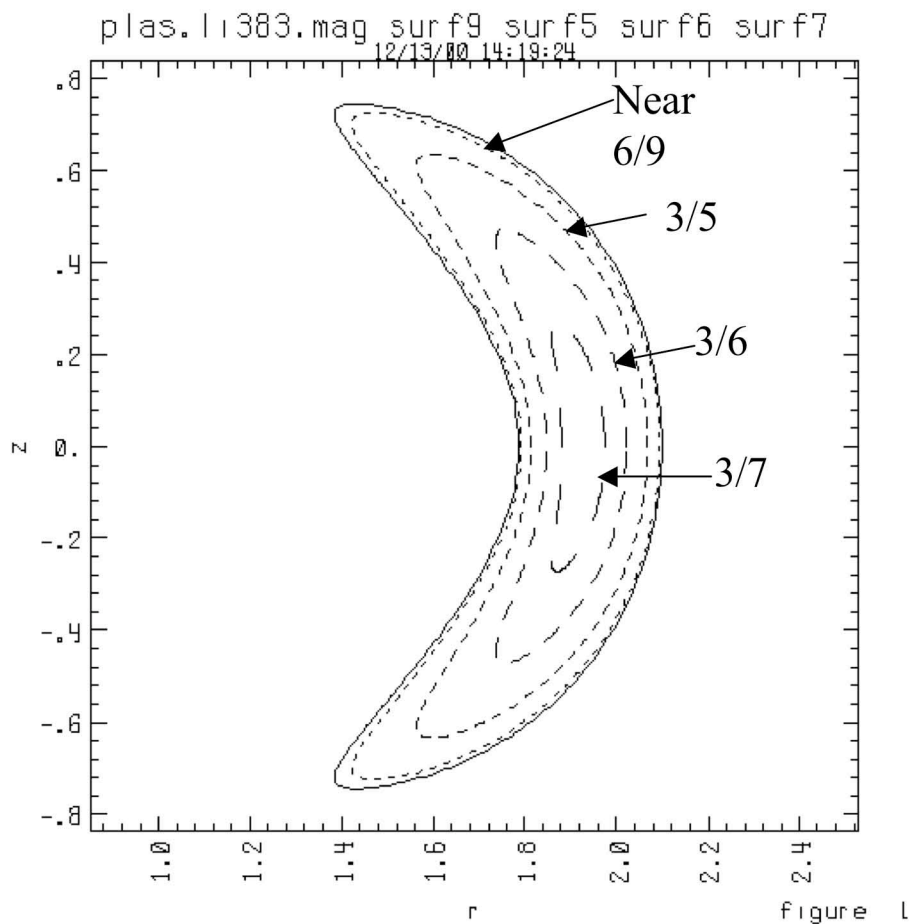
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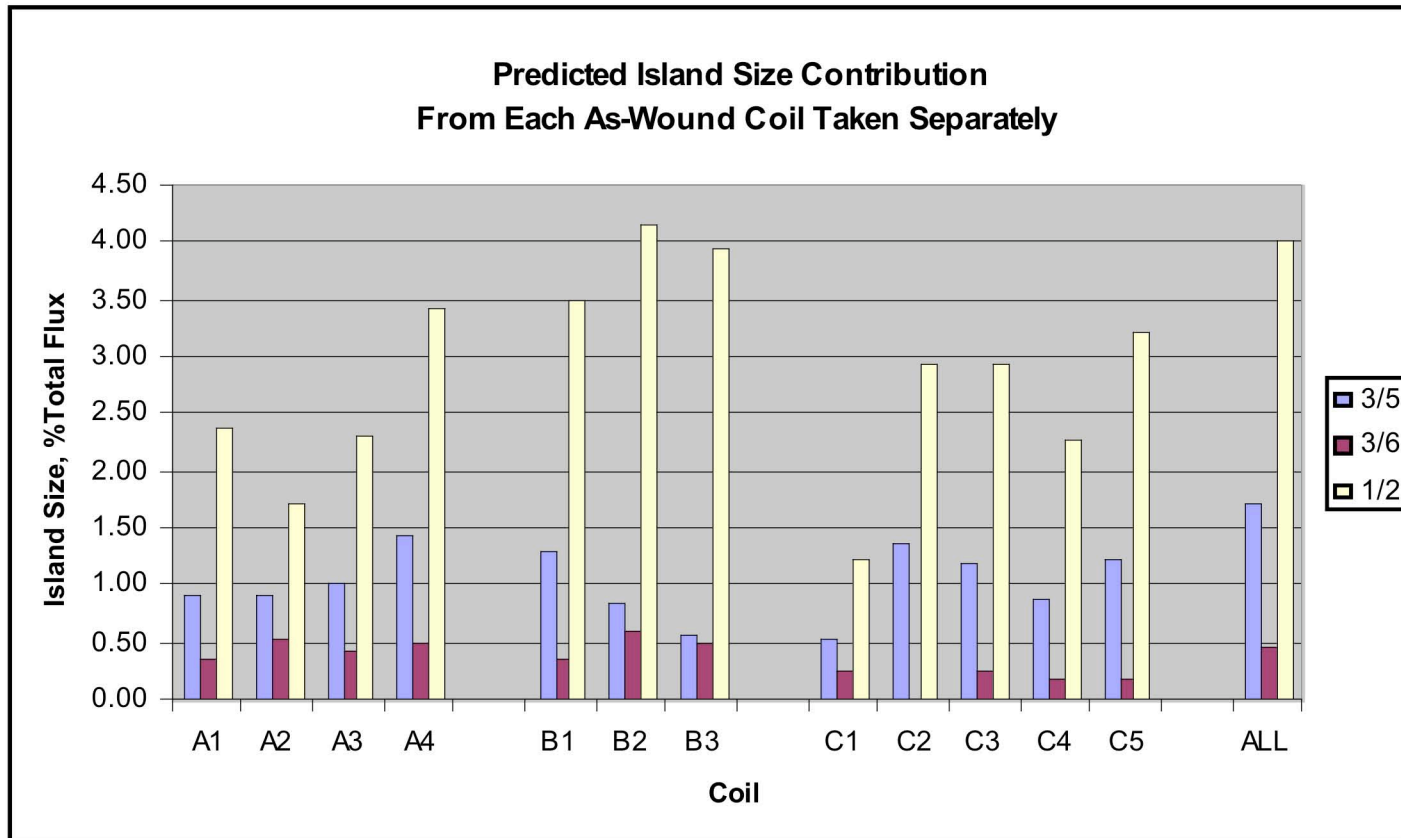
Field errors from as-built coils

- Island sizes for 3/5, 3/6, and 1/2 resonances calculated from as-built coils



Field errors from as-built coils

- Field errors from all coils not much different that from the worst coil considered separately



TF coil fabrication is underway at Everson Tesla

- Fabrication of the 1st TF coil is nearing completion
 - The nose wedge castings have been attached to the sides of the winding pack
 - Cold testing the 1st coil is expected to take place soon
- The ground wrap has been applied to the 2nd TF coil
- Winding of the 3rd TF coil is underway



A detailed assembly sequence plan has been developed

- Field period and final assembly will be accomplished in 5 stations
 - Station 1 – assemble diagnostic loops, cooling tubes, heater tape, and thermocouples onto vacuum vessel subassemblies (VVSA's)
 - Station 2 – assemble modular coils into half-period assemblies
 - Station 3 – assemble two half-period assemblies over the VVSA into a full field period
 - Station 5 – install ports, TF coils, and TF/PF support structures
 - Station 6 – assemble three field periods into a full torus
- Stations 1 and 2 are operational
- Tooling design for Stations 3, 5, and 6 is underway

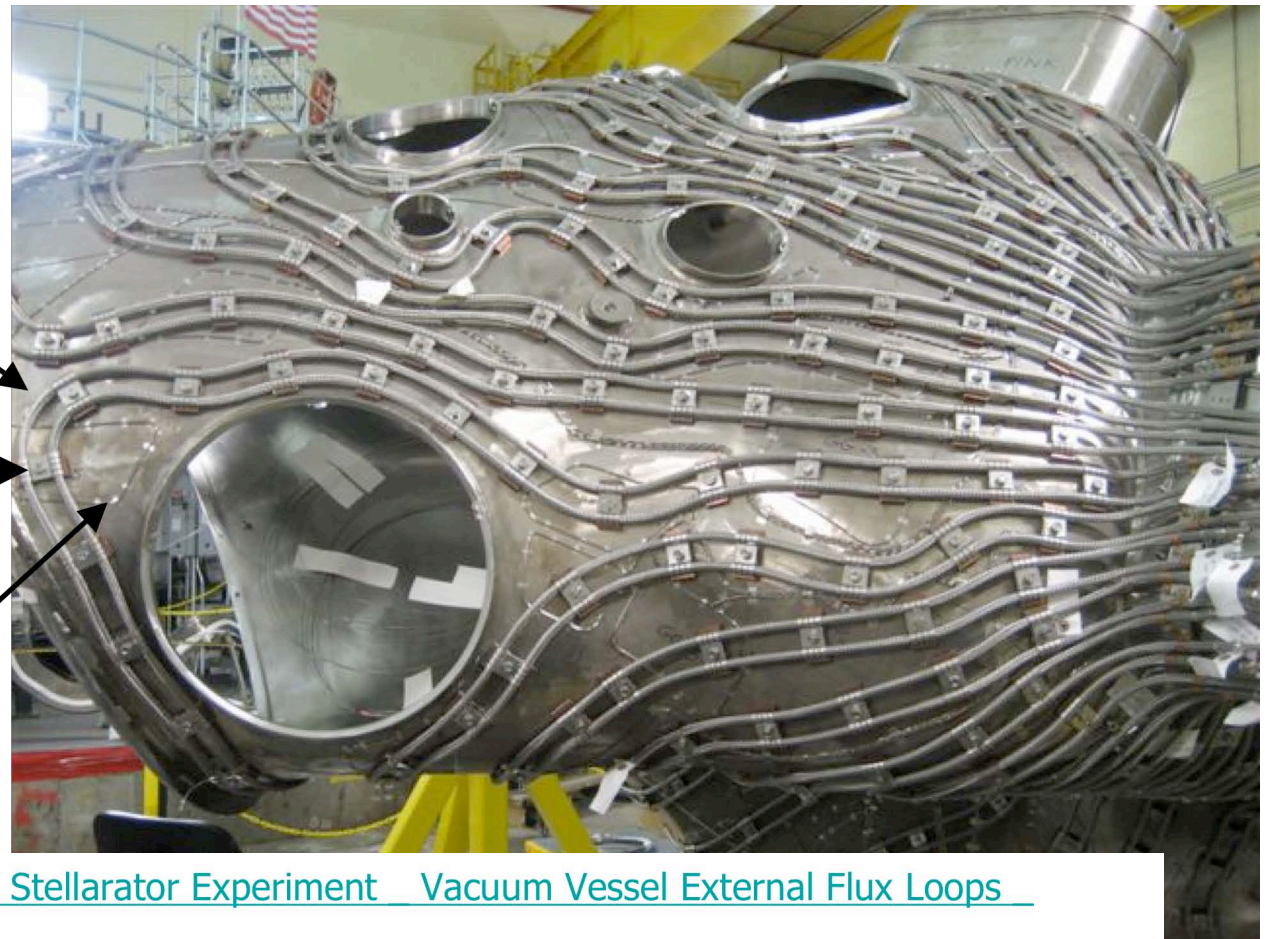
Field period assembly is underway in Station 1

- Assembly of the diagnostic loops, cooling tubes, heater tapes, and thermocouples on the 1st VVSA is nearly complete and the 2nd is in progress

Flexible heating/cooling tubes

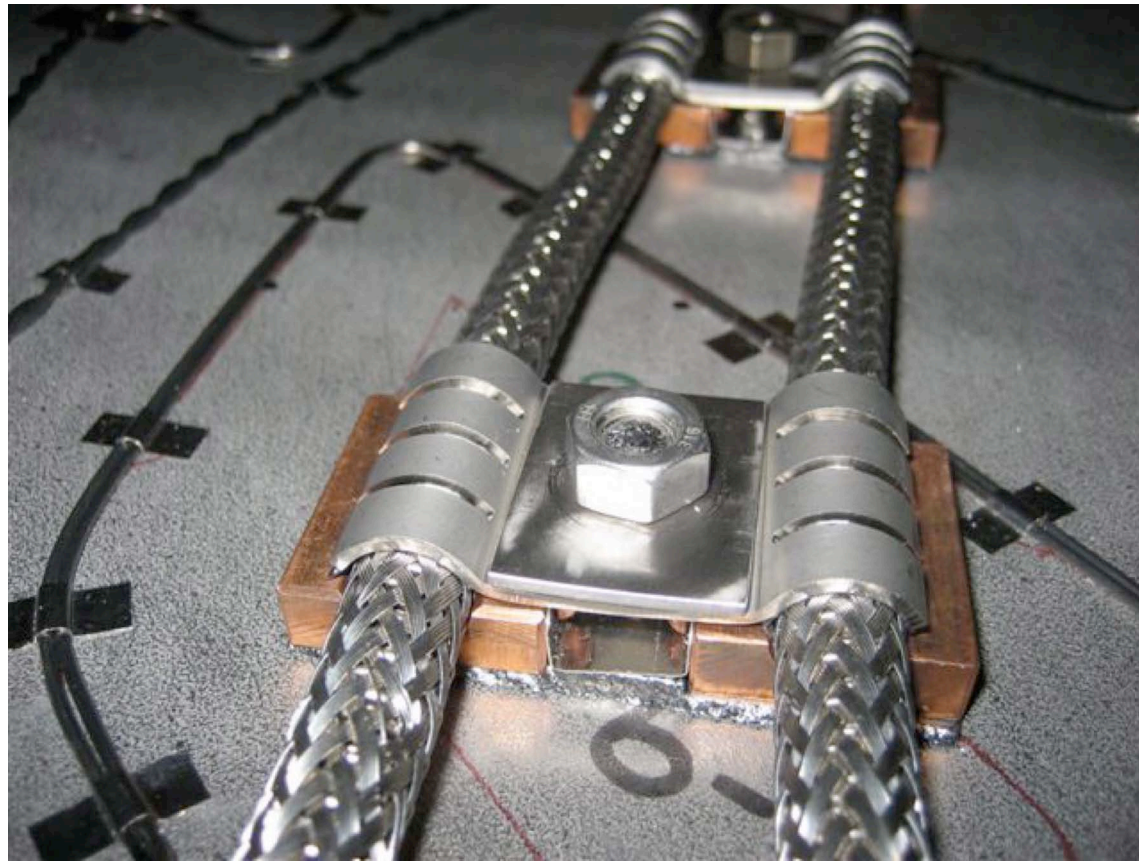
Copper-Grafoil saddles for heat transfer

Flux loops for plasma reconstruction

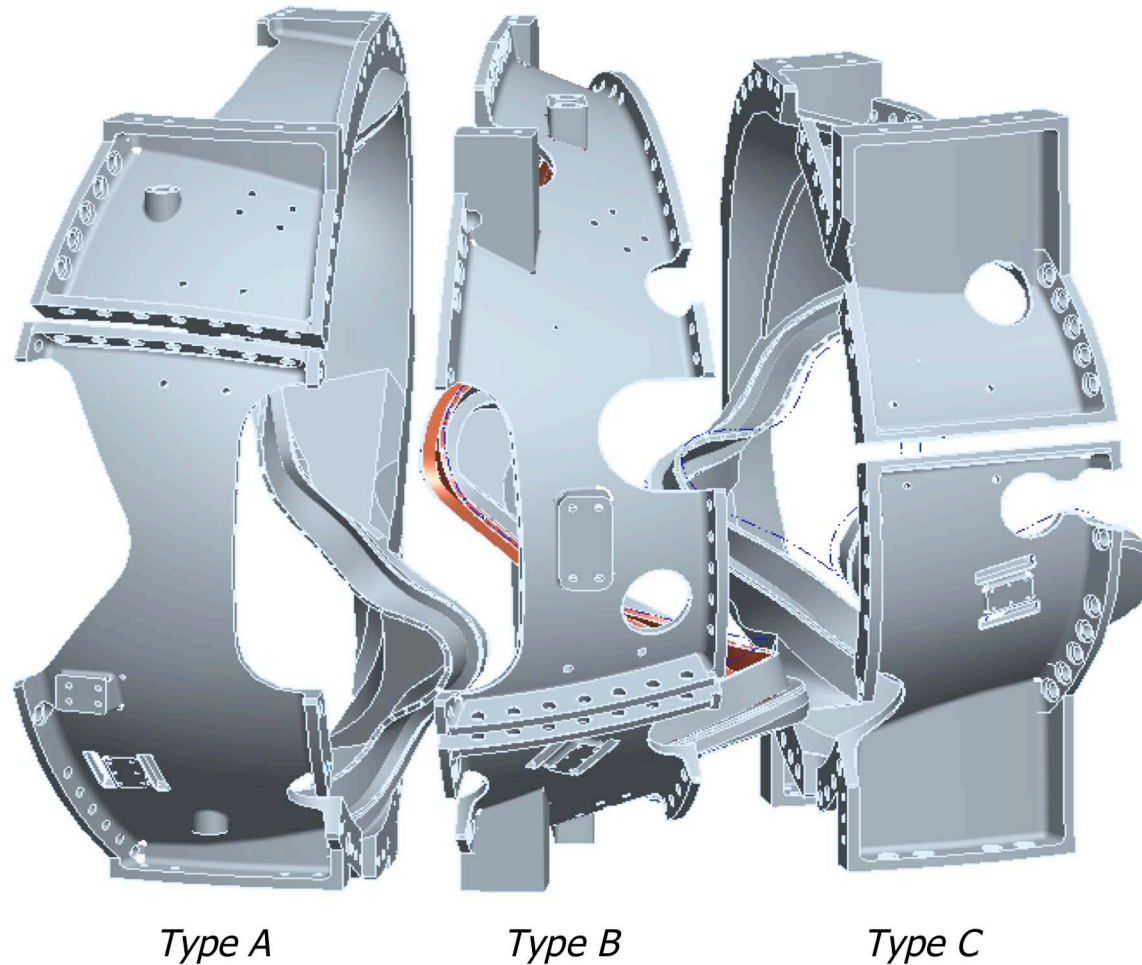


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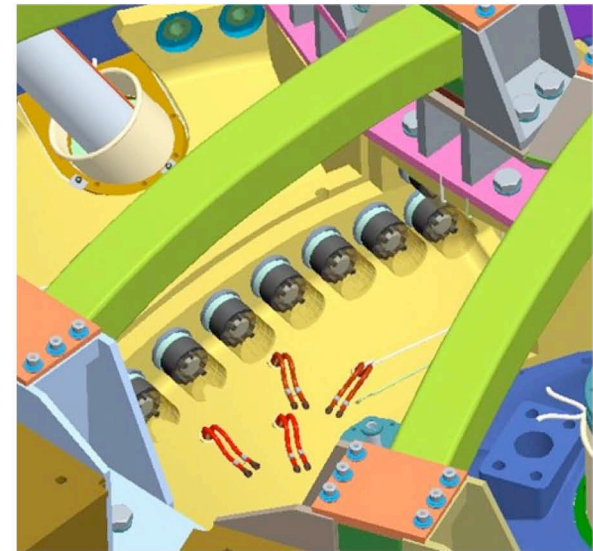
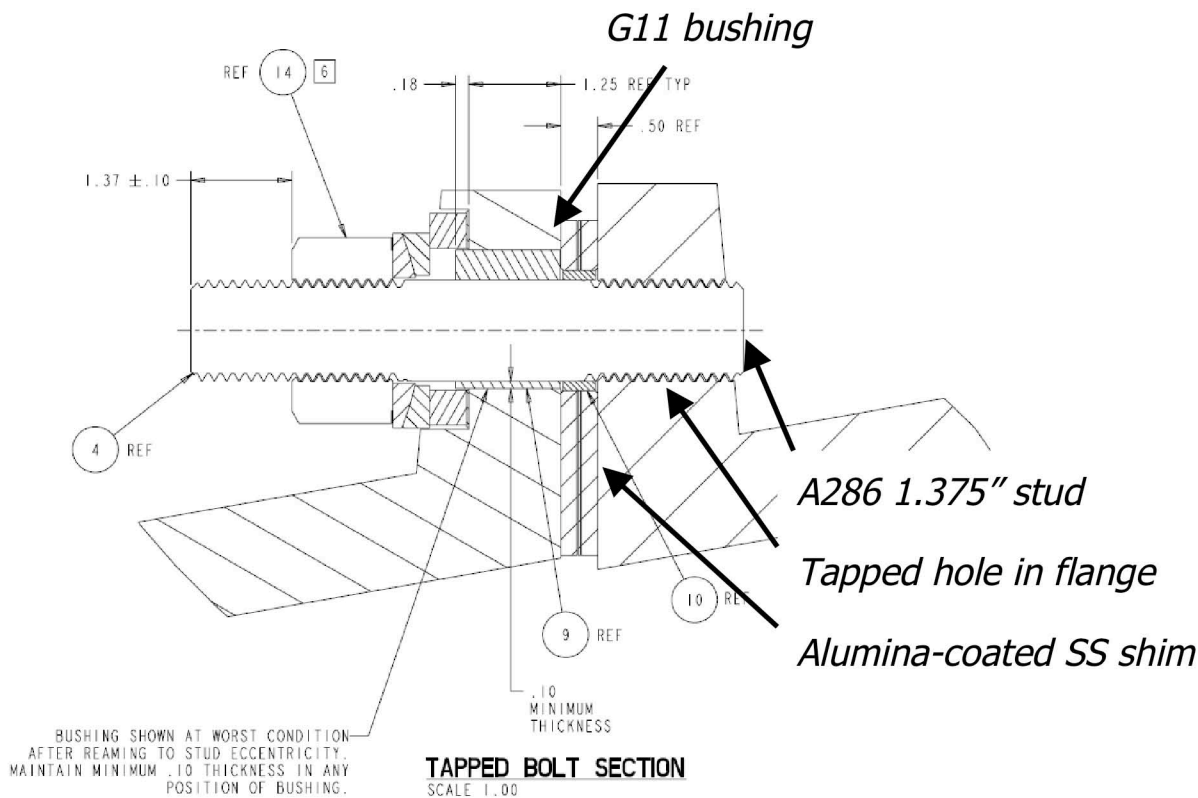
Modular coils are assembled into half-period assemblies on Station 2



Half-period assembly consists of three modular coils – one of each type

Work on Station 2 is being paced by completion of MC interface design

- Bolted joints along the outboard perimeter react shear loads through a high friction ($\mu \sim 0.67$) alumina-coated shim

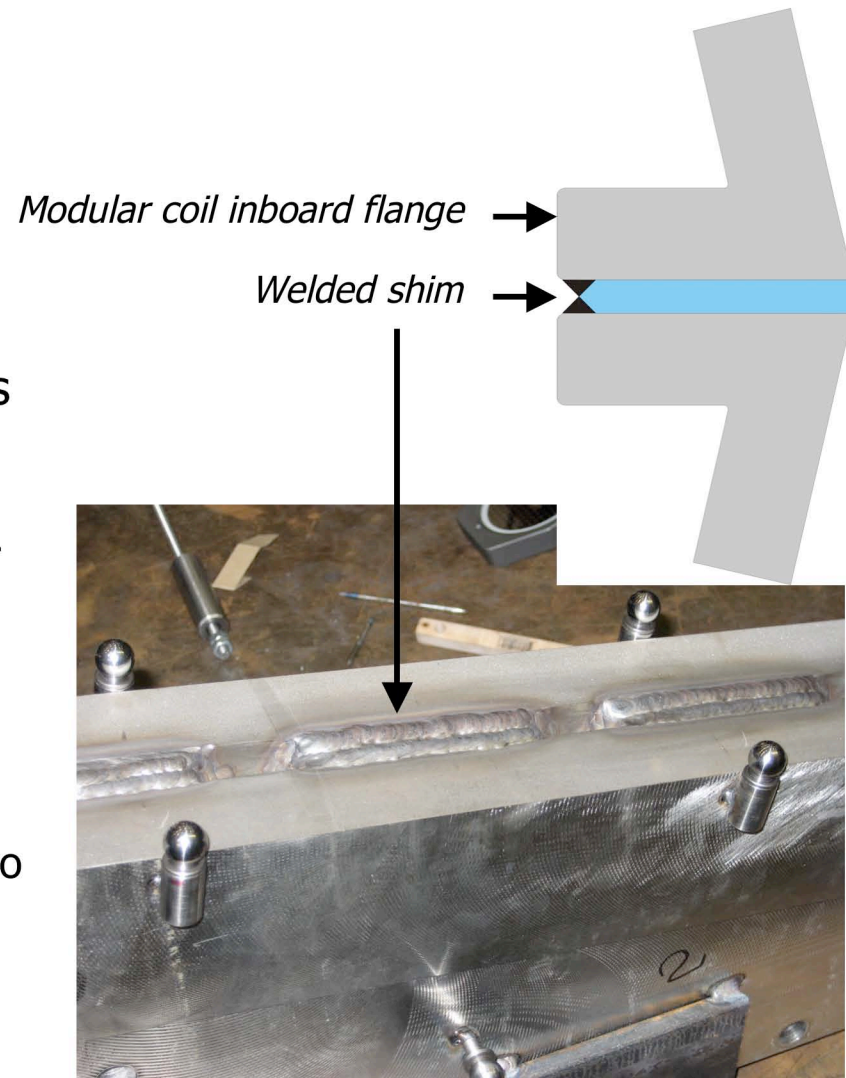


Studs tensioned to 74 kips using tensioning nuts from Superbolt



Welded shims join modular coils on inboard perimeter within a field period

- Bolt locations on inboard perimeter would be inaccessible for re-tensioning following machine assembly
- Flat shims are used to position coils and react compressive loads
 - Custom ground to right height
 - Welded to flanges to react shear loads
- Weld distortion is main concern
 - Development trials underway
 - Demonstration planned using two bare winding forms
 - Error fields from eddy currents are acceptable



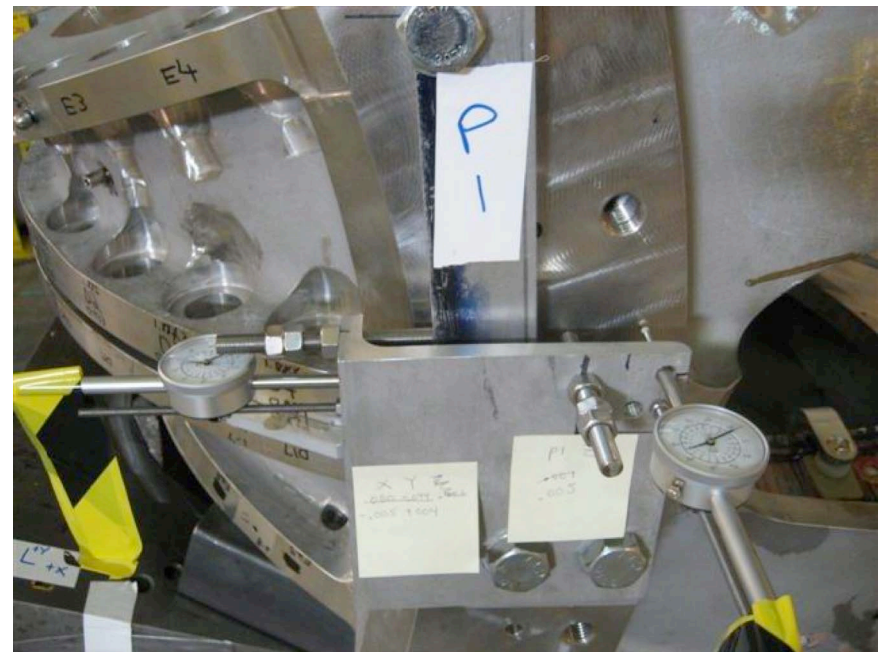
Coil positioning trials are underway

- Coils within a half-period (3 modular coils) are required to be positioned within +/- 10 mils (0.25mm)
- Requires the use of a laser tracker for measurement
- The locations of the coil current centroids are known with respect to a set of tooling balls which are used for determining the position of the coils
- Coil position is set in the z-direction (normal to the mating flanges) by adjusting shim thicknesses
- The relative position in the xy-plane (nominally in the plane of the flanges) is adjusted using set screws and dial indicators
- When the coils are properly positioned, they are bolted together



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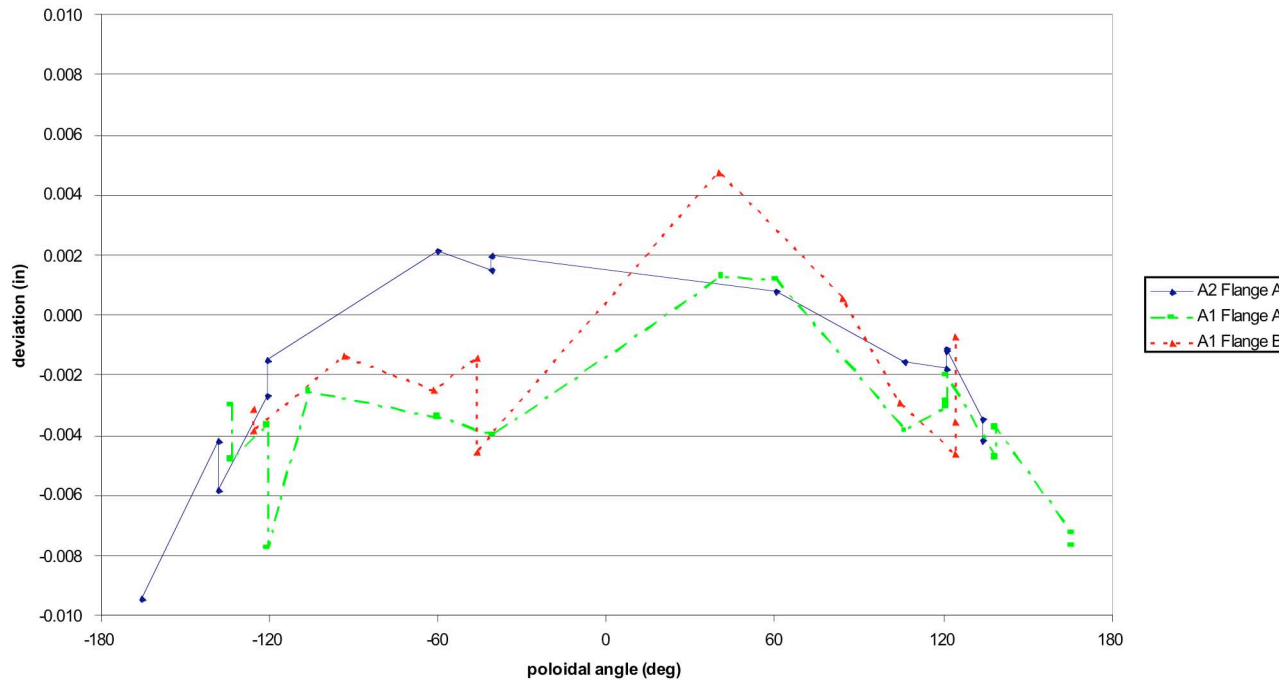
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Capability to meet positioning requirements has been demonstrated

- A1-A2 coils were positioned and bolted together
- Required fit-up of +/- 10 mils (0.25 mm) was achieved

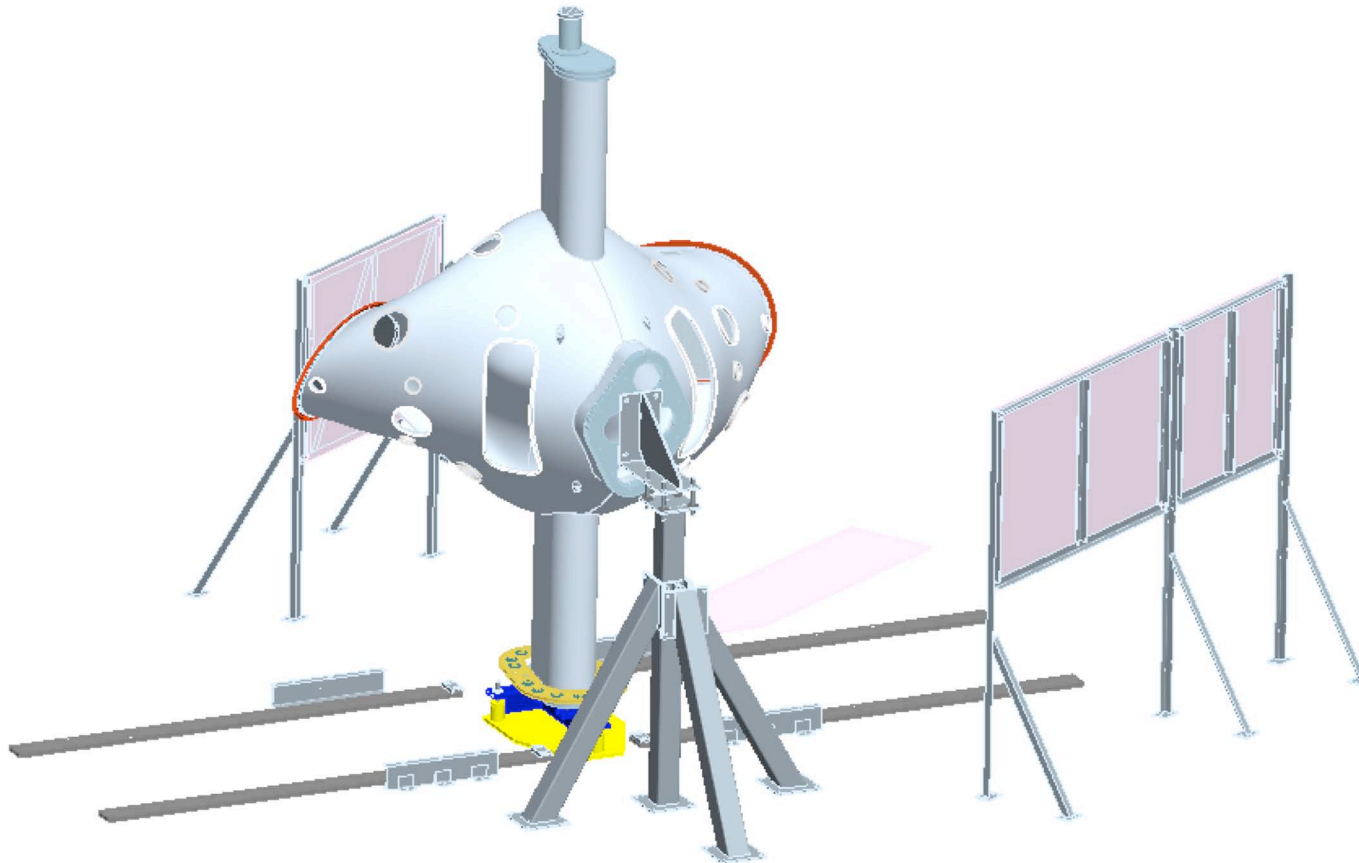
A1-A2 Fitup Ground Shim Test; compensated z deviations vs poloidal angle after torquing



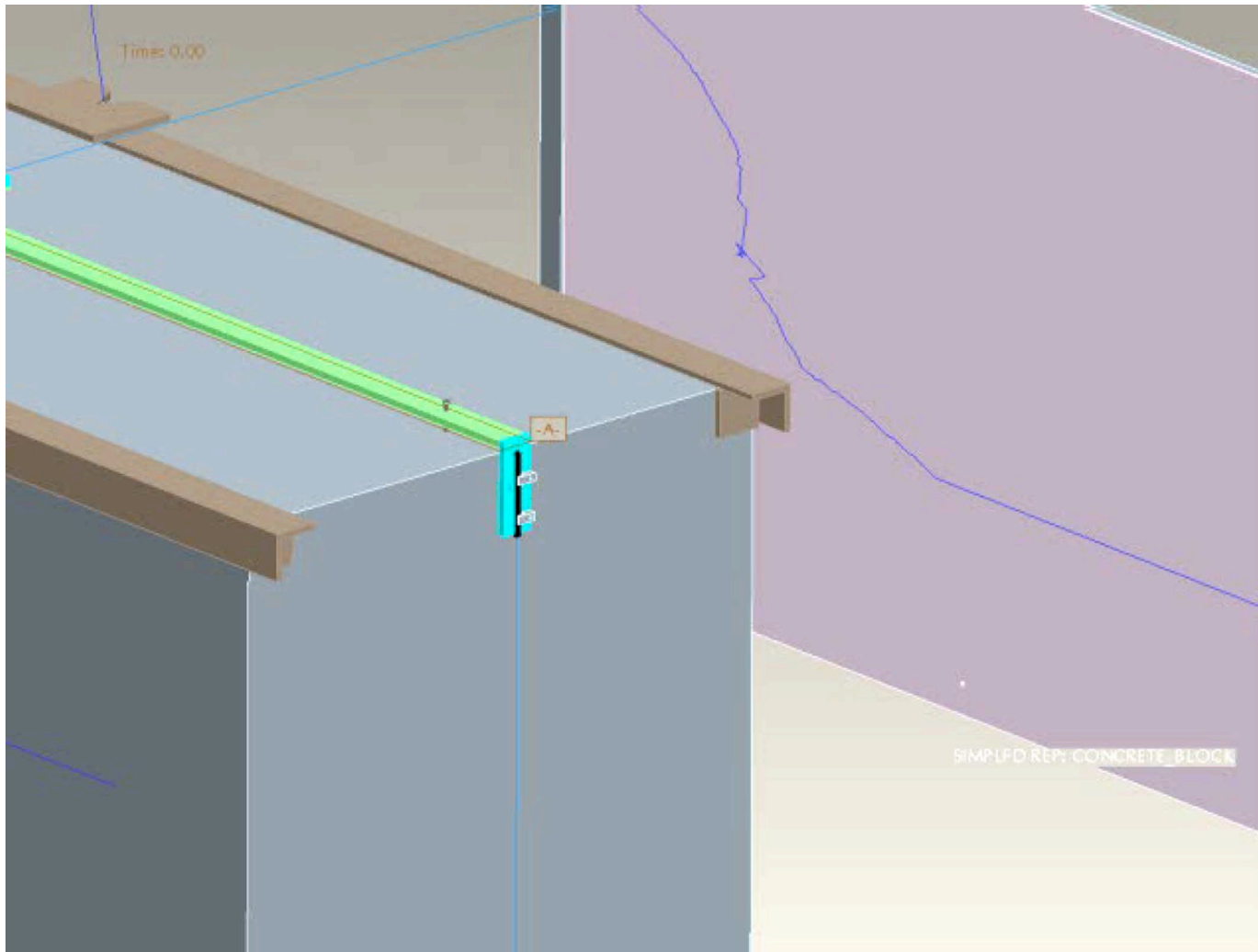
OE-1, (10:00) [Dimensional Control for the National Compact Stellarator Experiment*](#), R. Ellis

P1-25, (13:00) [Metrology for the NCSX Project](#), S. Raftopoulos

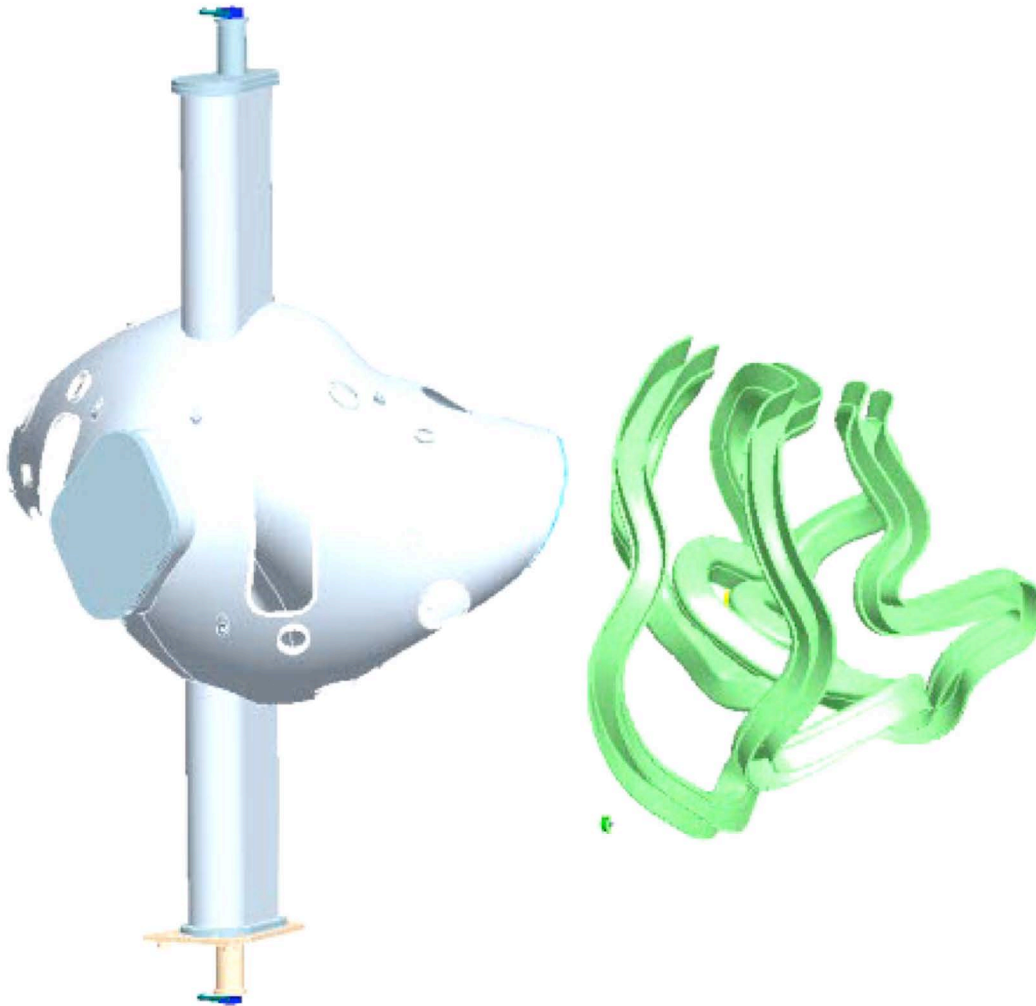
Modular coils are assembled over the vacuum vessel in Station 3



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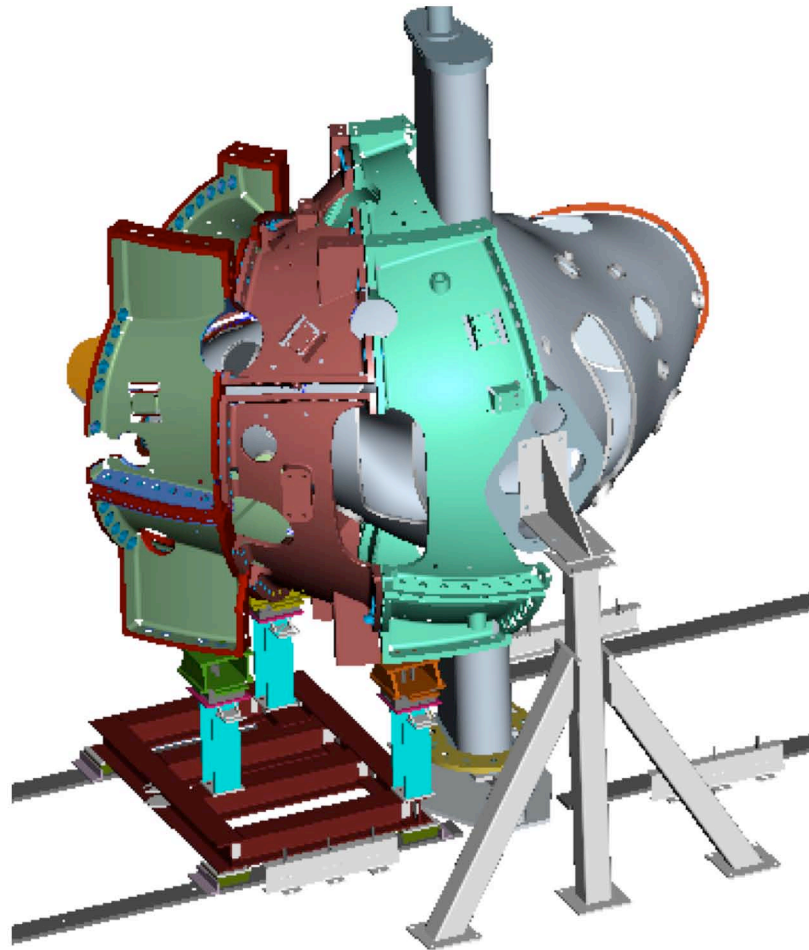


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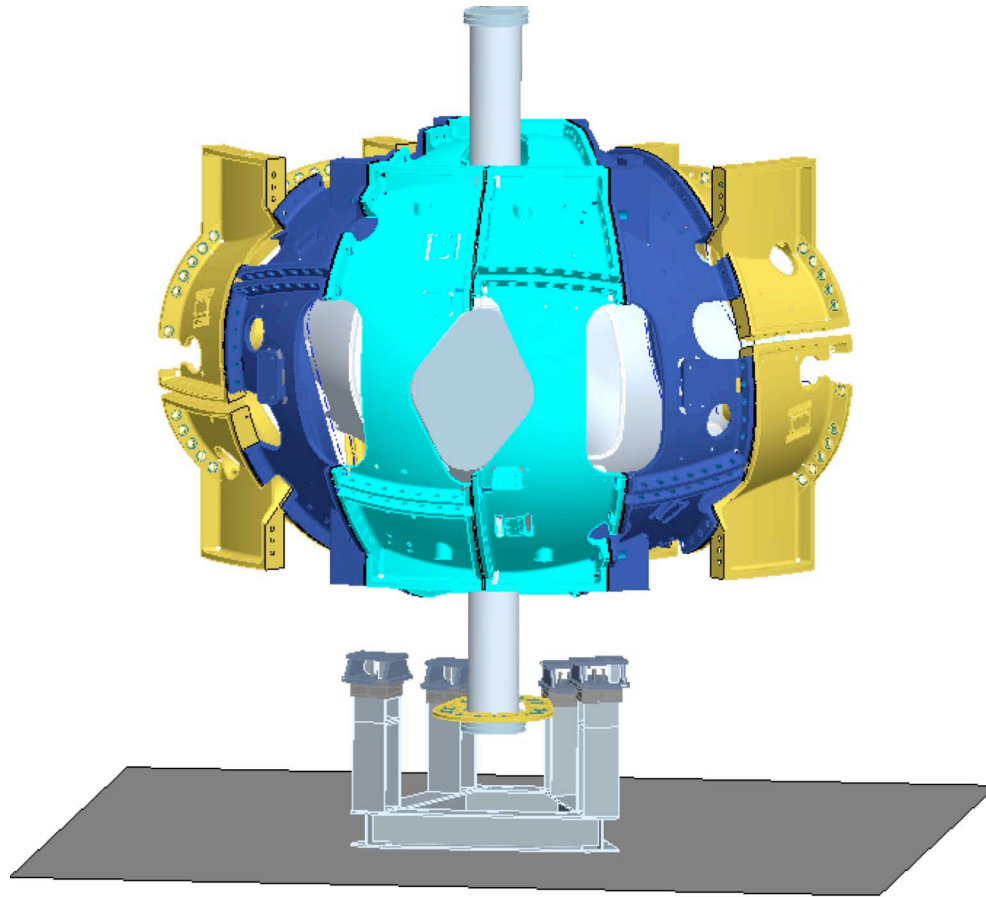


SIMPLFD REP: MC_CLAMP_STUDY

Modular coils are assembled over the vacuum vessel in Station 3

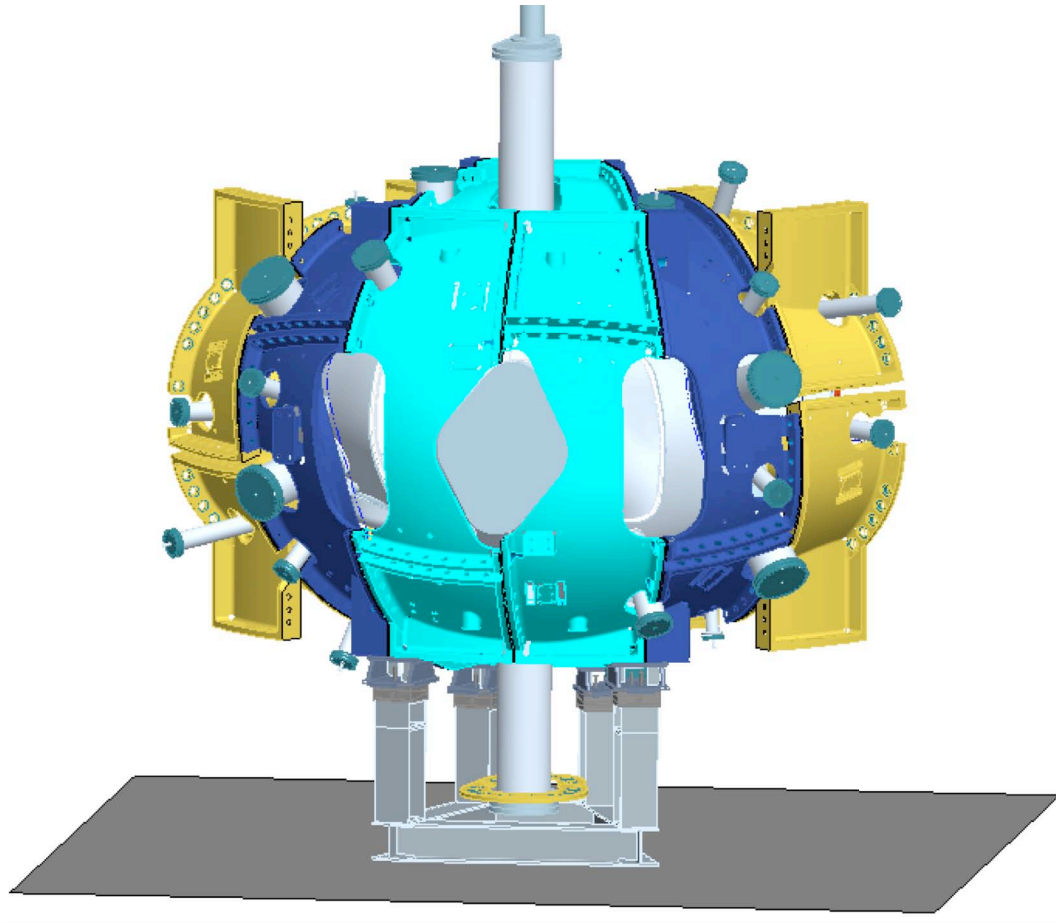


VV ports are attached, TF coils, and TF/PF support structures are added in Station 5



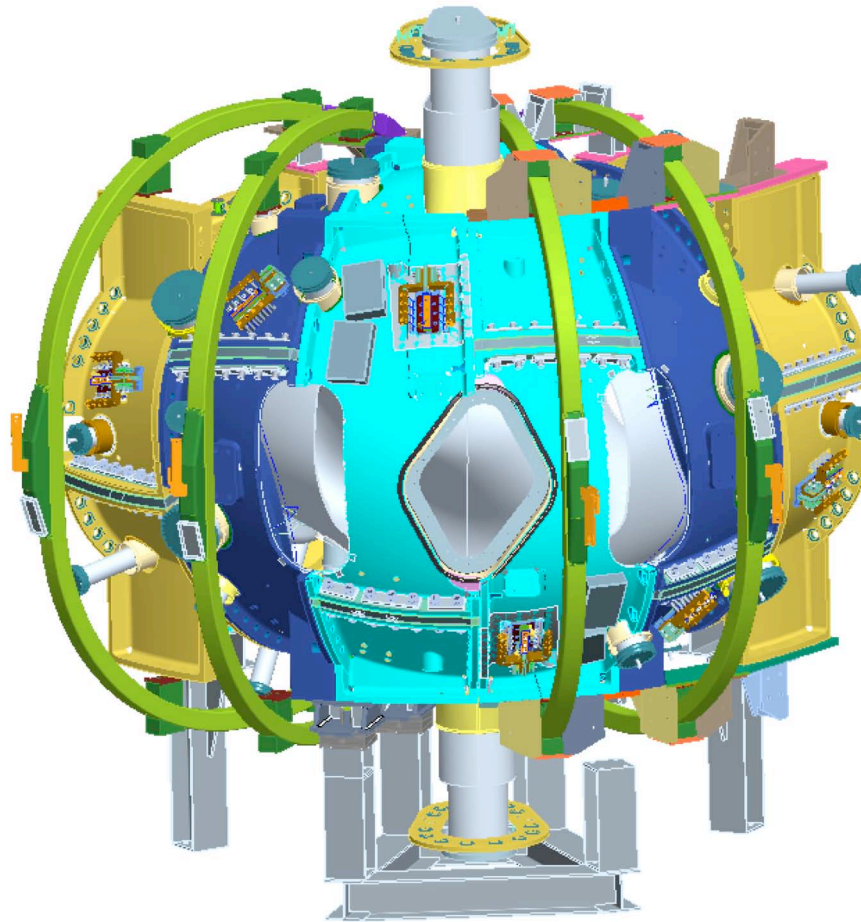
Field period lowered onto support stand

VV ports are attached, TF coils, and TF/PF support structures are added in Station 5



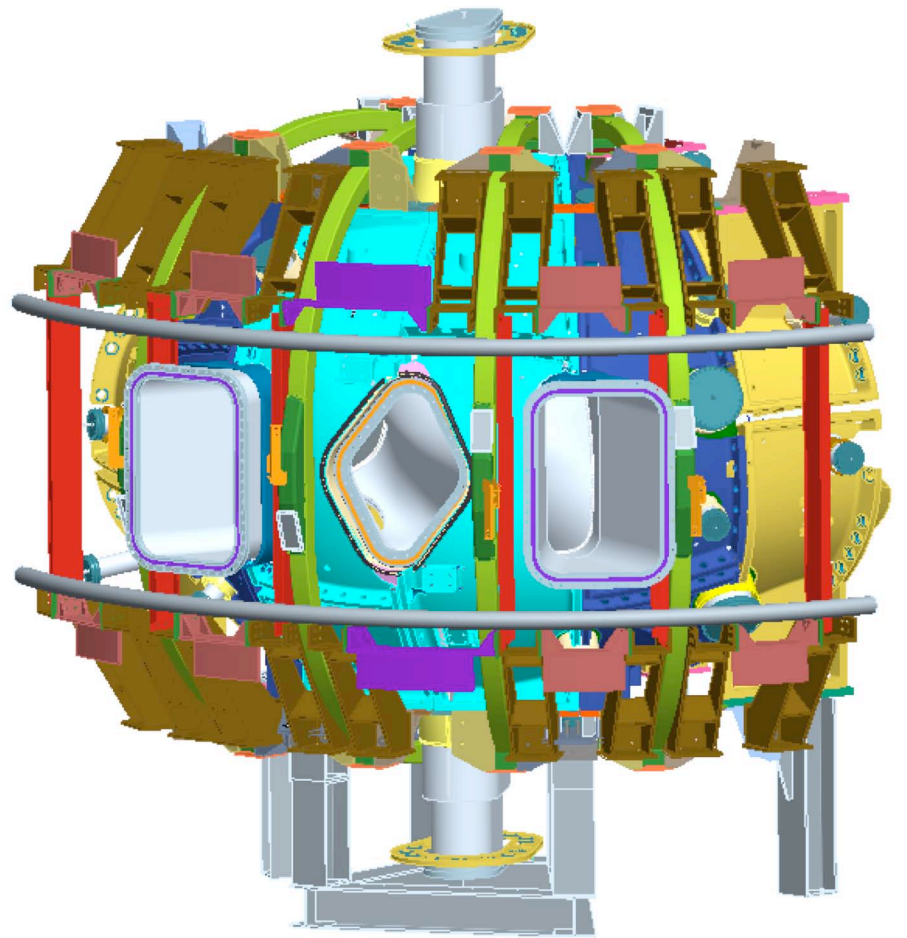
VV ports installed and leak checked

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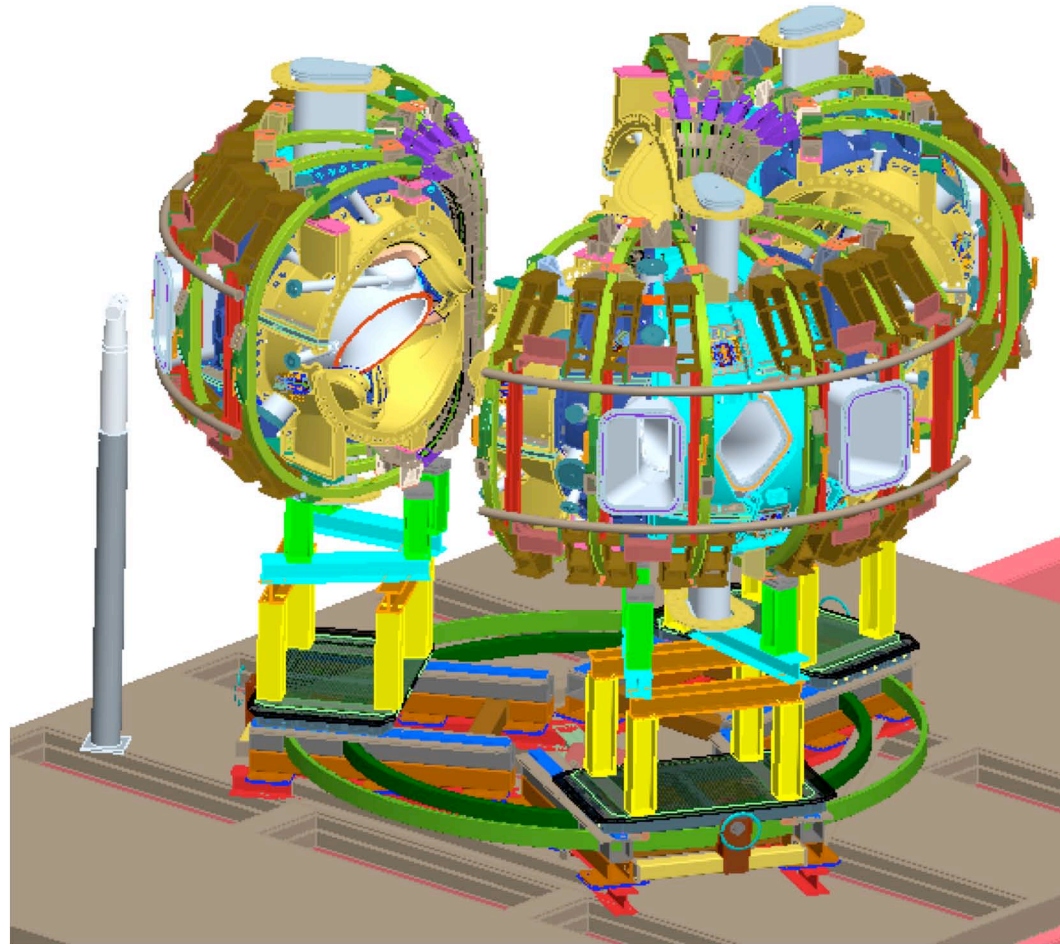
TF coils are then installed

VV ports are attached, TF coils, and TF/PF support structures are added in Station 5



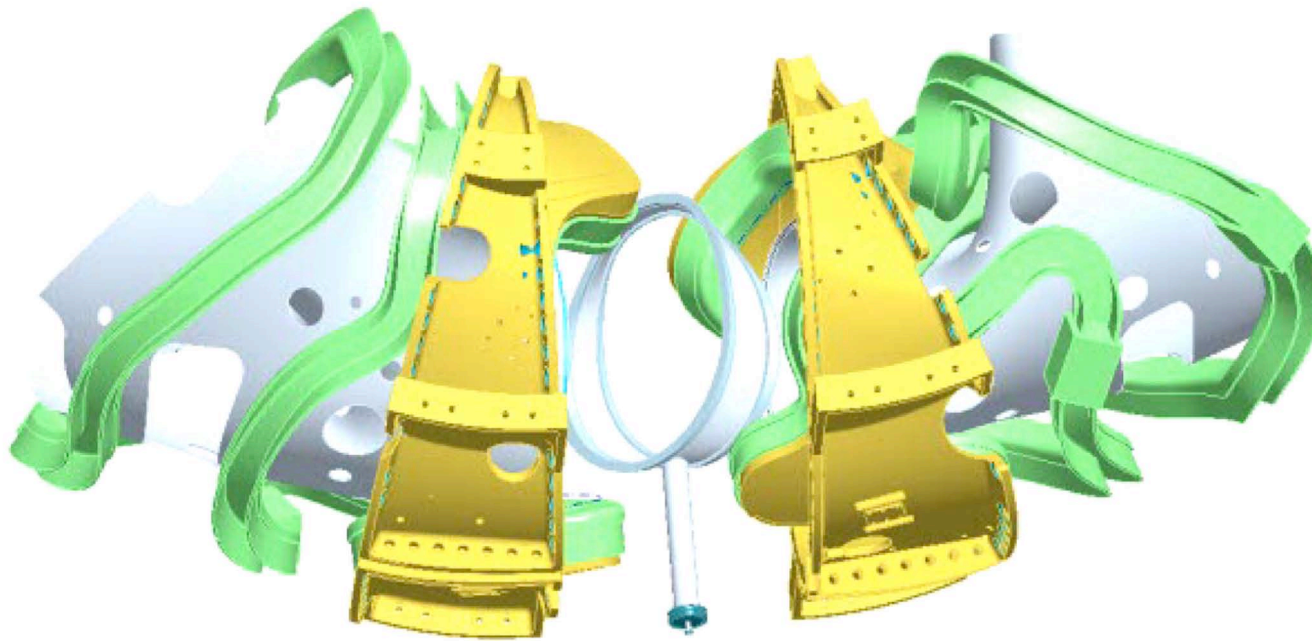
PF support structures and LN2 manifolds are then added

Three field periods are brought together to form a full torus in final assembly (Station 6)



Field periods mounted on sleds and brought together for final assembly

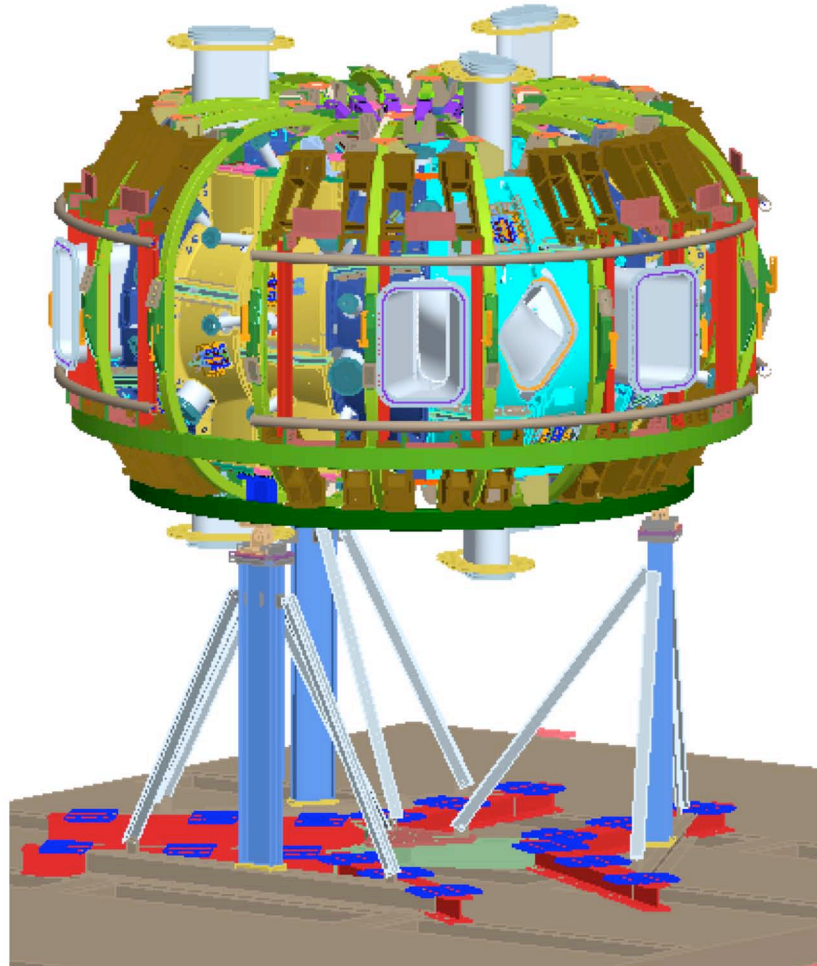
Three field periods are brought together to form a full torus in final assembly (Station 6)



SIMPLFD REP: BASELINE

INSERT MODE

Three field periods are brought together to form a full torus in final assembly (Station 6)



Permanent machine supports are installed and the assembly sleds removed

Three field periods are brought together to form a full torus in final assembly (Station 6)

- VV is welded together with spool pieces to joint the VVSAs
- PF coils and solenoid are installed
- Coils are tested at RT prior to cryostat installation and cooldown to 80K
- Field line mapping and first plasma mark the completion of CD-4

- NCSX has progressed from design and procurement to construction
 - All modular coil winding forms and vacuum vessel subassemblies have been delivered
- Modular coil winding operations are progressing well
 - 12 of 18 modular coils have been epoxy impregnated
 - Coil tolerances are being met
- TF coil fabrication is underway at Everson Tesla
- A detailed assembly sequence plan has been developed
 - Diagnostic loops, cooling tubes, heater tapes, and thermocouples are being assembled onto the vacuum vessel subassemblies on Station 1
 - Development trials on Station 2 are underway
 - Assembly of modular coils into half-periods is expected to begin in Nov07 on Station 2
 - Tooling design for remaining stations is in progress