

WBS 18

Field Period Assembly

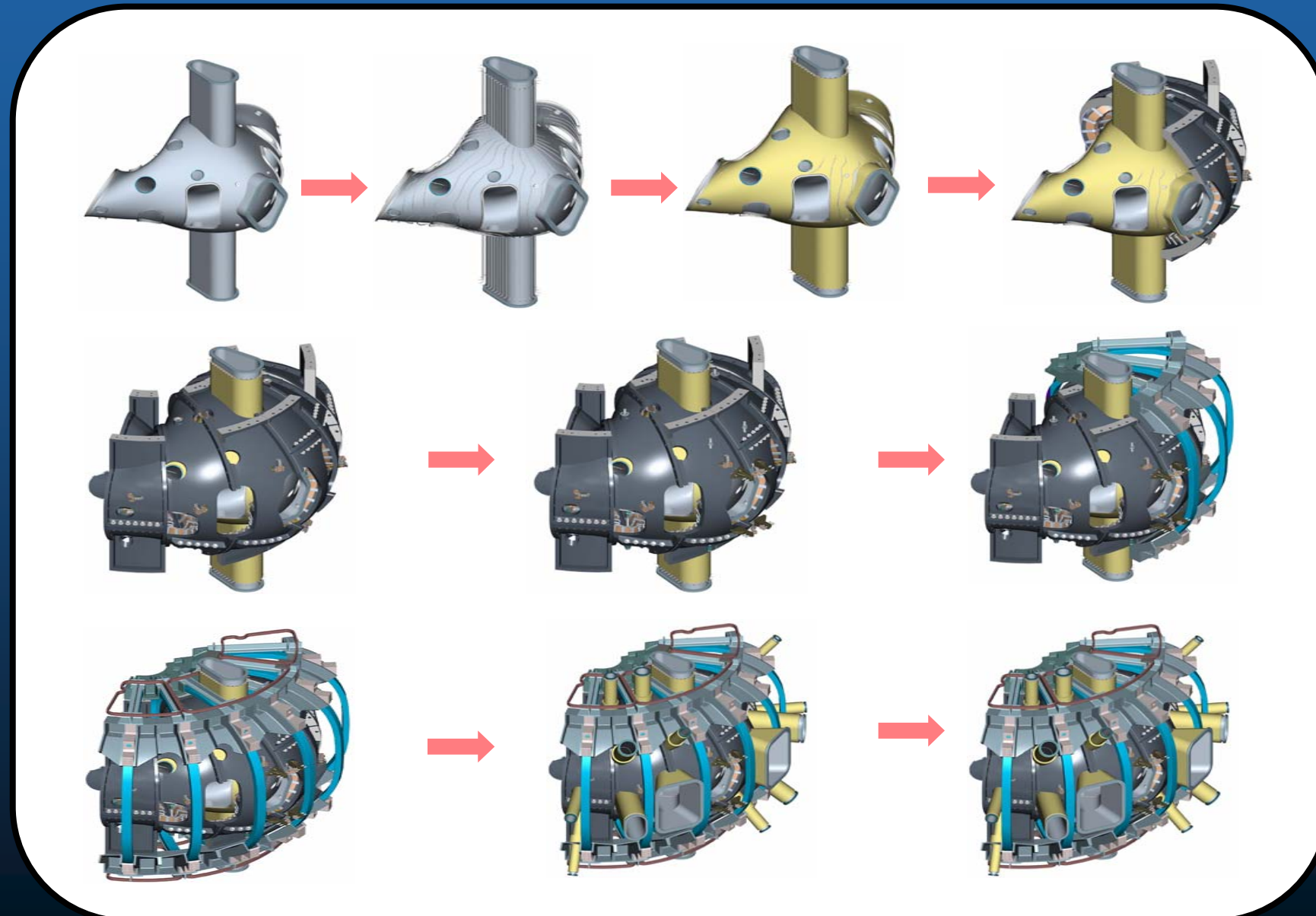
M. Cole
and the WBS 1 team

Peer Review March 30, 2004

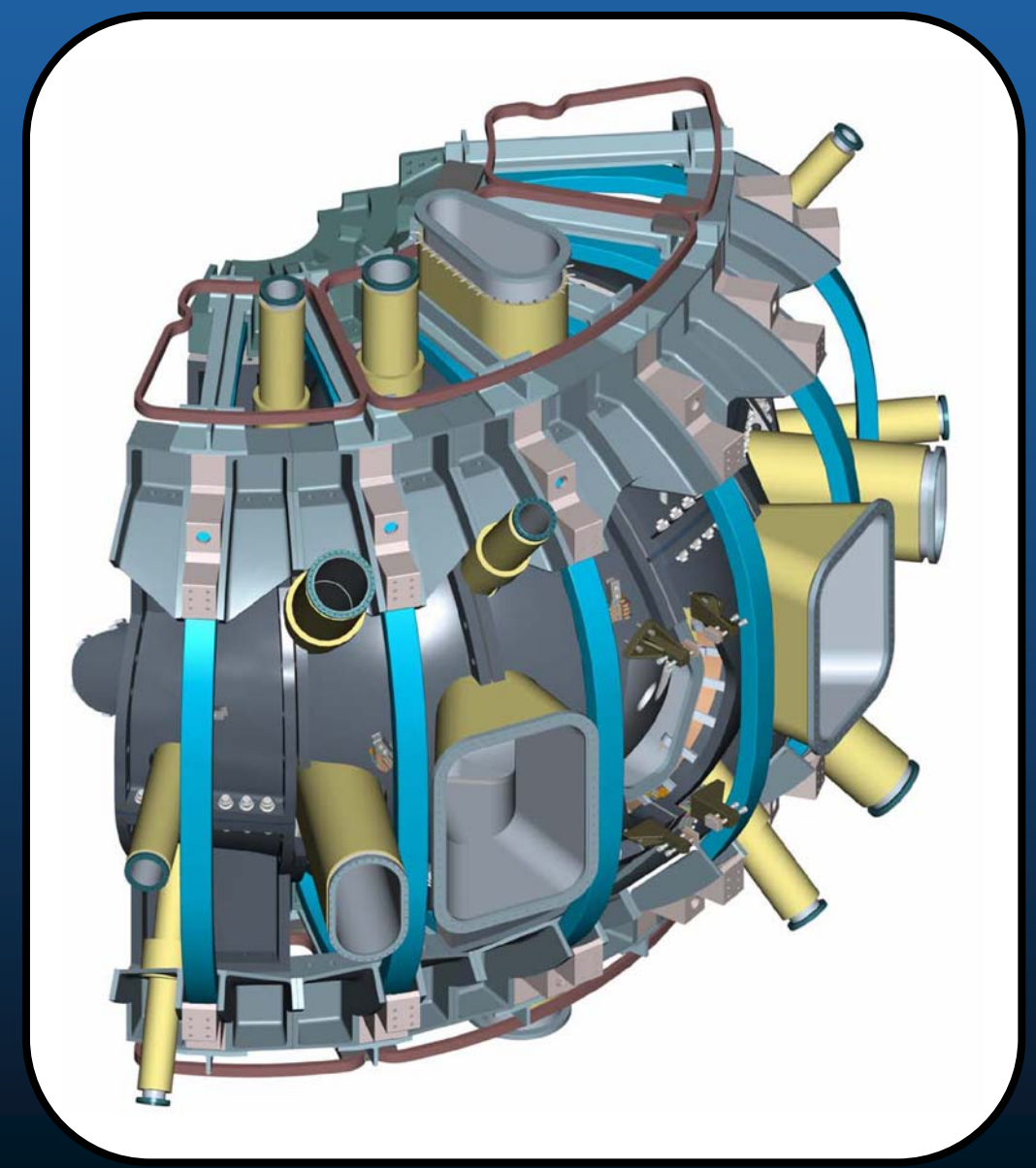
Field Period Assembly



Field Period Components



Complete Field Period Assembly



For the Field Period Assembly:

- Requirements
- Metrology
- Assembly Steps
- Cost and schedule
- Summary

Field Period Assembly Requirements



- **The Modular Coil winding center shall be positioned to a tolerance of +/- 0.020 inch**
- **The Magnetic Diagnostic Sensor locations must be known to a tolerance of +/- 0.03 inch**
- **TF Coils and structure will be aligned laterally to field period, final radial and vertical adjustments will be made at machine assembly.**
- **The Vacuum Vessel is positioned for port installation only. Final adjustments will be made at machine assembly**
- **External Trim Coils shall be located to a tolerance of +/- TBD inch**
- **The Vacuum Vessel Period shall have a total leak rate $< 6.7 \times 10^{-6}$ torr-l/sec**

Field Period Assembly Tolerance Stackup



Where does the tolerance go?

- **+/- 0.020 inch allocated to the winding fabrication**
- **+/- 0.020 inch allocated to the field period assembly**
- **+/- 0.020 inch allocated to the machine assembly installation.**

Field Period Assembly Tolerance Stackup

Where does the tolerance go in the Field Period Assy?

- Tolerance associated with half period assy +/- tbd inch
- Tolerance in positioning and mounting left and right Mod Coils together +/- tbd
- Tolerance due to measurement accuracy +/- 0.005
- The +/- 0.020 inch could be distributed evenly between the two but it would probably be better to allow more tolerance for the assembly of the left and right mod coils which will be harder to control. The straw man is to apply 40% to the half period assy (+/- 0.006) and 60% to the installation of the mod coils (+/- 0.009).
- If the tolerance from winding the coils and the half period assy is better than expected this tolerance could be used at the installation of the left and right mod coil assy.

Metrology is Critical to Field Period Assembly



- **The FPA depends on the ability to measure major components to a tolerance of +/- 0.005 inch.**
- **We need software that can read the data collected during the manufacturing and inspection process and display the image of the collected data.**
- **We have to compare the actual part data to the cad data and determine how the actual part varies from the ideal part.**
- **We will need the capability to best fit parts or optimize the data we have to obtain the best fit possible with the ideal configuration.**
- **We have to build parts (shims) based on the data taken.**
- **We have to re-inspect often to verify that we have met the requirements.**

How Will We Meet Positional Requirements?

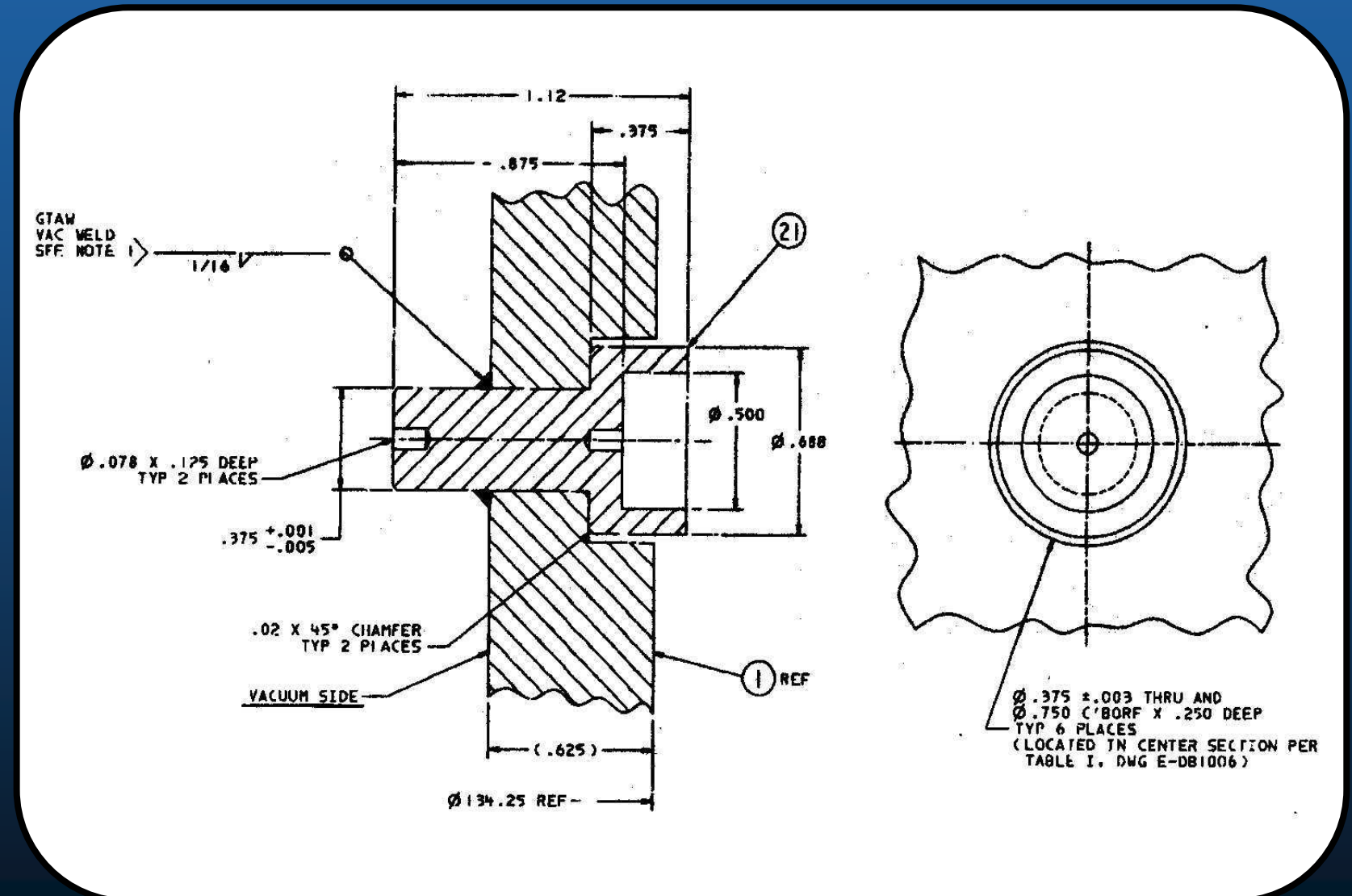


- **Hardware for measuring the orientation and global position**
 - Arcsecond Constellation 3DI- System uses triangulation to create a universal coordinate frame similar to GPS – Accurate to approximately 0.005 inch anywhere in the Test Cell
 - Laser Tracker – Interferometer-based measuring system – Accurate to 0.0002 inch
 - FARO Arm – Mechanical measurement system – Accurate to 0.001 inch with its operating volume
- **Hardware for efficiently measuring contoured shapes**
 - Nvision “ModelMaker” Scanner – Surface scanner capable of capturing 3D geometry
- **Specialty measurement devices, custom-built for unique processes**
 - Special Fixtures ex. measuring turn location during coil winding
- **Software for the post-processing of metrology data.**
 - Pro E – Cad package capable of reading data files to create surfaces for comparison to models

Measurement Targets and Monuments

Target used for NSTX

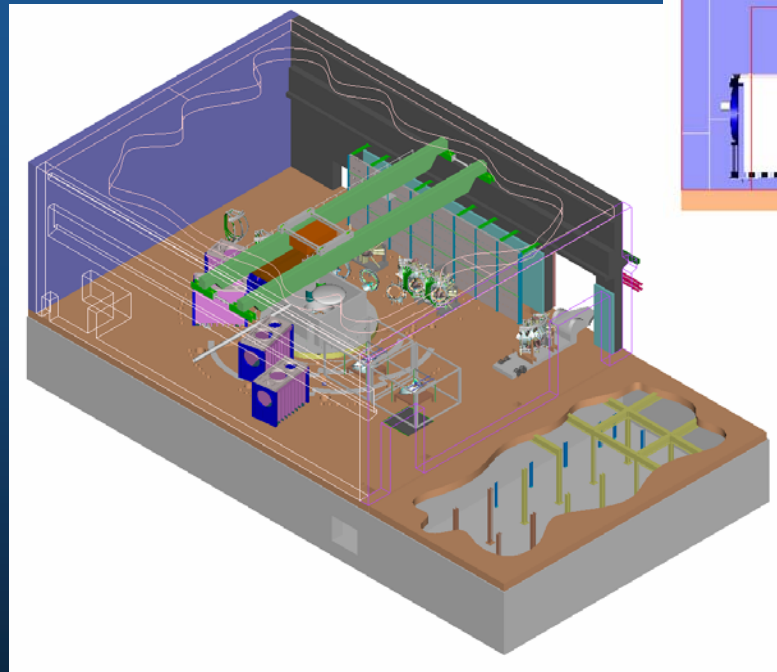
This would include the set of tooling balls, reference marks, holes, countersinks or other features required on the various components to establish the frame of reference for transferring data between measurement sets or for establishing the rigid body location of an object relative to other objects.



Field Period Assembly Area

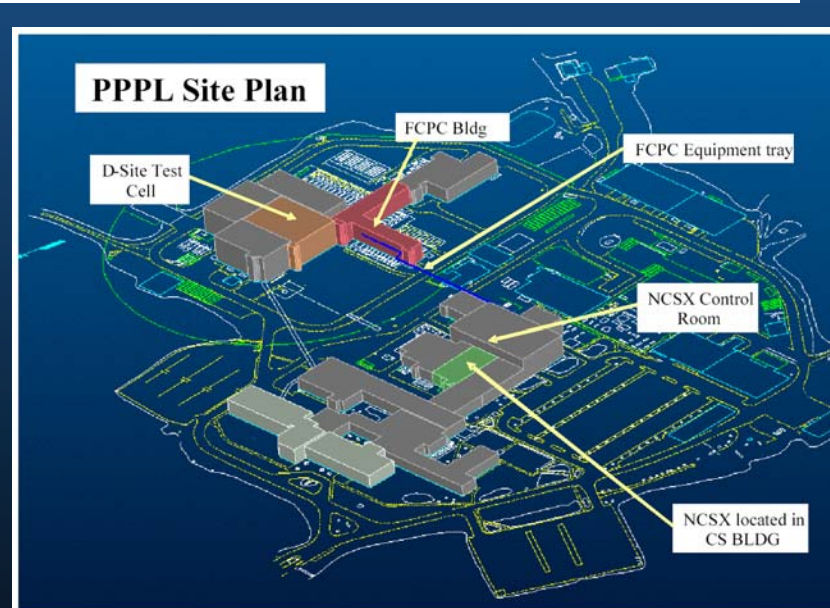
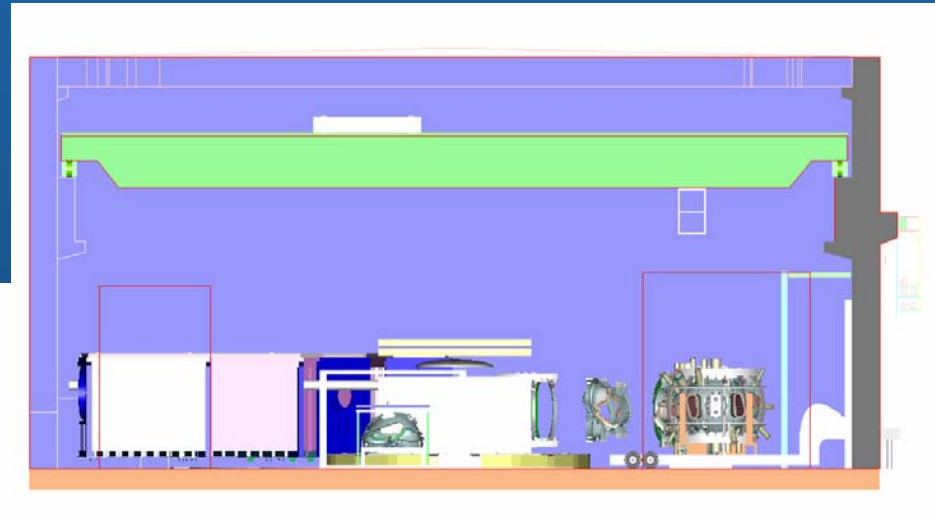
NCSX

TFTR Test Cell



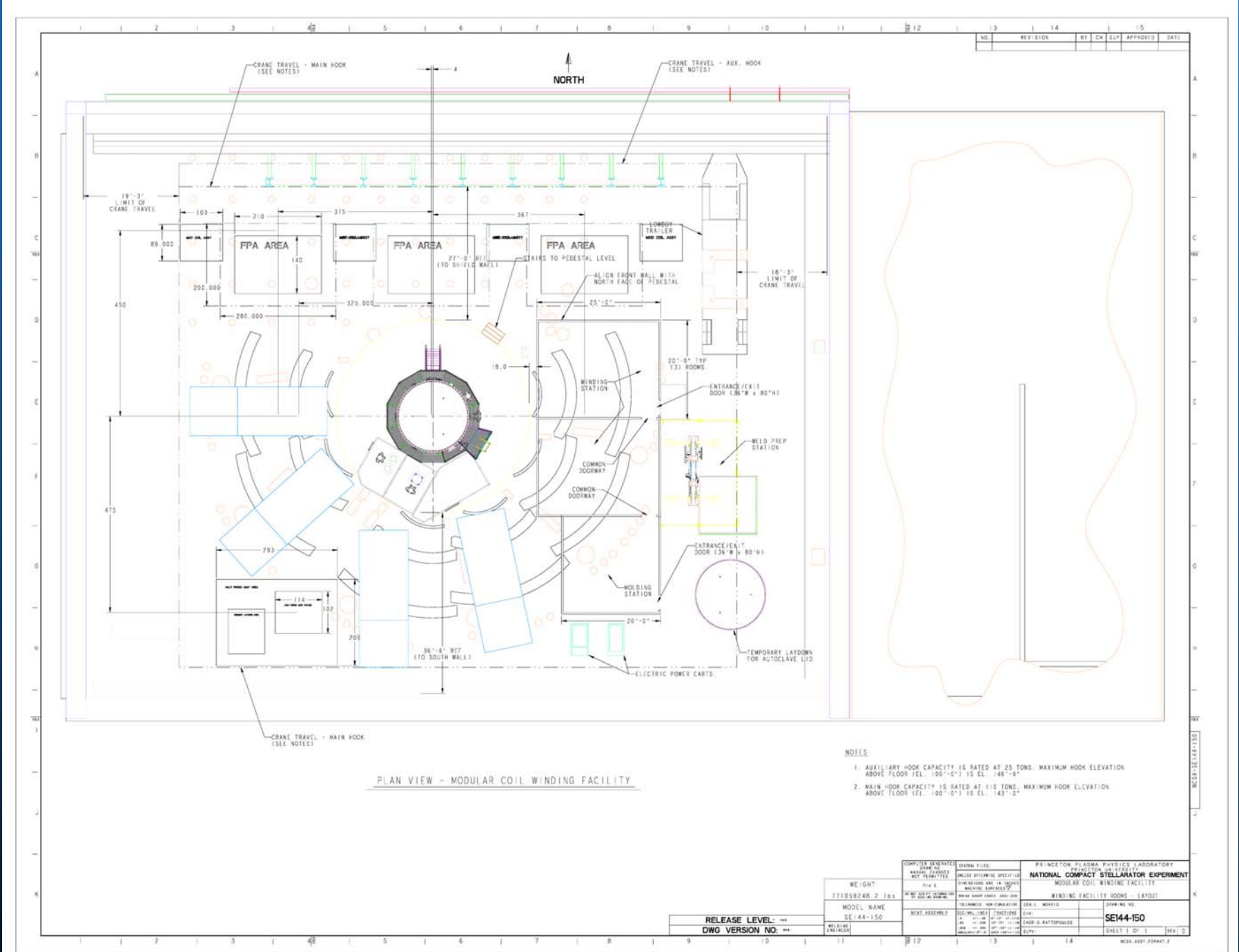
PPPL Site Plan

Crane



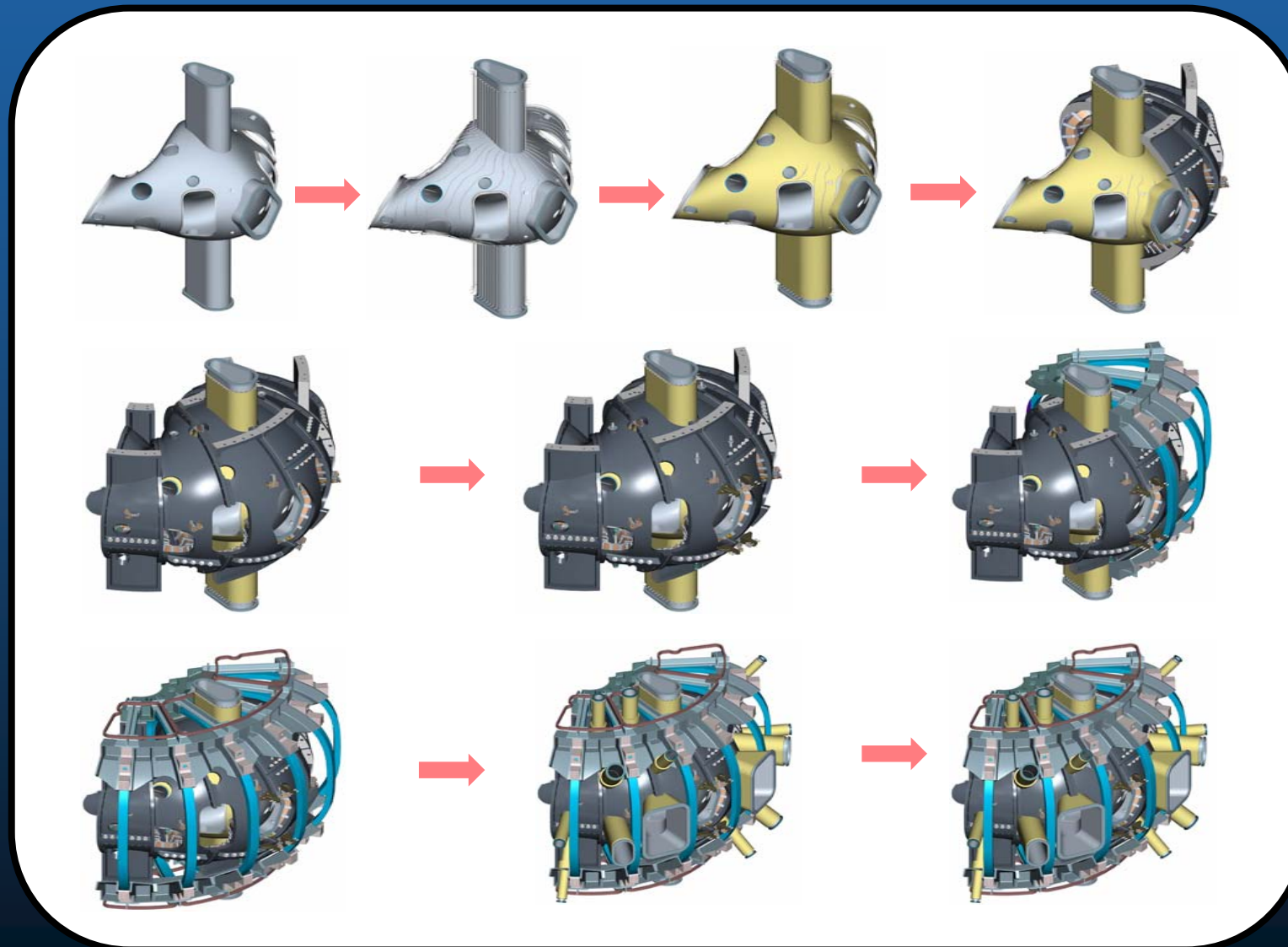
- **The TFTR Test Cell** will be used to assemble the Field Period Assembly (FPA)
- **Crane**
 - 110 Ton Big Hook
 - 25 Ton Small Hook (micro control)
 - 42' main hook motorized rotation
 - Small hook freely rotates height 42 ft plus
- **Temperature Control** - 75 degrees F +/- 5 degrees with 50% Relative Humidity +/- 10%
- **Assembled FPA** will be trucked from the TFTR test cell to the NCSX test cell

Field Period Assembly Area



Field Period Assembly

Field Period Components



Field Period Assembly Steps

- Receive and inspect vacuum vessel. Mount magnetic diagnostic sensors to surface.
- Install cooling/heating lines to vacuum vessel surface
- Insulate vacuum vessel
- Assemble right Modular Coil Assembly
- Assemble left Modular Coil Assembly
- Assemble vacuum vessel support hardware to Modular Coil structure
- Assemble right TF Coil Assembly
- Assemble left TF Coil Assembly
- Assemble external trim coils to TF Coil
- Attach ports to vacuum vessel

Receive and Mount Vessel



Field Period Assembly Steps

- The first step in the FPA is to position the vacuum vessel on the support frame
- Magnetic diagnostics sensors will be added to the vessel before the installation of vacuum vessel cooling tubes.
- A total of 132 diagnostics will be installed on the first period

Vacuum Vessel Support Requirements

Vacuum Vessel Support Requirements

- **Support Vacuum Vessel weight (shell, ports, diag, insulation).**
- **Position Vacuum Vessel relative to machine coordinate system in assembly area within +/- tbd. Since the vessel will be supported from the mod coils at the end of the Field Period Assy this tolerance should be based on the amount needed to slide the mod coils over the vessel.**
- **Conform to NCSX Structural Design Criteria**

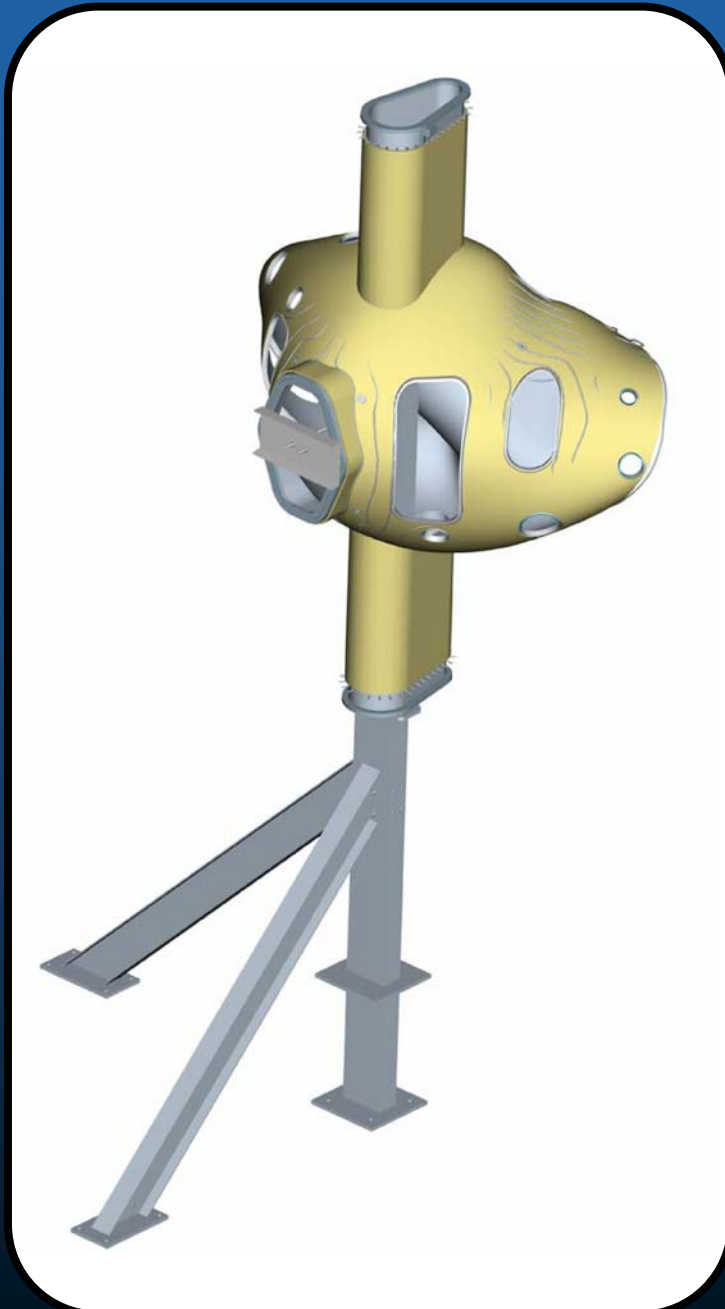
Install Cooling Tubes

NCSX



Field Period Assembly Steps

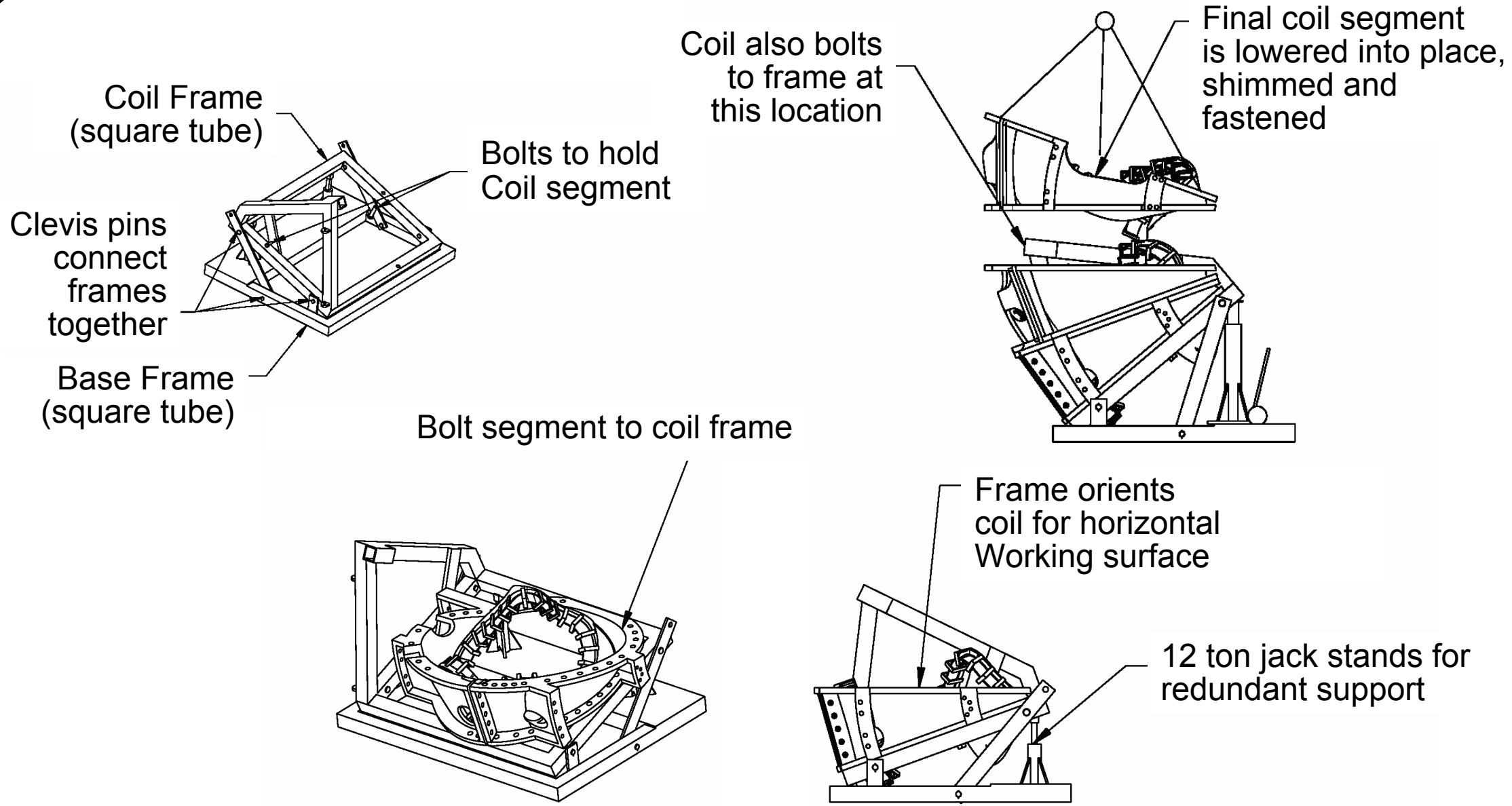
- Cooling/Heating tubes will be installed over the magnetic diagnostics sensors.
- The cooling tubes will be attached by spot welding a “J” clamp to the vacuum vessel surface.
- A thermal conducting epoxy, Stycast, will be cast between the tubes and the vessel for good thermal contact
- A total of 32 tubes will be installed on the vessel surface



Field Period Assembly Steps

- Microtherm insulation will be installed on the vessel surface
- The thickness of insulation around the vessel is 1.0 inch
- The insulation thickness around the ports is 1.5 inches

Assemble three Modular Coils

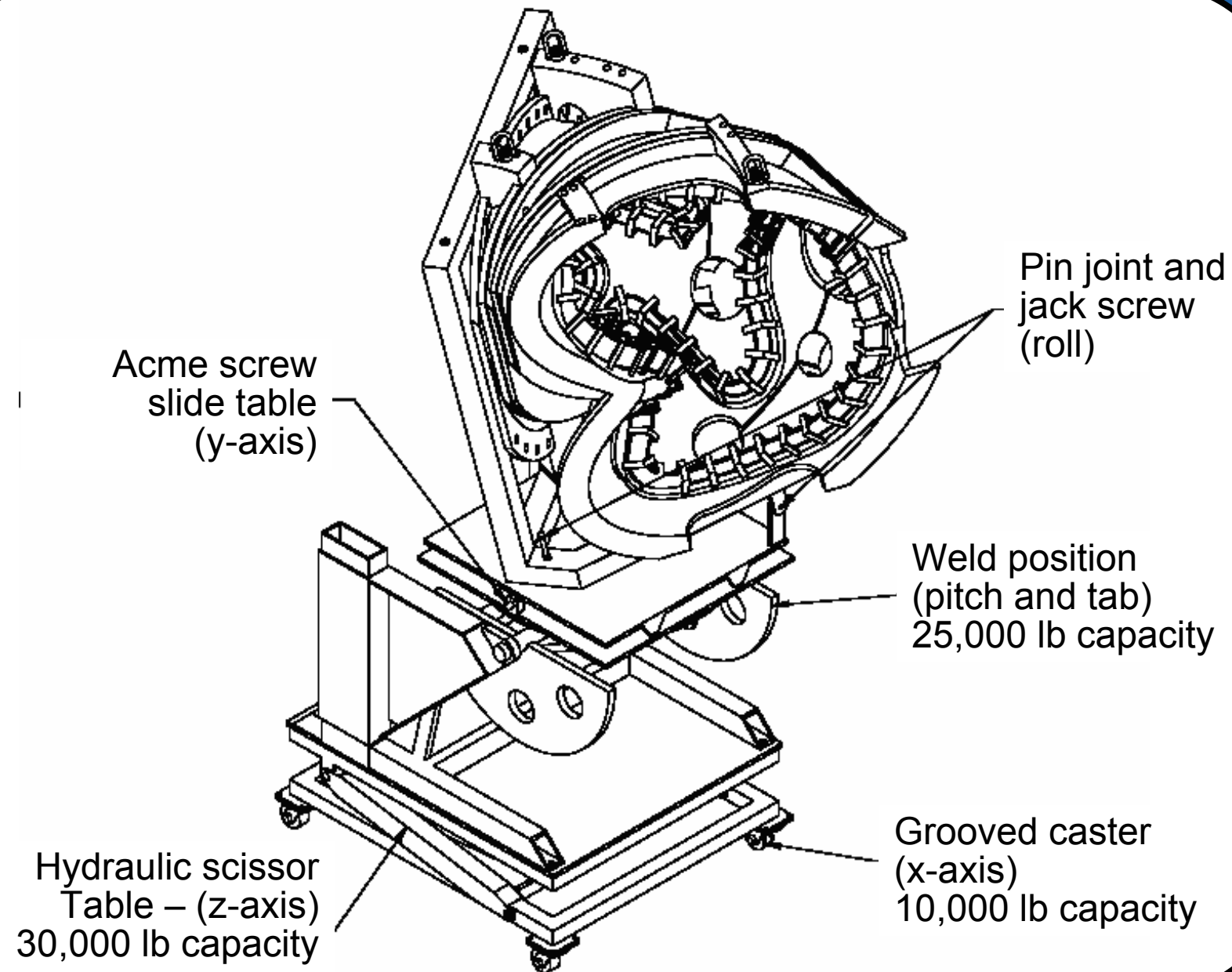


Half Period Assembly Fixture Requirements

- **Provide support for Segments 1, 2, & 3 during assembly**
- **Provide a stable base for assembly operations**
- **Positioning tolerance shall be provided by the offset cams between the mod coils**
- **Inspection data to be taken during assembly**
- **Conform to NCSX Structural Design Criteria**

Install Modular Coil in Assembly Fixture

NCSX

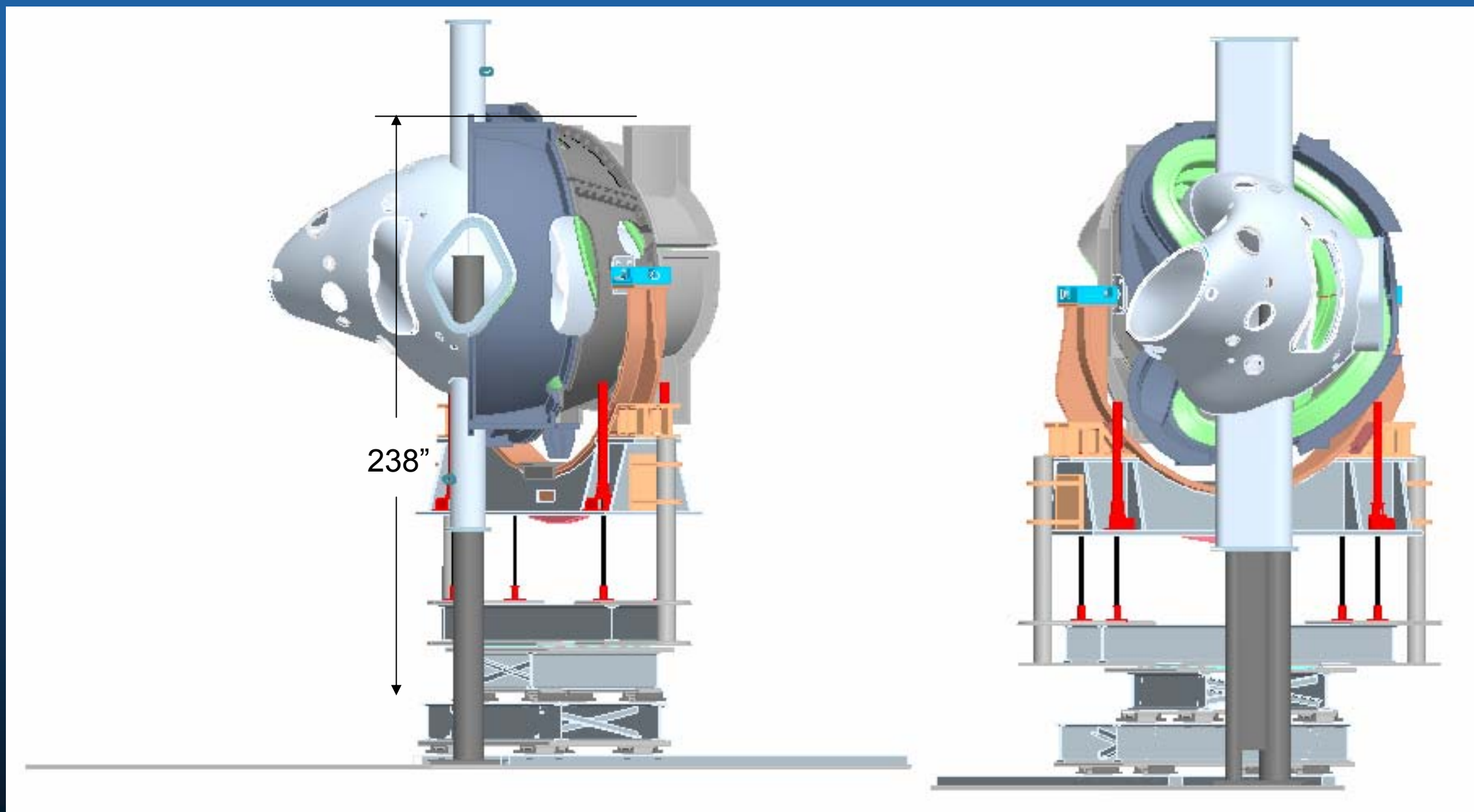


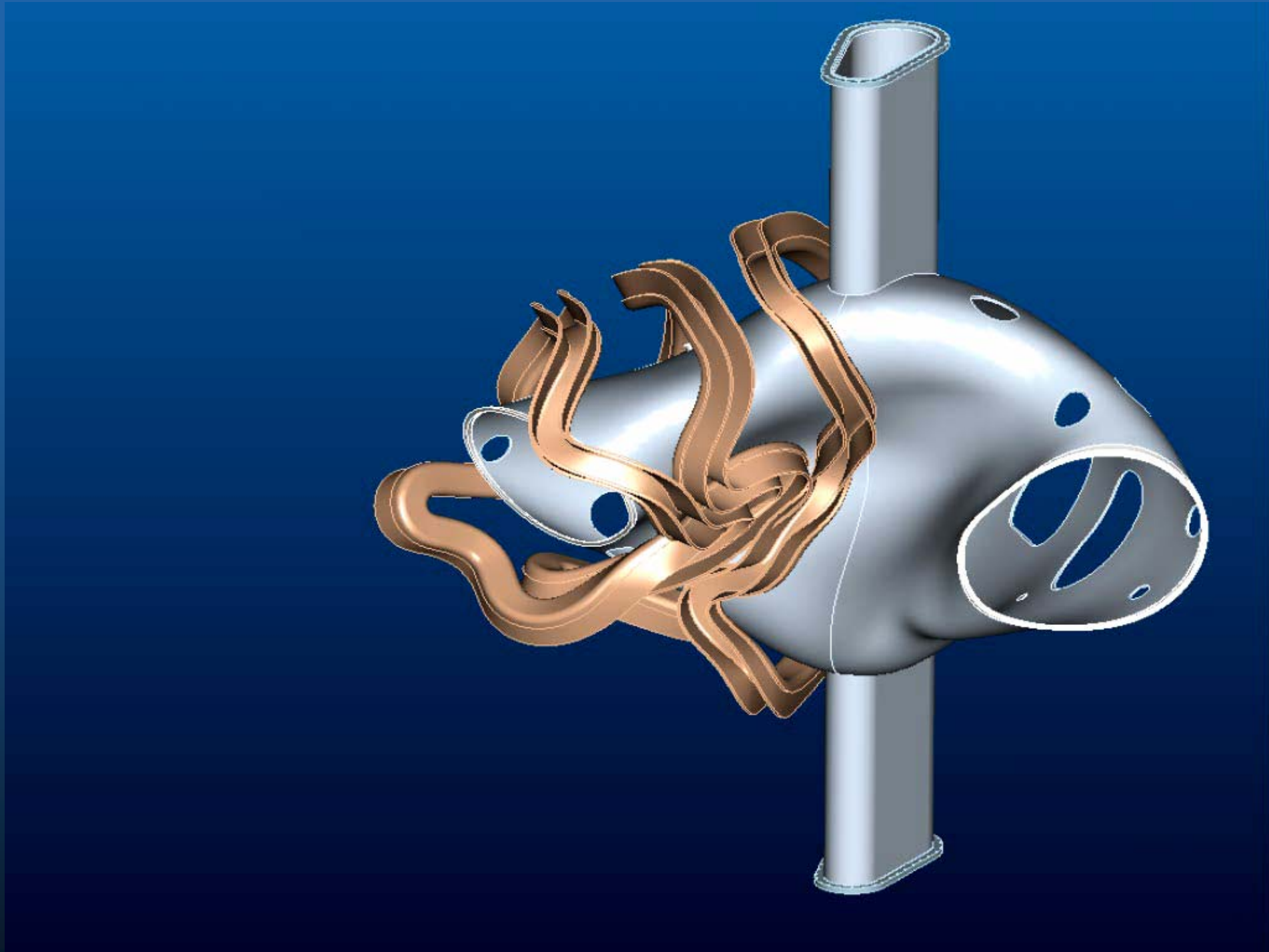
Two concepts are being pursued

- **NASA “TAP” Three Axis Positioner**
- **Tom Brown’s concept**

Install Modular Coil in Assembly Fixture

NCSX

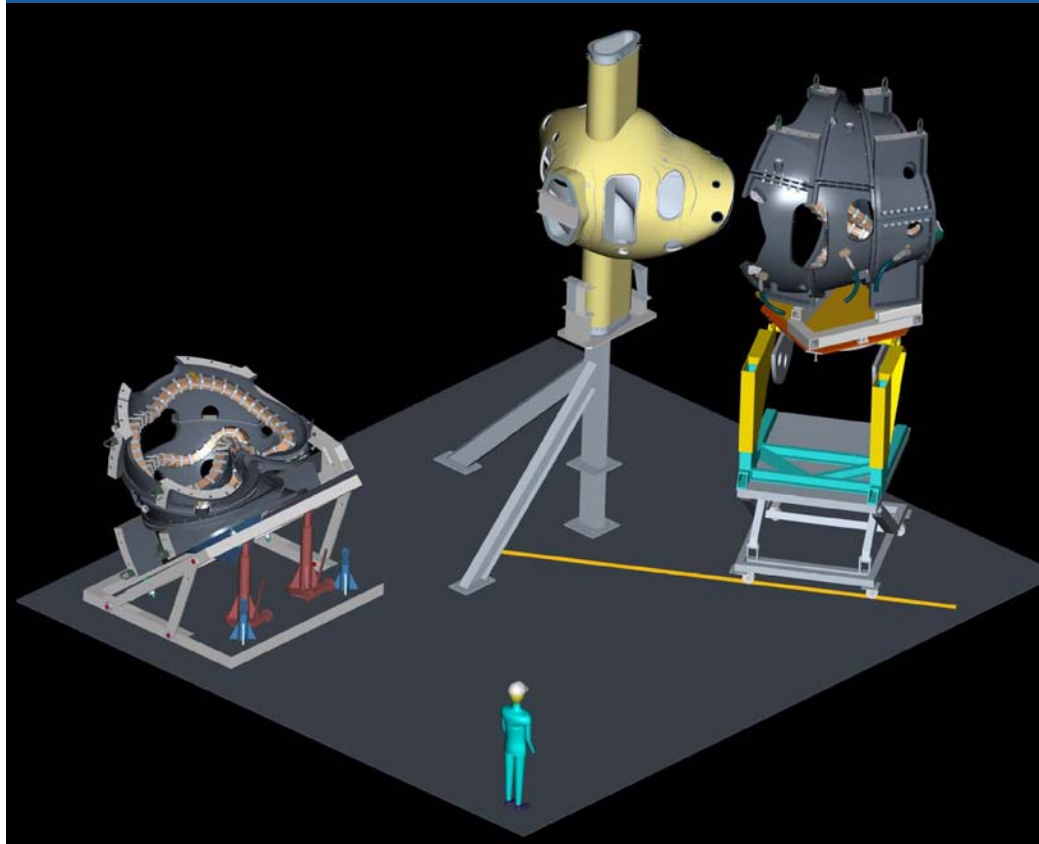




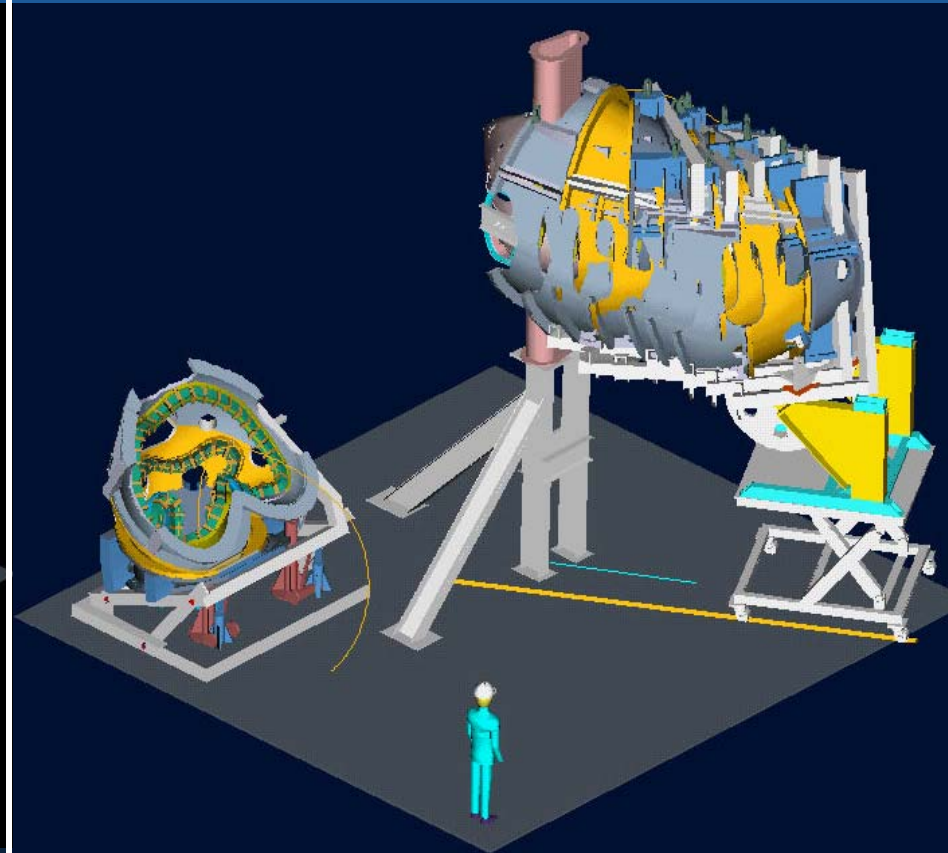
Install Modular Coils Over Vessel

NCSX

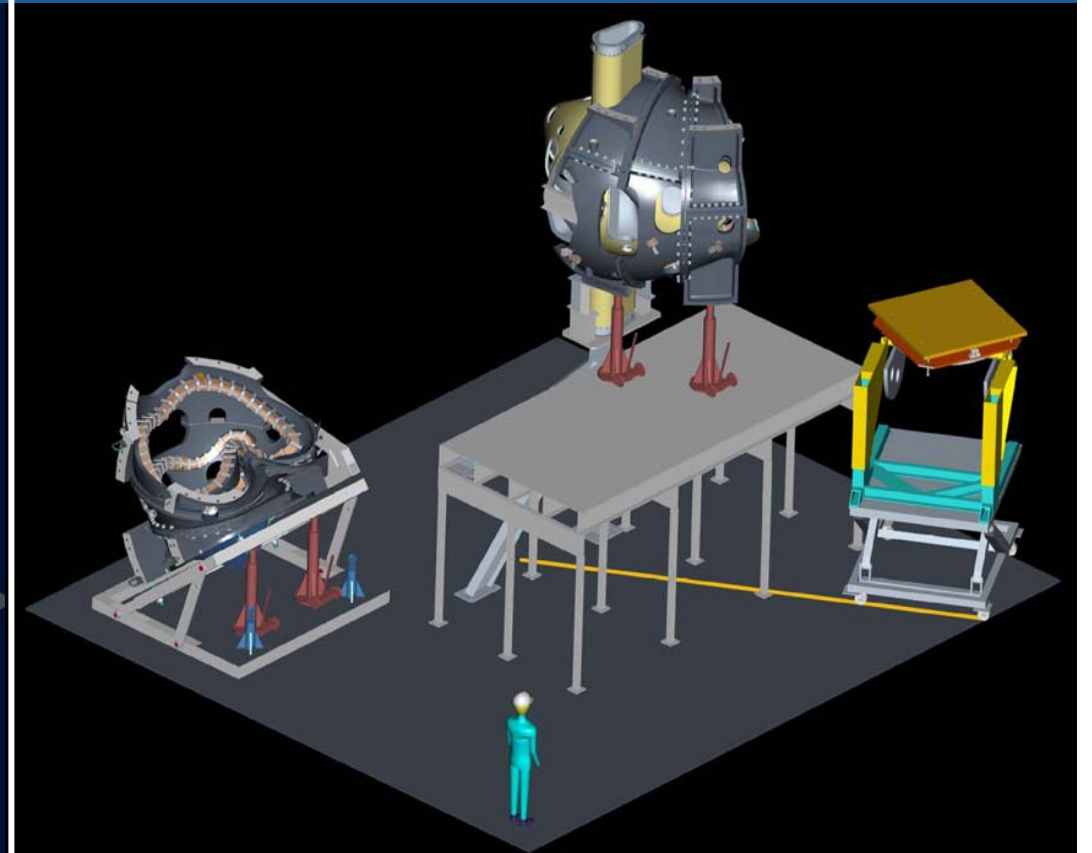
Positioning Modular Coil for assembly



Installing Modular Coil over vessel

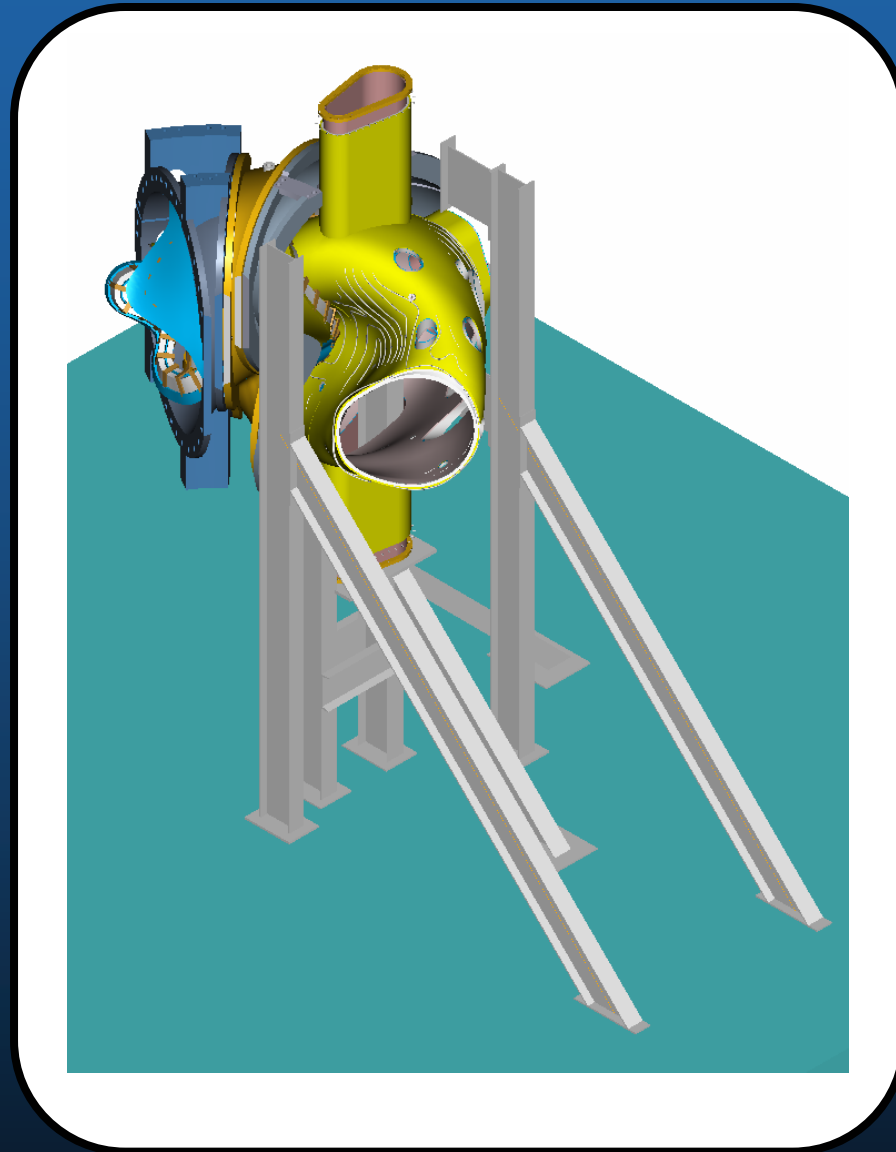


Temporary supports for Modular Coil



Install First Temporary Support

NCSX

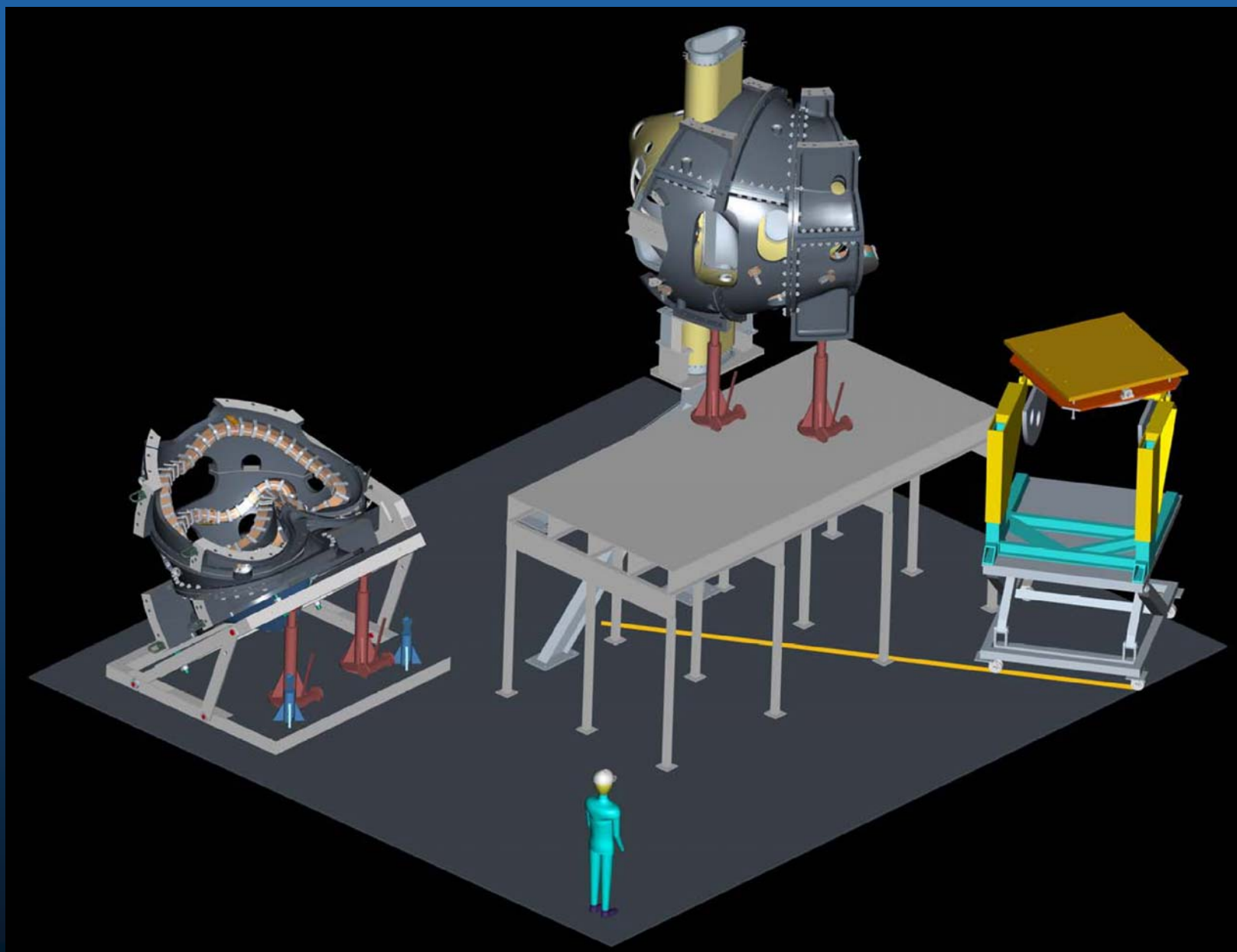


Field Period Assembly Steps

Temporary support to remove assembly fixture before installing supports for next modular coil half period

Install 2nd Temporary Support

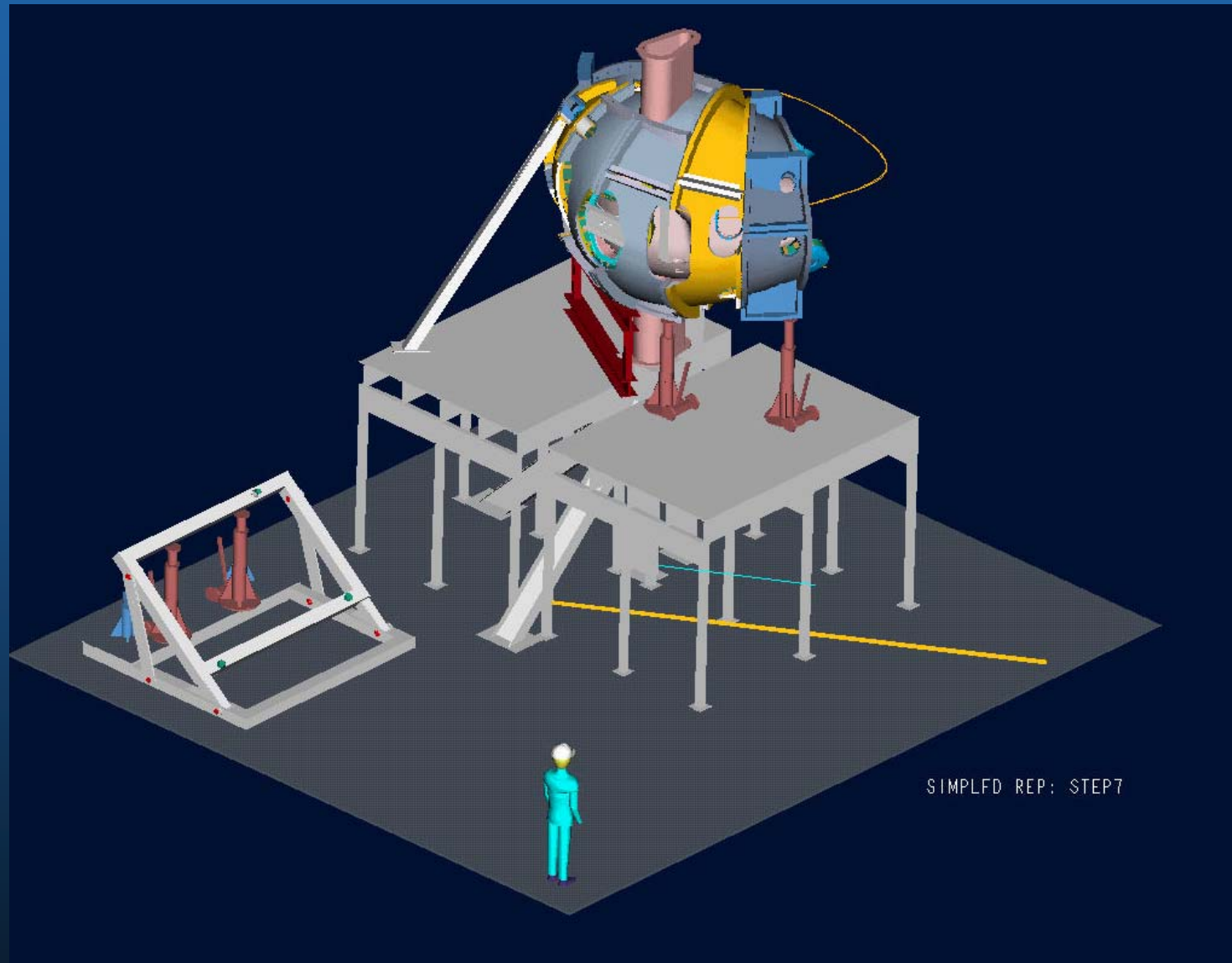
NCSX



Field Period Assembly Steps

This step shows the right half period Modular Coil assembly installed on the vessel.

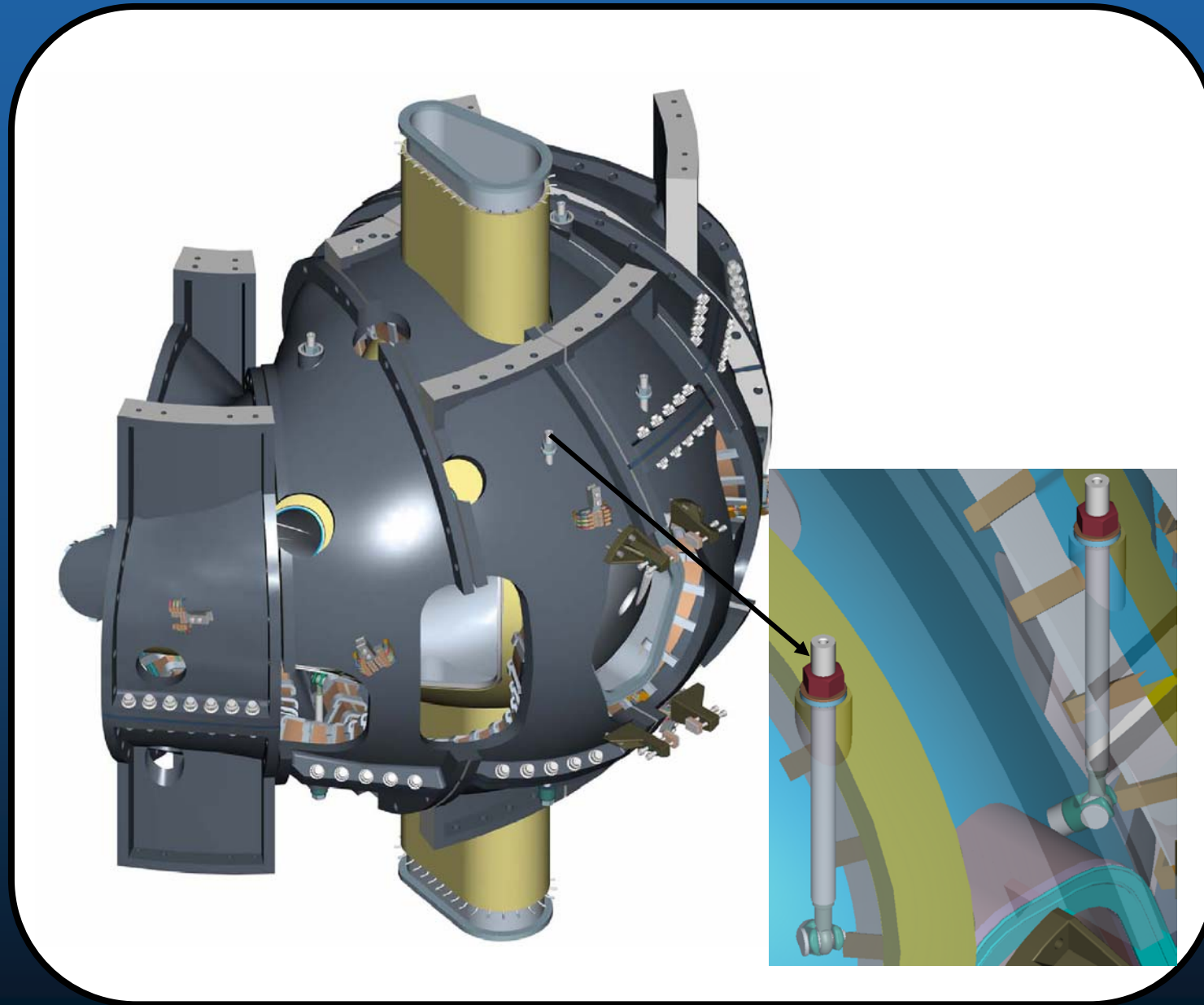
Field Period Assembly



Field Period Assembly Steps

- The assembly of the left half of the modular coils has been assembled to the right half modular coils
- **The shim between the left and right half has been installed and insulating bolts were matched reamed and torqued.**
- Inspection of the modular coils has been performed to verify that the coils are correctly installed.

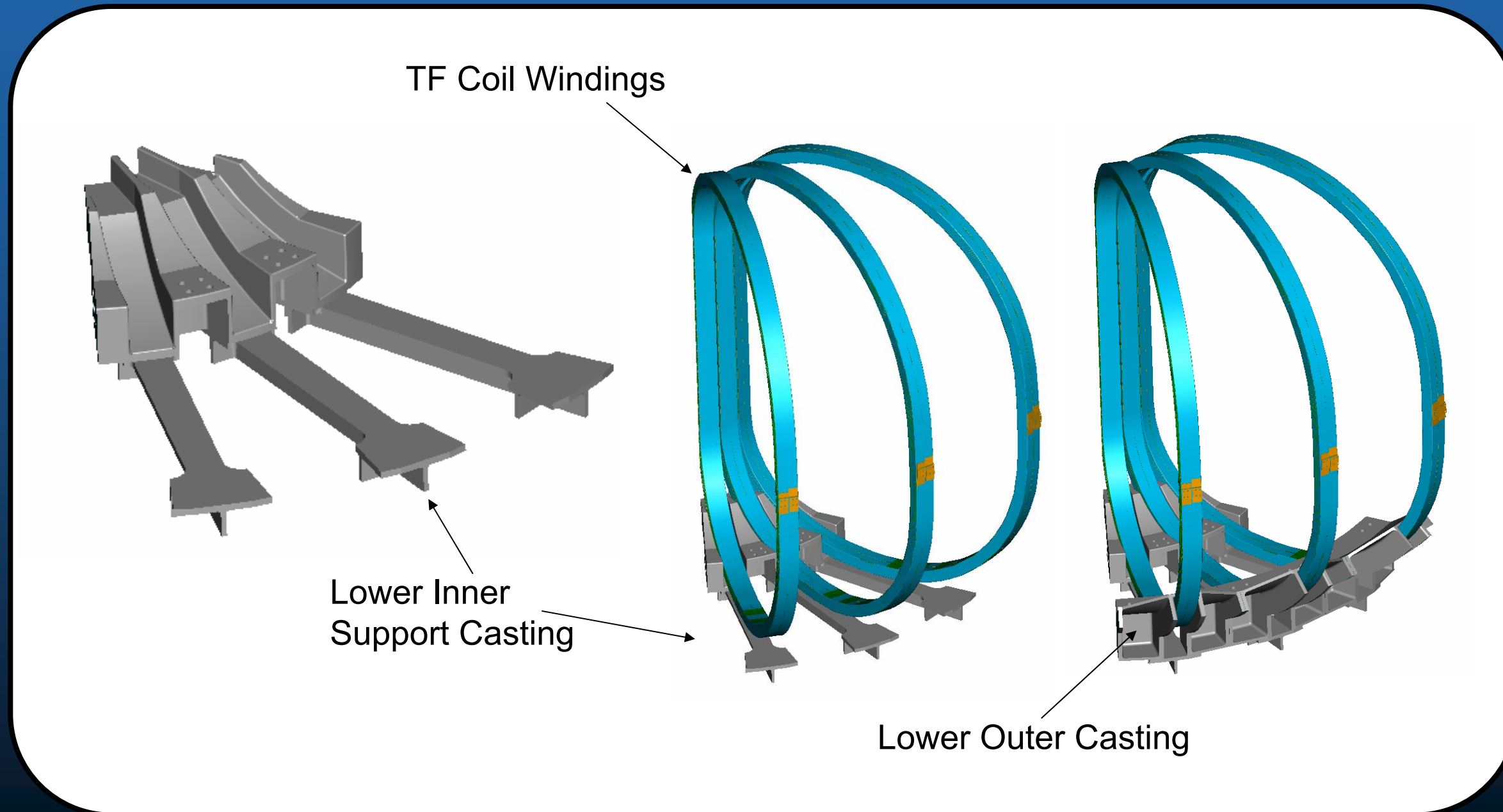
Field Period Assembly



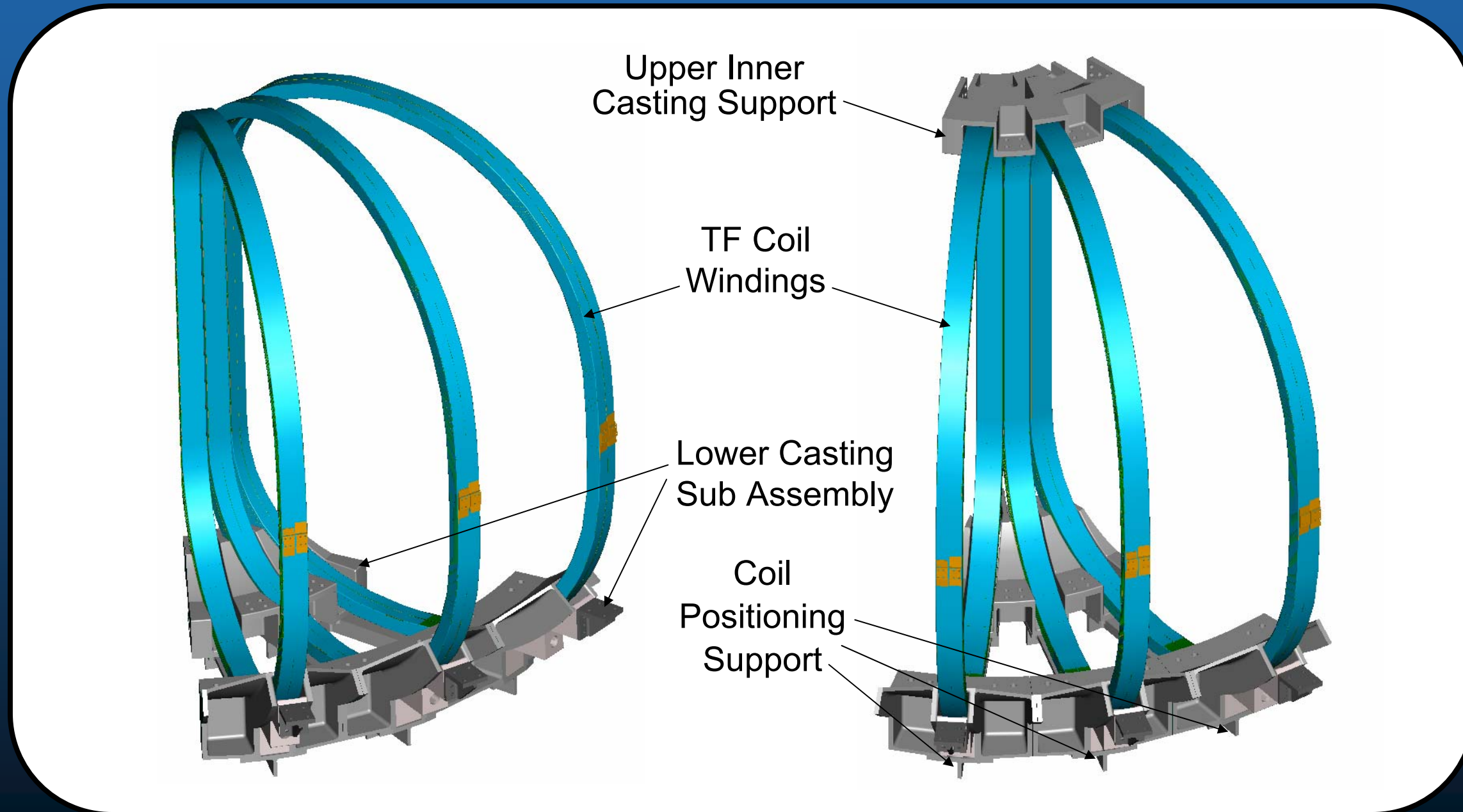
Field Period Assembly Steps

- Hardware for supporting the vacuum vessel is installed between the vessel and the shell structure
- The vessel support hardware is installed thru the open ports
- The vessel supports are snug but do not fully support the weight of the vessel.
- Before installing the half period TF Coil subassembly this component is fabricated as follows

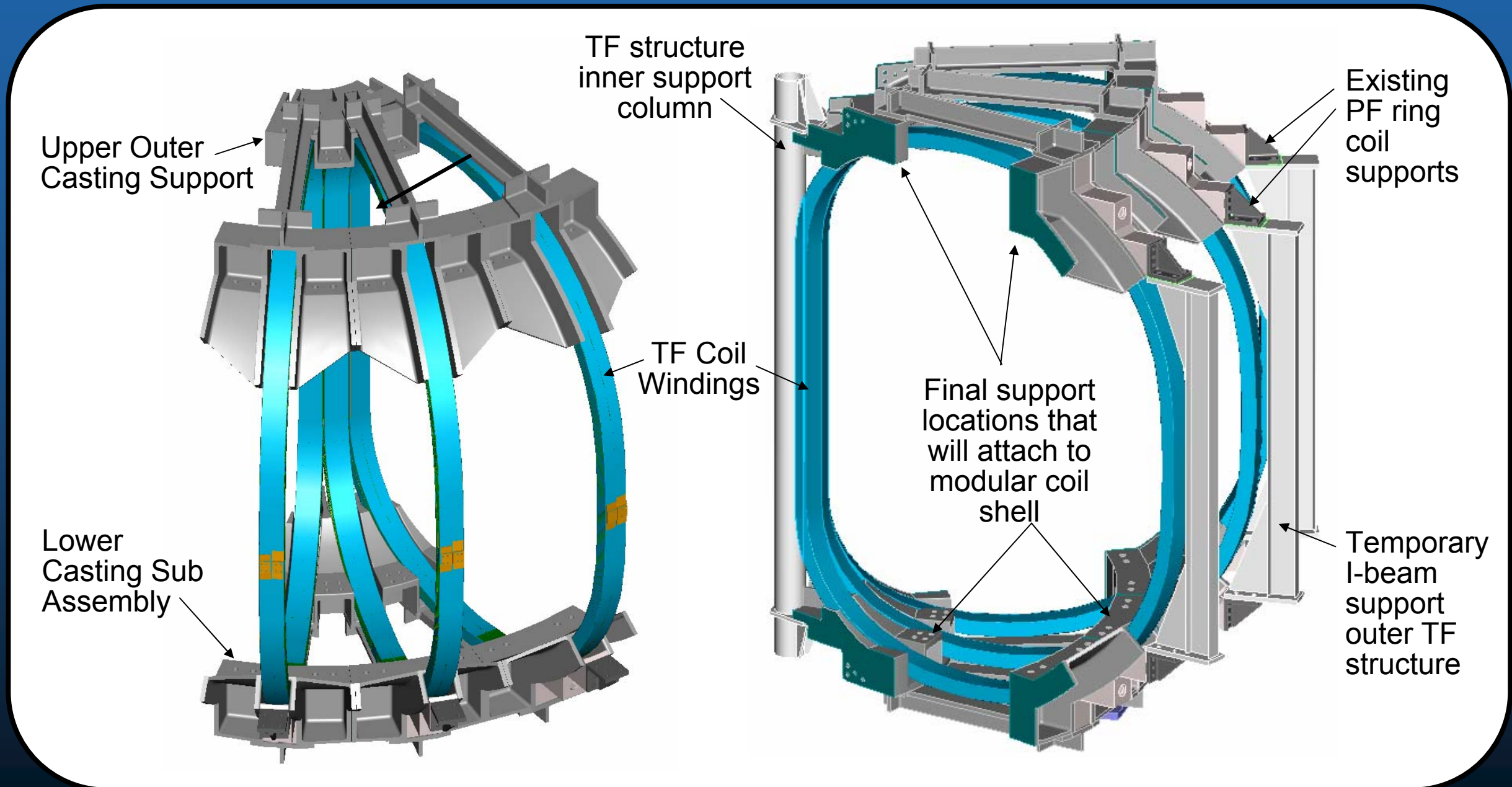
TF Coil Half Period Assembly



TF Coil Half Period Assembly

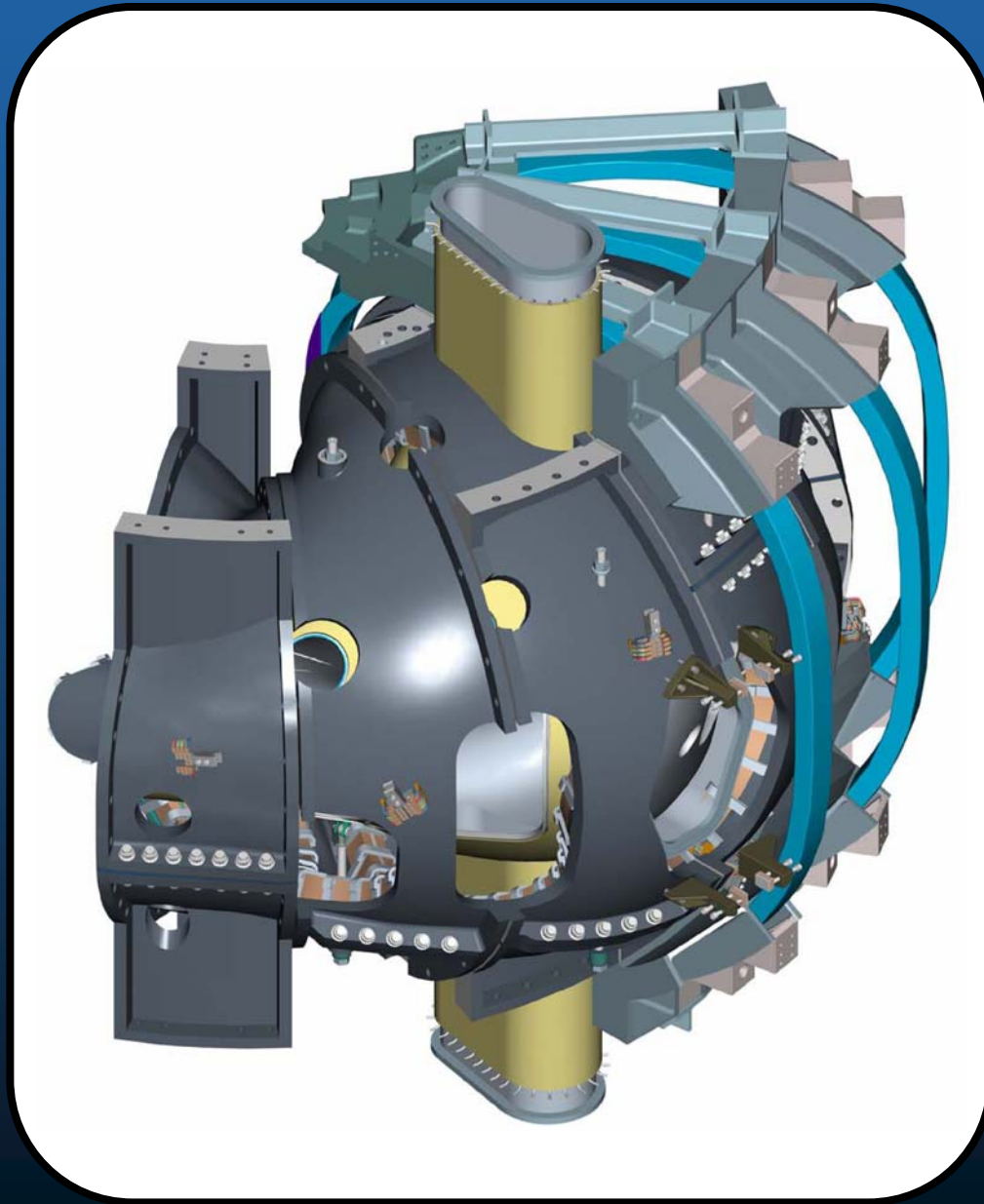


TF Coil Half Period Assembly



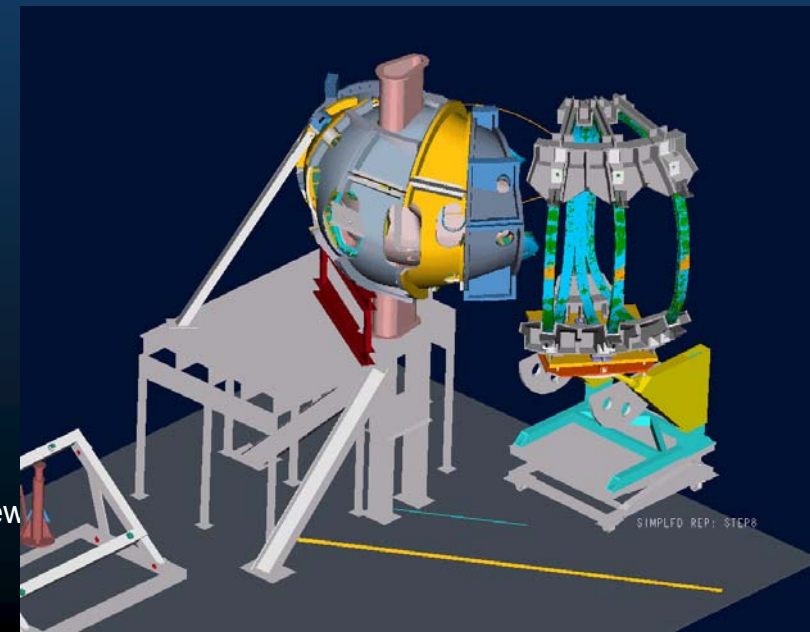
Assemble Right TF Coil Over Modular Coils

NCSX



Field Period Assembly Steps

- The installation of the right half period TF Coil subassembly is performed by first supporting the modular coil sub-assembly on the left side and cantilevering the right side of the mod coil. Temporary supports are removed from the right side of the Modular coil sub-assembly
- The TF coil half period
- sub-assembly is a simple rotation that can be accomplished from the crane or by using special fixtures.



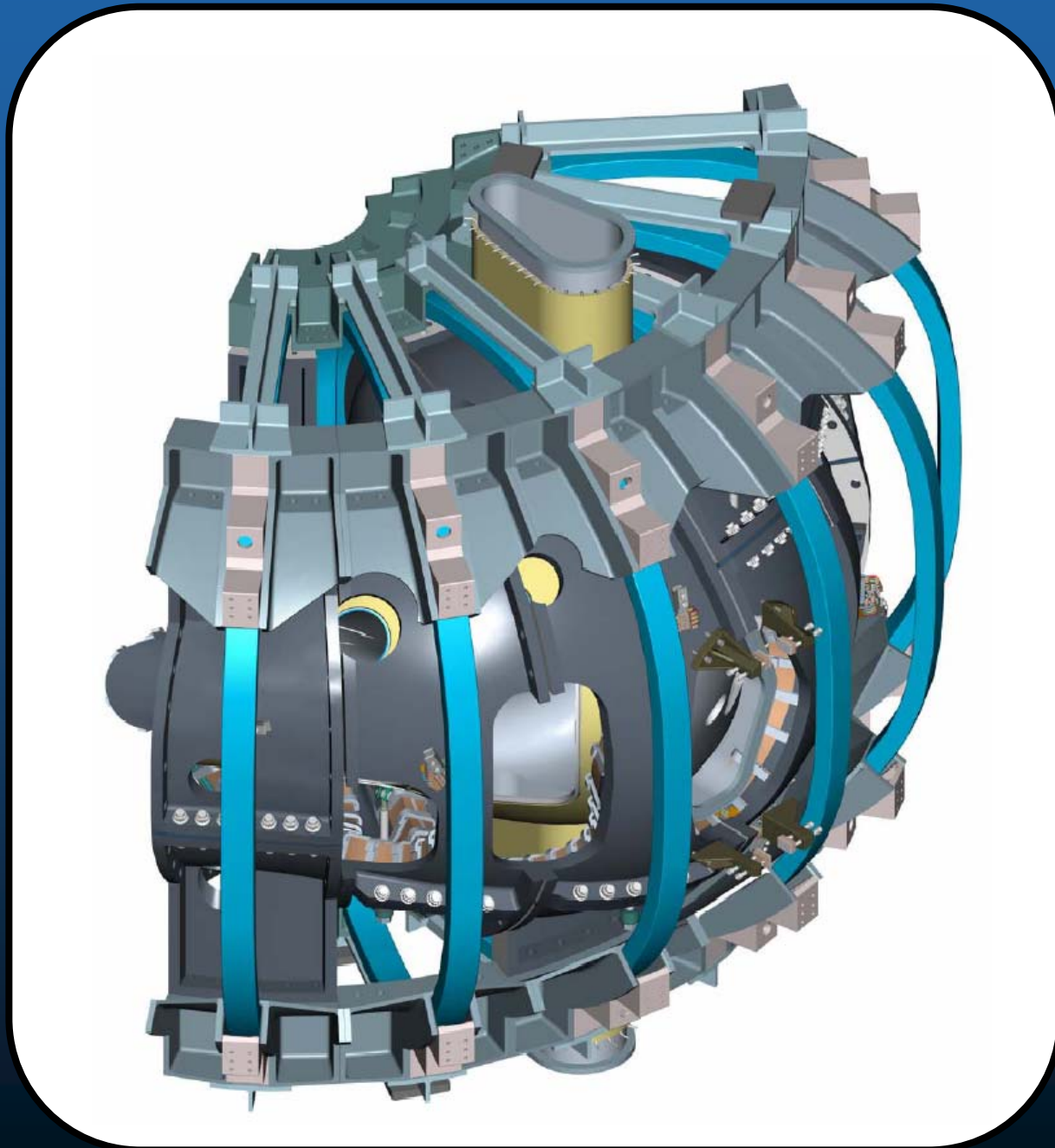
March 30, 2004

NCSX FPA Peer Review

M. Cole
30

Assemble Left TF Coil Over Modular Coils

NCSX



Field Period Assembly Steps

The left TF Coil sub-assembly is installed using the same technique as the right TF Coil.

Shimming Between the TF Coil and Modular Coil

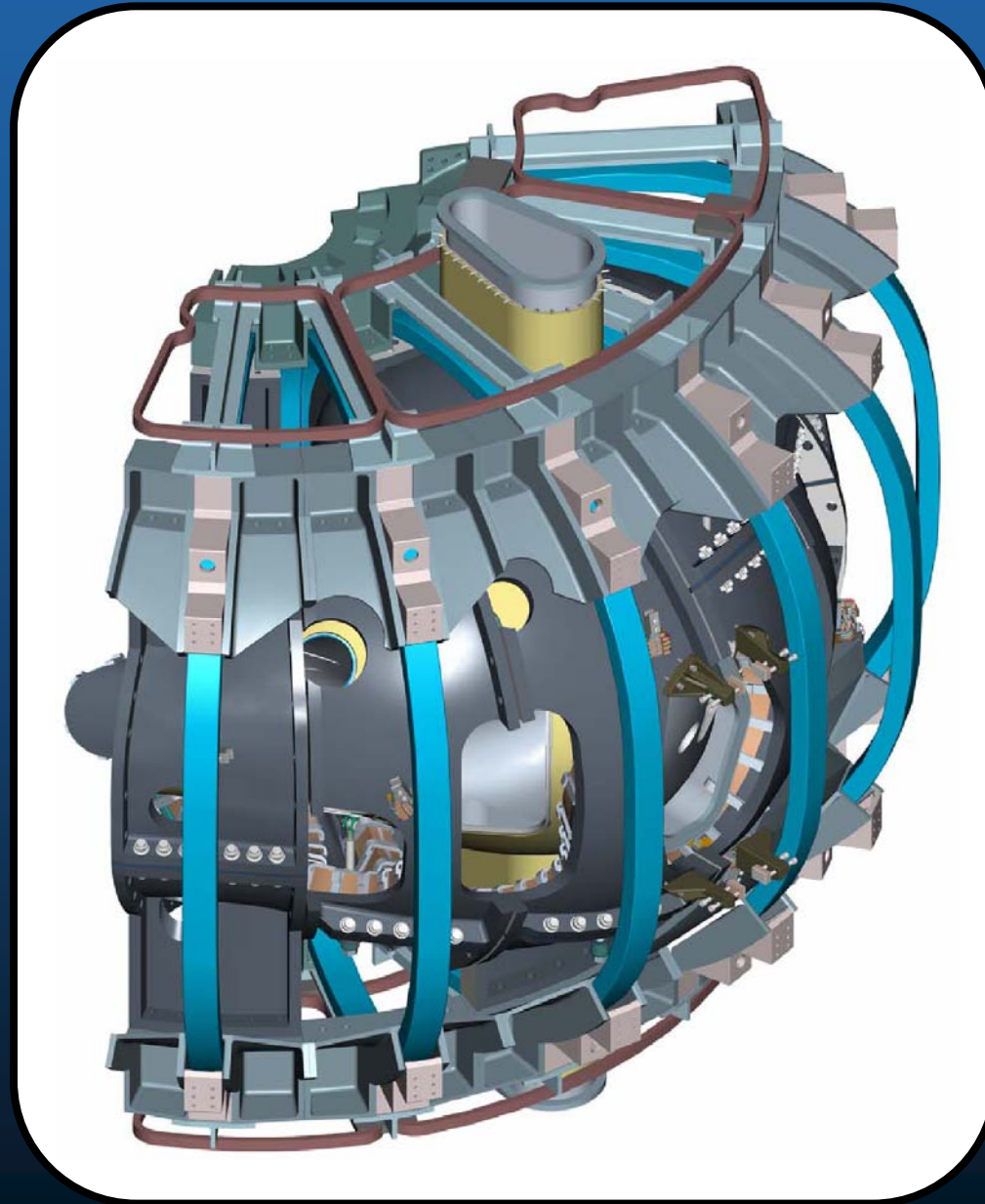
NCSX



Field Period Assembly Steps

- During the assembly of the TF Coils shims are placed between the Modular Coils and the TF Coils.
- The shims are located on the upper and lower supports on the inside and outside shelf.

Install External Trim Coils



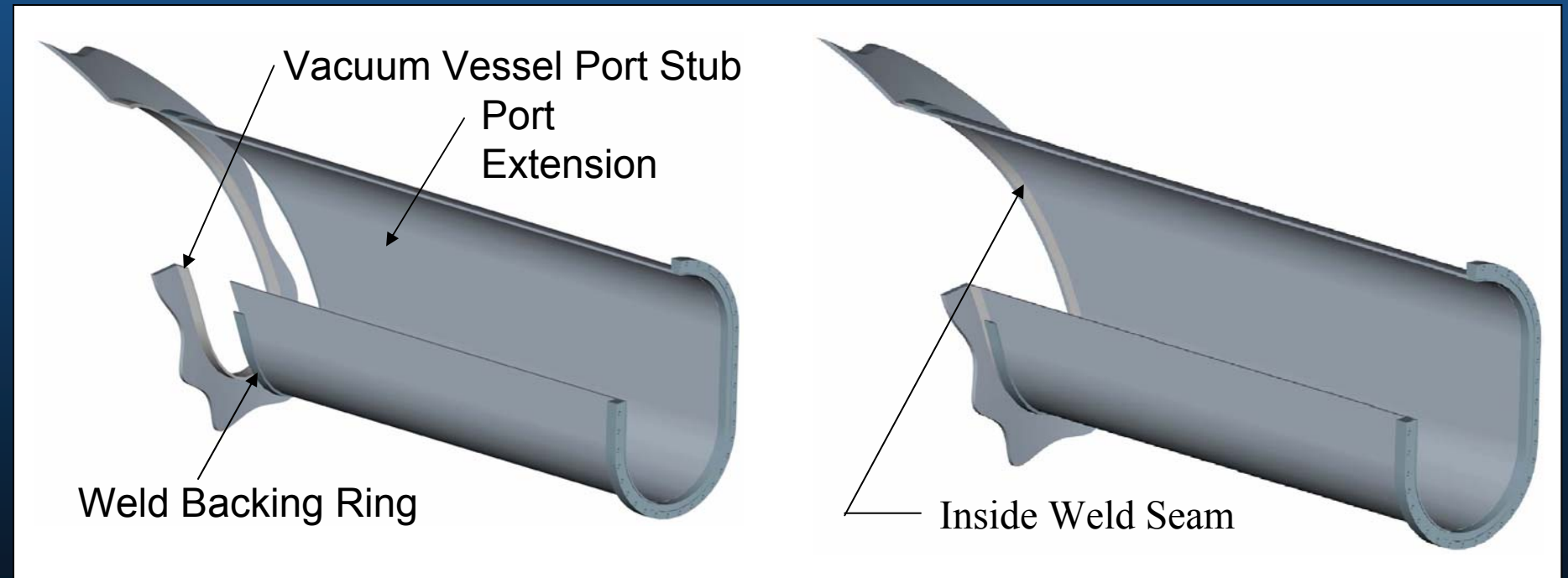
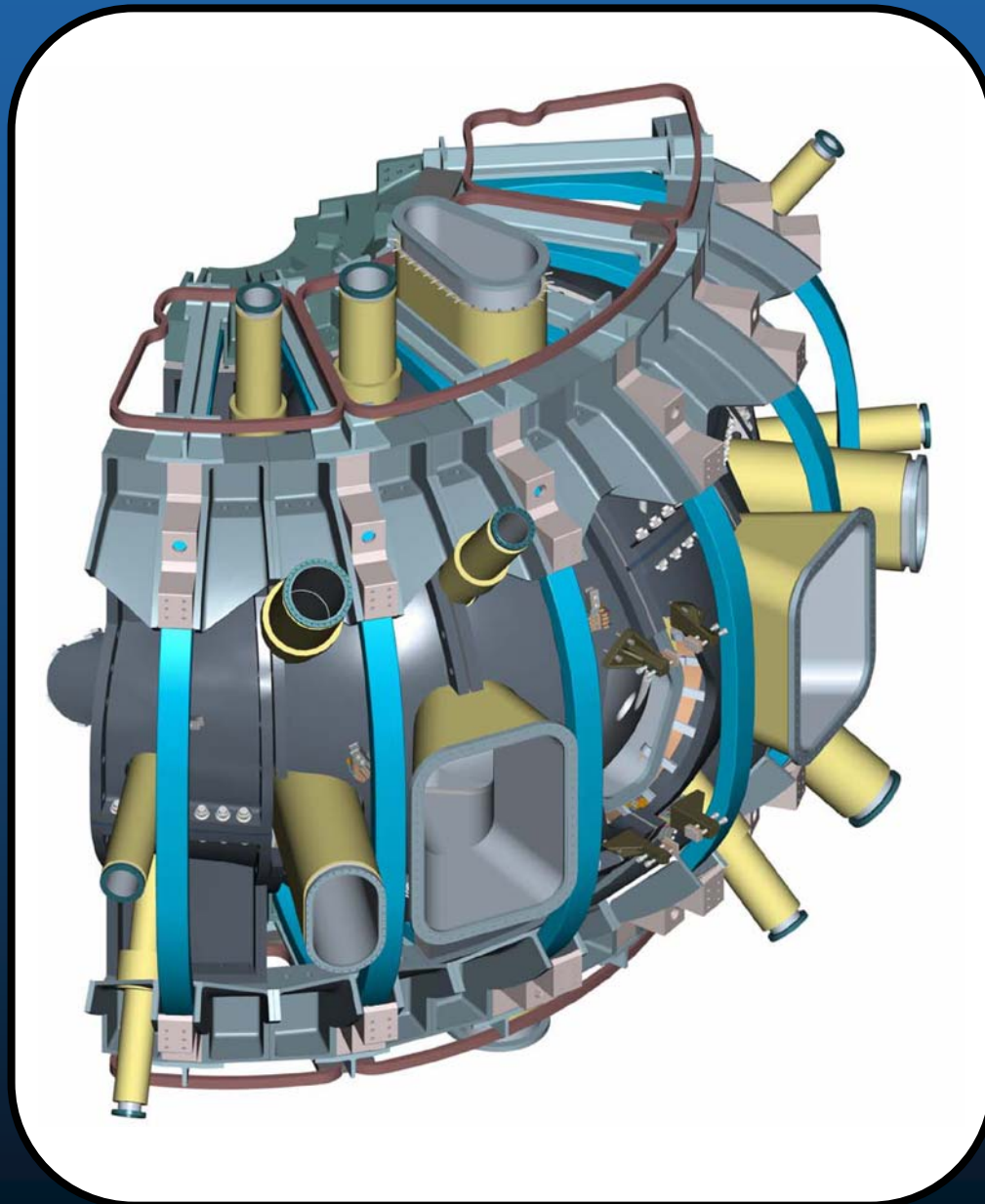
Field Period Assembly Steps

- The top and bottom External Trim Coils are attached to the structure of the TF Coil assembly. The outboard External Trim Coils will be assembled at the machine assembly

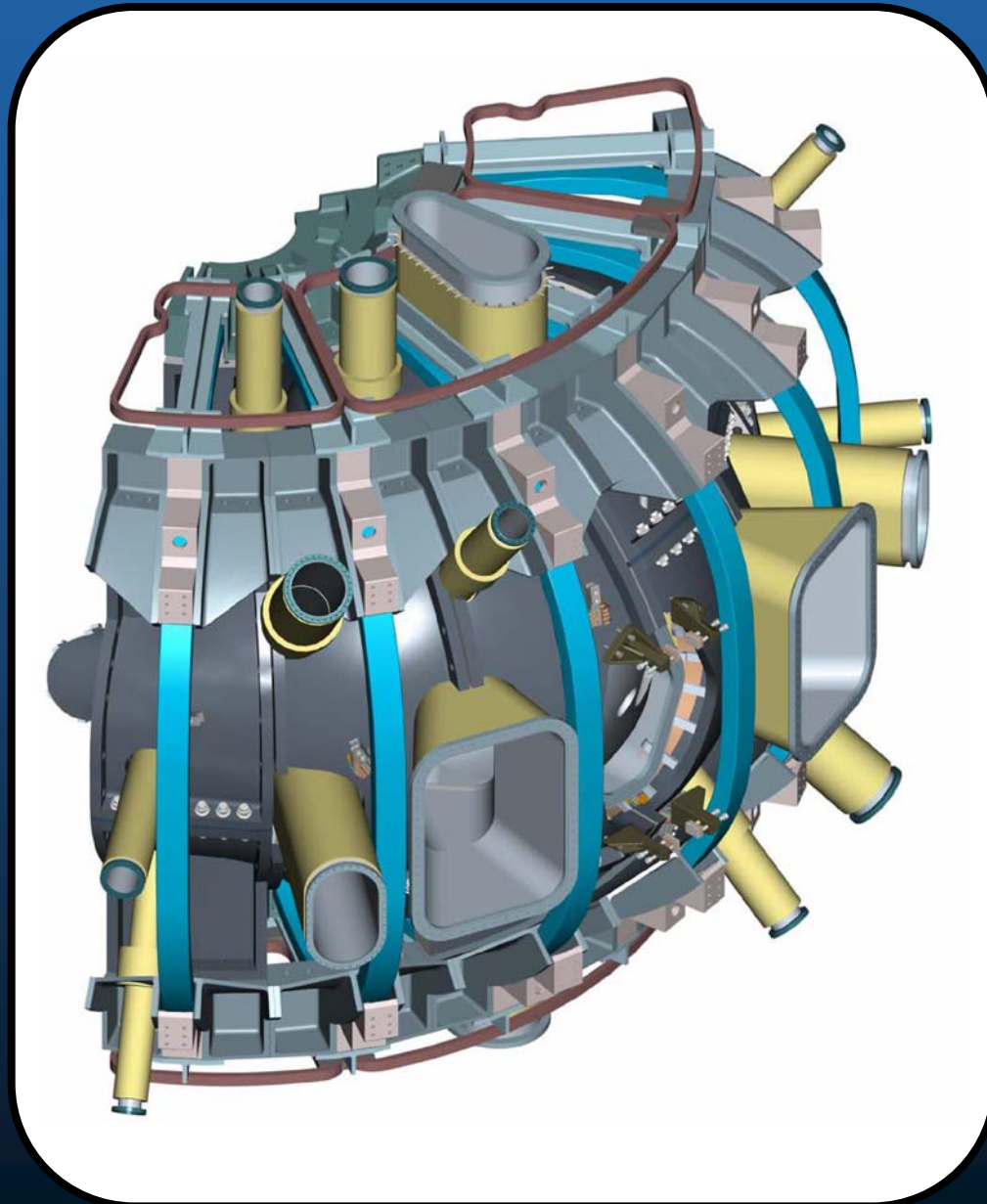
Weld Ports to Vacuum Vessel

Field Period Assembly Steps

- Weld port extension to vacuum vessel port stub
- Ports are positioned and welded from the inside

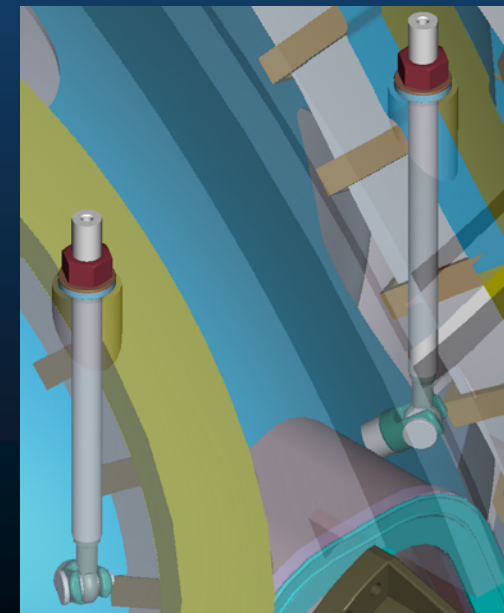


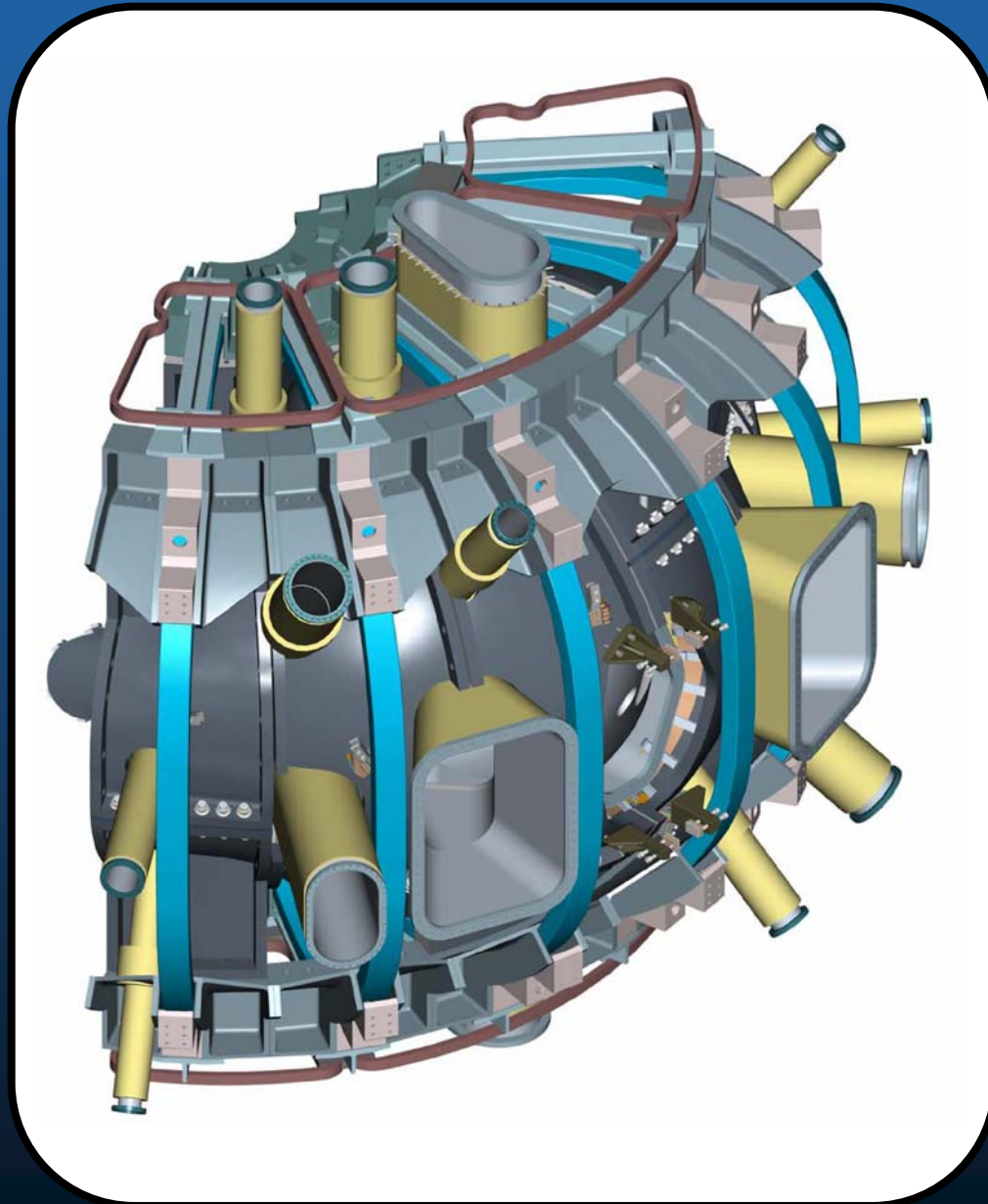
Suspend Vessel in Modular Coil Shell



Field Period Assembly Steps

- After the Ports have been installed the support hardware for the vacuum vessel is now adjusted to lift the vessel from the support stand.
- The vessel is fully supported from the Modular Coil shell.
- The Field Period Assembly has been completed

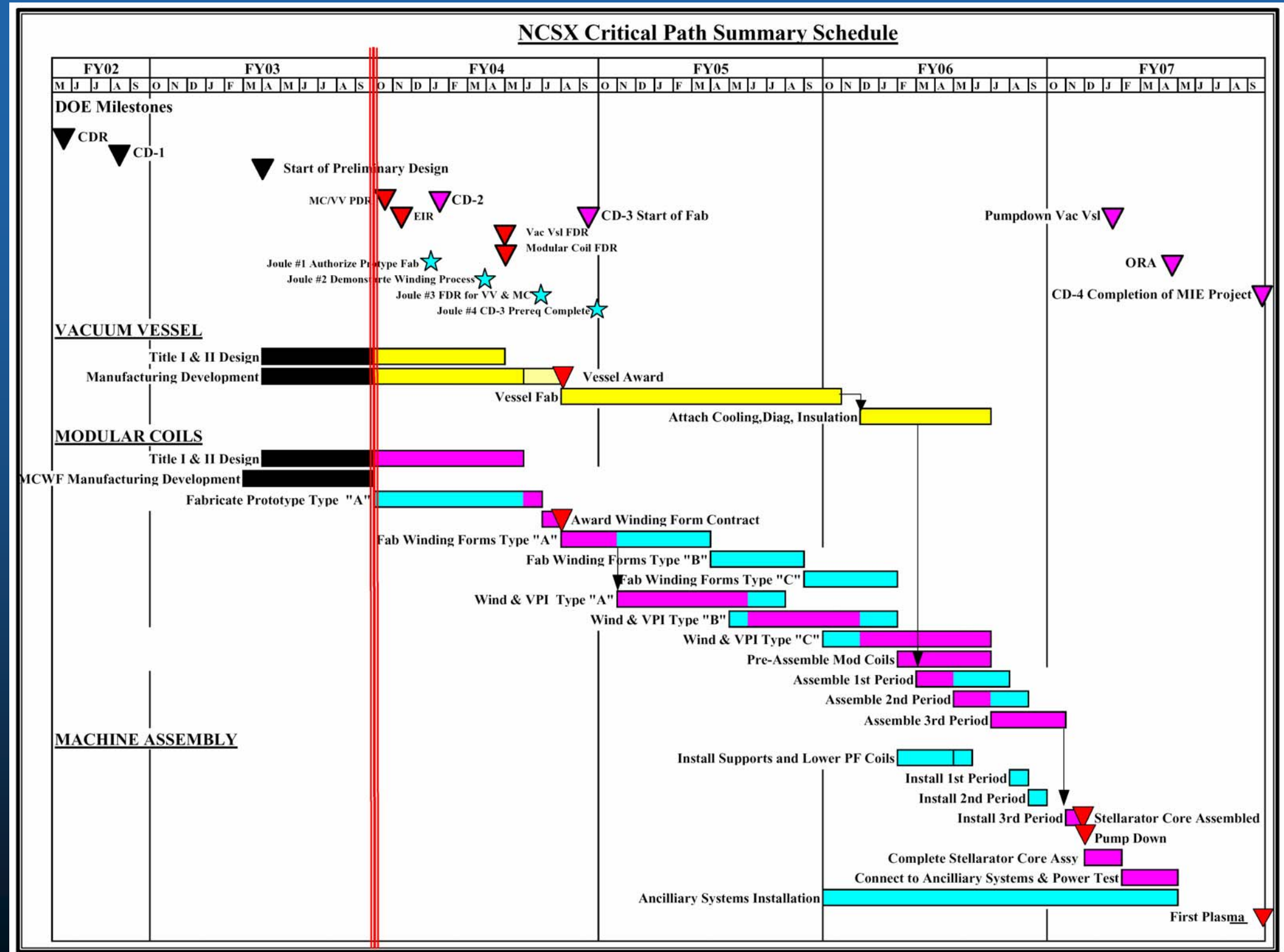




Field Period Assembly Testing

- Dimensional inspection data has been taken during every stage of the Field Period Assembly. An additional inspection will be made to verify all components have maintained tolerance.
- The Vacuum Vessel will be sealed with blank off port covers and heated to 150°C.
- The vessel temperature will be cycled to open any potential cracks that may have occurred during welding.
- A total vacuum leak rate test will be performed to verify the vessel leak rate requirement.

Schedule



| WBS | Description |
|-----------|---|
| 18 | Stellarator Core Systems |
| | Field Period Assembly |
| | 181 Planning and Oversight |
| | 182 Preparation of the TFTR Test Cell |
| | 183 Receipt, Inspection, and Testing of Coils |
| | 184 Receipt, Inspection, and Testing of Vacuum Vessel |
| | 185 Field Period Assembly |
| | 186 Tooling Design and Fabrication |
| | 187 Measurement Systems |

| Sum of cost | | WBS | | | | | | | Grand Total |
|--|---------------|----------------|-------------|-------------|--------------|----------------|----------------|--------------|----------------|
| Cost Category | Expense class | 181 | 182 | 183 | 184 | 185 | 186 | 187 | |
| 2) Title I & II | Labor/Other | | | | | | \$490 | \$51 | \$541 |
| | M&S | | | | | | \$158 | | \$158 |
| 3) Fabrication/Assembly (incl title III) | Labor/Other | \$1,371 | | \$77 | \$288 | \$1,325 | \$17 | \$10 | \$3,089 |
| | M&S | | | | | | \$423 | \$439 | \$862 |
| 3) Fabrication/Assembly (incl title III) Total | | \$1,371 | | \$77 | \$288 | \$1,325 | \$440 | \$450 | \$3,951 |
| 4) Installation/Test | Labor/Other | | \$91 | | | | \$244 | \$49 | \$385 |
| 4) Installation/Test Total | | | \$91 | | | | \$244 | \$49 | \$385 |
| Grand Total | | \$1,371 | \$91 | \$77 | \$288 | \$1,325 | \$1,333 | \$550 | \$5,036 |

- **Cost for the Field Period Assembly was developed as a bottoms up estimate using estimated times and crew sizes**
- **Cost savings have been realized by using standard equipment where possible, such as the standard weld positioner, lifting table, and metrology equipment.**
- **Total cost of \$5036k is divided among the categories of oversight (\$1371k), inspection and assembly activities (\$1782k), and tooling/fixtures/metrology equipment (\$1883k).**
- **Contingency for the Field Period assembly and tooling fixtures has been assigned a value of 40%. The total contingency for WBS 18 is 32%**

| WBS Level 2 | FY03 (\$k) | FY04 (\$k) | FY05 (\$k) | FY06 (\$k) | FY07 (\$k) | TOTAL (\$k) |
|----------------------------|------------|------------|------------|------------|------------|-------------|
| 18 - Field Period Assembly | \$88 | \$964 | \$1,287 | \$2,631 | \$66 | \$5,036 |

Schedule



| Activity ID | Activity Description | Work Days | Weeks | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|---|-----------|-------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| Field Period #1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 184 - Receive, Inspect, and Test VV | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P1-180 | Rec'v VV, Attach clng tubes & Insul to 1st Period | 39 | █ | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 185 - Assemble Field Periods | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Modular Coil Sub-assembly | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 184-200 | Mount/align right mod coil in fixture-Period #1 | 15 | | | | | | | █ | | | | | | | | | | | | | | | | | | | | | | |
| 184-205 | Mount/align left mod coil in fixture-Period #1 | 12 | | | | | | | | | | █ | | | | | | | | | | | | | | | | | | | |
| TF Coil Sub-assembly | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 184-100 | Assemble 3 TF coils&structure -Right -Period #1 | 10 | | | | | | | | | | | | █ | | | | | | | | | | | | | | | | | |
| 184-105 | Assemble 3 TF coils&structure -Left -Period #1 | 10 | | | | | | | | | | | | | █ | | | | | | | | | | | | | | | | |
| Period 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P1-181 | Assemble 1st. Field Period - coils/VV | 37 | | | | | | | | | | █ | | | | | | | | | | | | | | | | | | | |
| P1-191 | Position and weld port assemblies | 15 | | | | | | | | | | | | | | | | | | █ | | | | | | | | | | | |
| P1-201 | Bakeout vessel segment to 150 degrees C | 6 | | | | | | | | | | | | | | | | | | | | | █ | | | | | | | | |
| P1-211 | vacuum leak check & Ext Trim coil instl | 25 | | | | | | | | | | | | | | | | | | | | | | | █ | | | | | | |
| P1-221 | Prepare field period for shipment | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | █ | |
| P1-231 | Ship 1st. Field period | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | █ | █ |
| P1-241 | Field period 1 ready for installation | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Risk areas addressed by design and R&D

- **Field Period Assembly**
 - Will the mod coils slide over the vacuum vessel?
Design analyzed several ways, all geometry fully inspected
 - Are the fixtures and metrology systems adequate?
R&D with full sized mockups is planned

- **The Field Periods are assembled using standard assembly techniques coupled with state of the art metrology.**
- **Extra care will be needed because of the size and positional tolerance required during assembly.**
- **The Laser Tracker, Faro Arm, and the Arcsecond Constellation are the tools needed to accurately measure the components during assembly**
- **With frequent measuring and checking as the assembly progresses all positional requirements are achievable.**
- **Fixture design will continue to evolve and make use of existing standard equipment to reduce cost.**
- **Full scale mockups are planned (and costed) to verify assembly tooling and inspection equipment**
- **Shimming during assembly will provide an opportunity to optimize positions for the Modular Coils, TF Coils, and External Trim Coils.**

Postscript – Effect of PDR recommendations

| PDR Recommendation | Schedule impact | Cost Impact |
|---|------------------------|-------------------------------------|
| Obtain metrology experience early | none | None (Shifts some costs forward) |
| Fit-check winding forms of each type | 1 month | ~ \$20k |
| Use full scale mockup to demonstrate assembly of mod coils over VV | None (in plans) | None (in plans) |