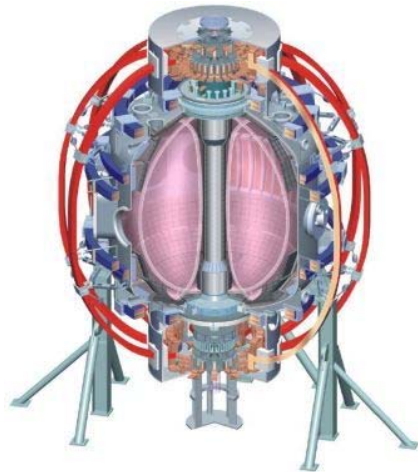


# Fabrication and Assembly of Center Stack

**James H. Chrzanowski  
and the NSTX Upgrade Team**

**NSTX Upgrade Project  
Peer Review  
LSB, B318  
May 18, 2011**



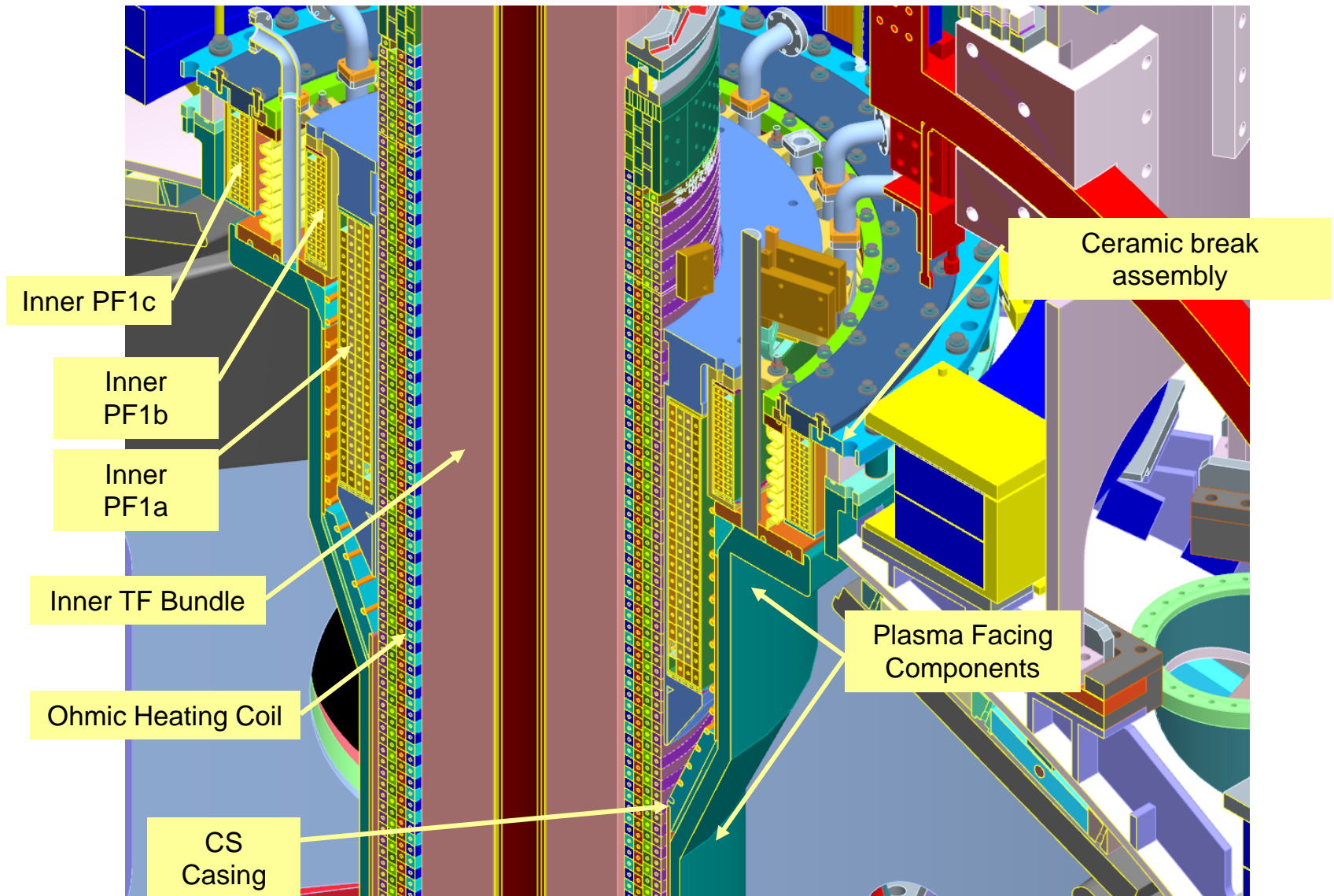
College W&M  
Colorado Sch Mines  
Columbia U  
CompX  
General Atomics  
INEL  
Johns Hopkins U  
LANL  
LLNL  
Lodestar  
MIT  
Nova Photonics  
New York U  
Old Dominion U  
ORNL  
PPPL  
PSI  
Princeton U  
Purdue U  
SNL  
Think Tank, Inc.  
UC Davis  
UC Irvine  
UCLA  
UCSD  
U Colorado  
U Illinois  
U Maryland  
U Rochester  
U Washington  
U Wisconsin

Culham Sci Ctr  
U St. Andrews  
York U  
Chubu U  
Fukui U  
Hiroshima U  
Hyogo U  
Kyoto U  
Kyushu U  
Kyushu Tokai U  
NIFS  
Niigata U  
U Tokyo  
JAEA  
Hebrew U  
Ioffe Inst  
RRC Kurchatov Inst  
TRINITY  
KBSI  
KAIST  
POSTECH  
ASIPP  
ENEA, Frascati  
CEA, Cadarache  
IPP, Jülich  
IPP, Garching  
ASCR, Czech Rep  
U Quebec

# Outline of Presentation

- **Discuss the procurement & Manufacturing plans for the CS upgrades**
- **Identify Major Procurements**
- **In-House Fabrications & Assembly**
  - Inner TF Coil Fabrication
  - OH Solenoid Fabrication
  - Centerstack Assembly

# Upgraded Centerstack Components



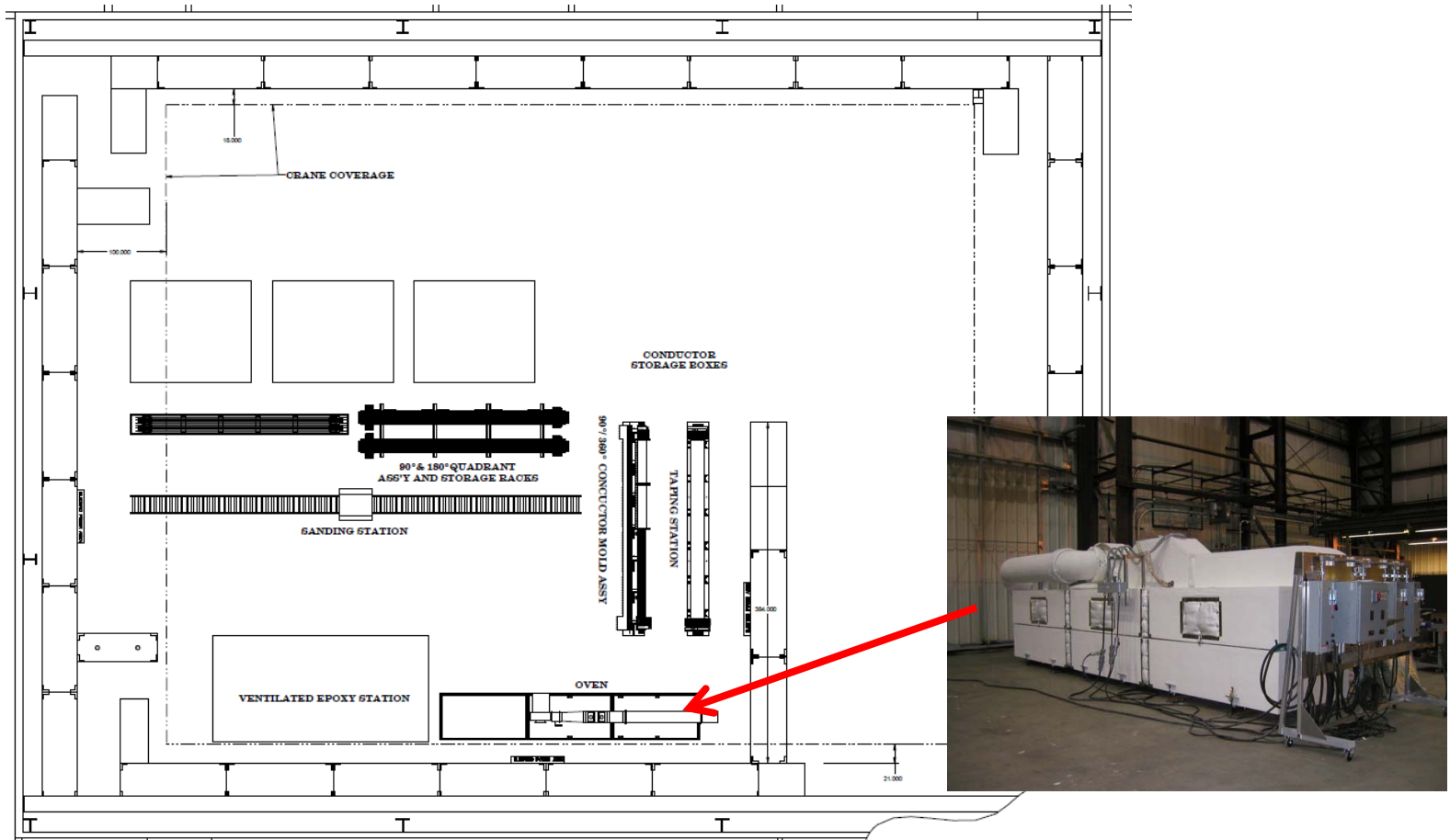
# Manufacturing/Procurement Plan

- **Manufacturing Plan** developed- ***NSTX-PLAN-MFG-1300***
- **Procurement Plan:**
  - Inner PF coils, support structures and conductor
  - CS Inconel Casing
  - CS Support Structure
  - Ceramic Breaks
  - OH Conductor
  - Inner TF Conductor Assemblies (largest single procurement for the CS Upgrade)
  - TF Flex bus joint and hardware
- **In House Manufacturing/Assembly**
  - Inner TF bundle
  - OH Solenoid
  - Centerstack Assembly
- *The center stack fabrication is the critical path of the project*
- *The design, procurement and fabrication is approx \$15M (20% of the project's \$77M BAC)*

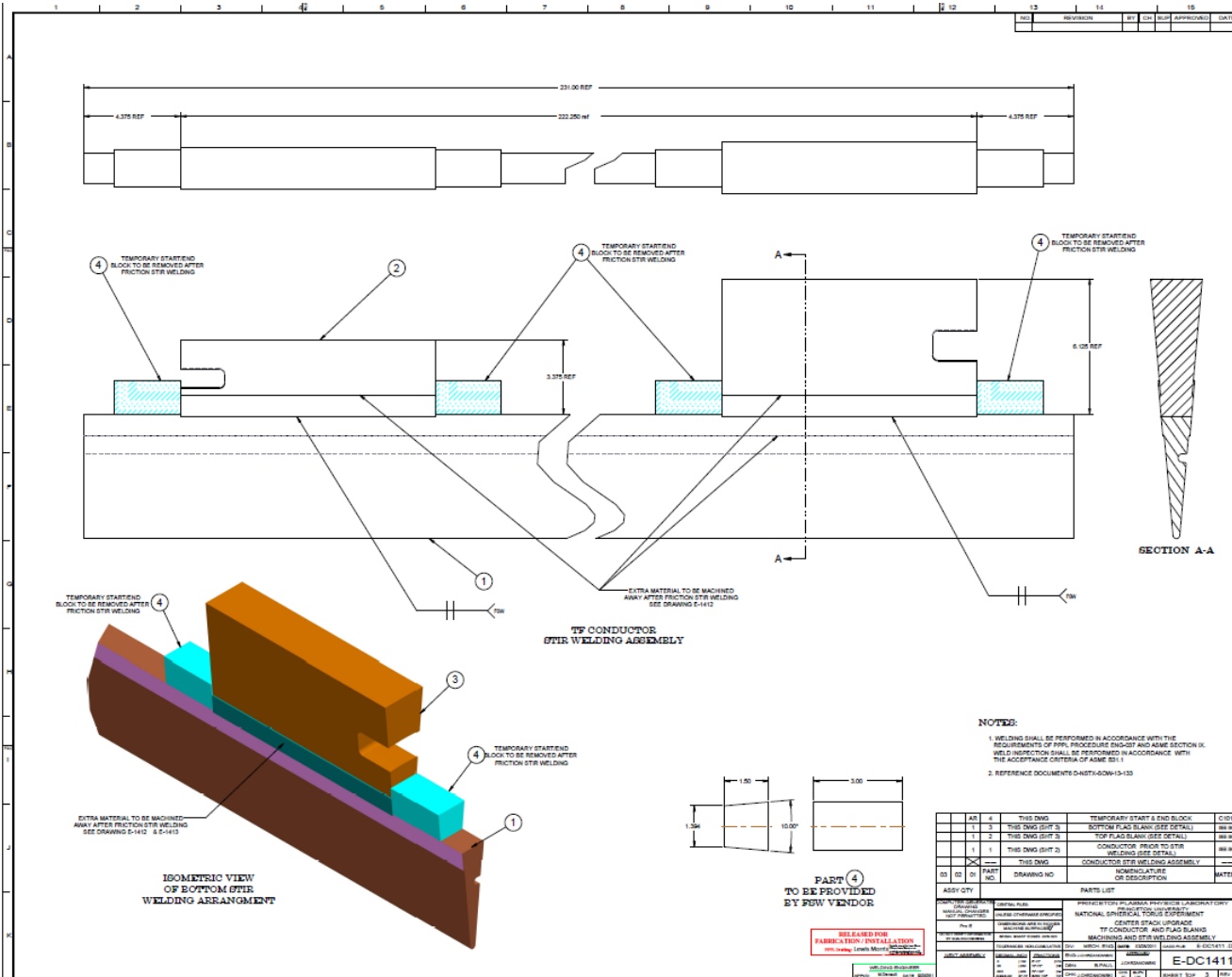


# TF Manufacturing Area Layout

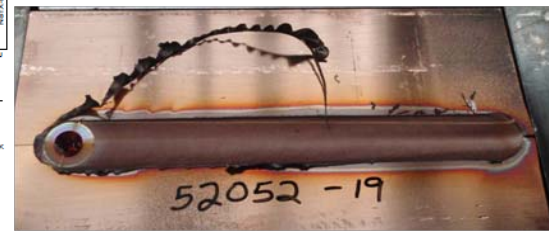
- The Inner TF/ OH fabrication will occur at PPPL in the CS High Bay area (Former NCSX Test Cell)
- Crane capacity (45 T), environmental control and adequate work space



# Inner TF Conductor Assembly

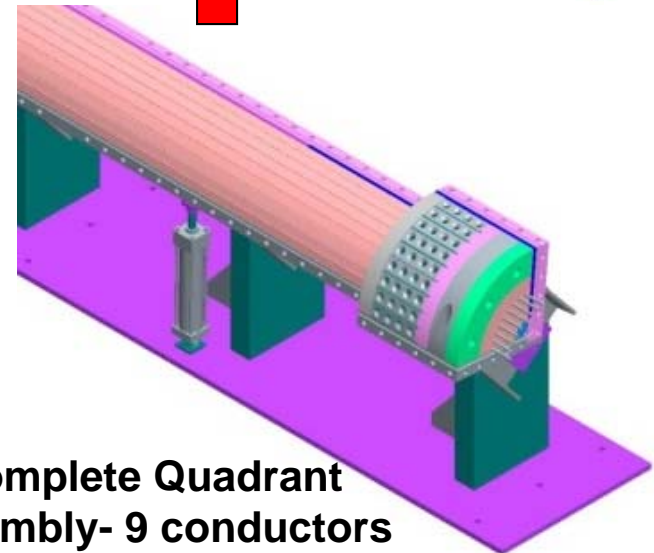
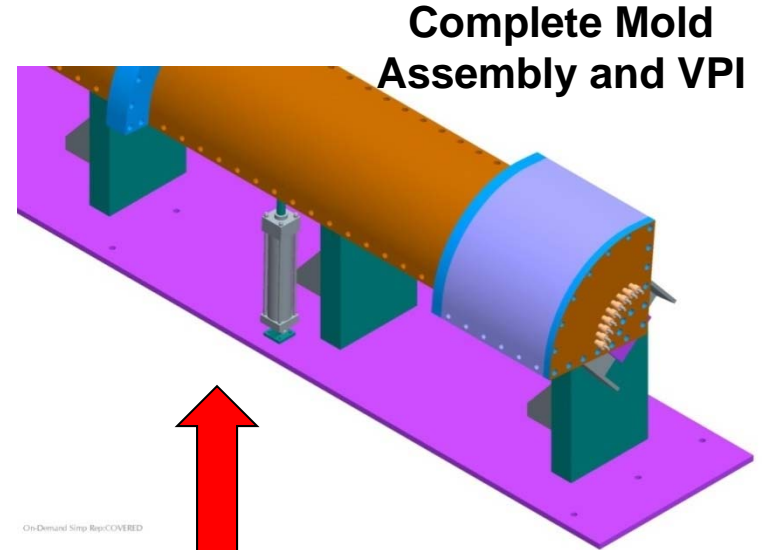
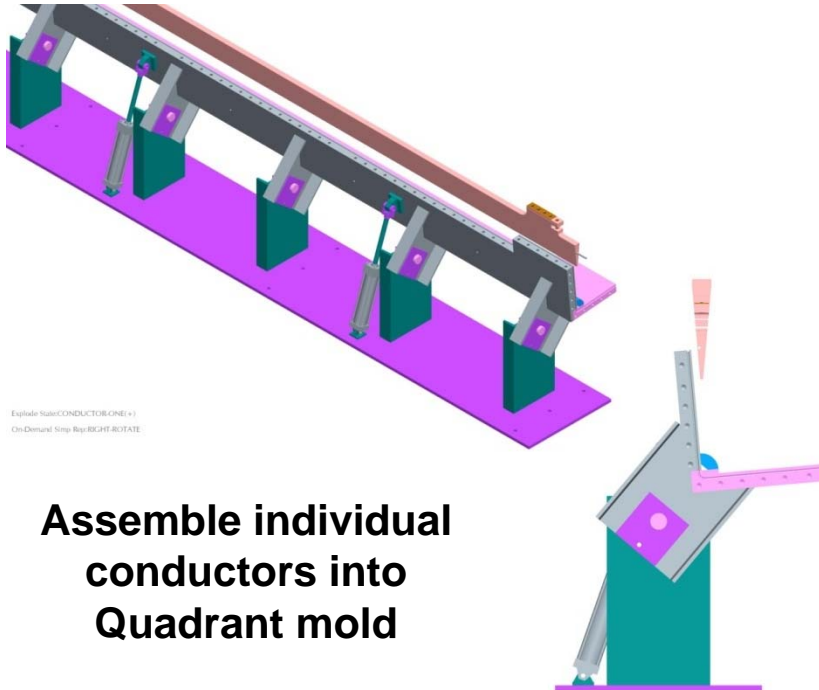


- Largest single procurement for the CS upgrade
- Copper Extrusion procured
- Conductor assy. in procurement



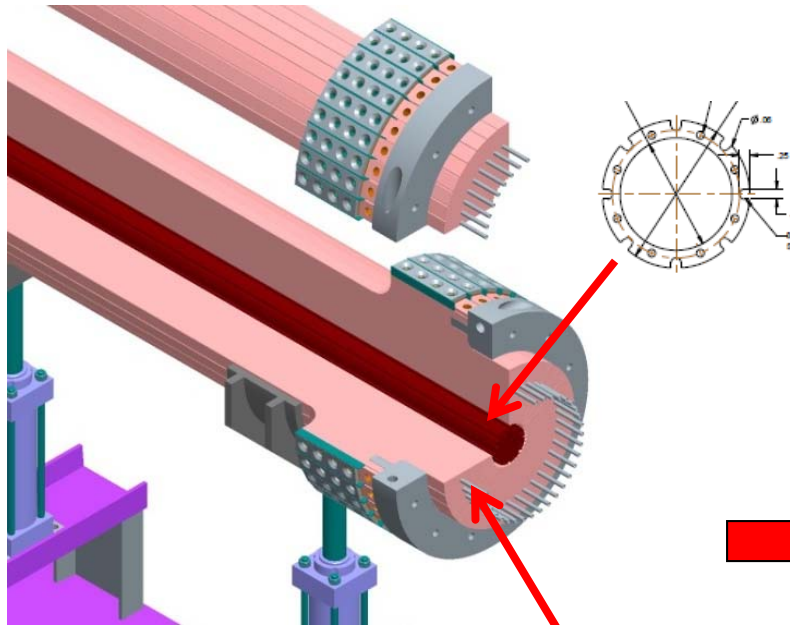
# Step 1- Fabrication of Inner TF Bundle

- **Inner TF Conductors:**
  - Solder cooling tube
  - Grit blast
  - Apply primer and oven cure
  - Hand insulate 3 half-lapped layers of (S-2) glass tape
- **Quadrant Assembly**

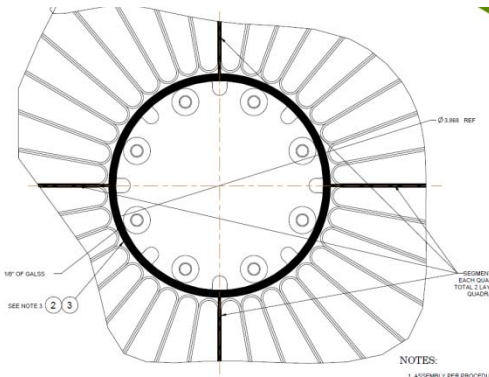


# Step 2- Full TF Assembly

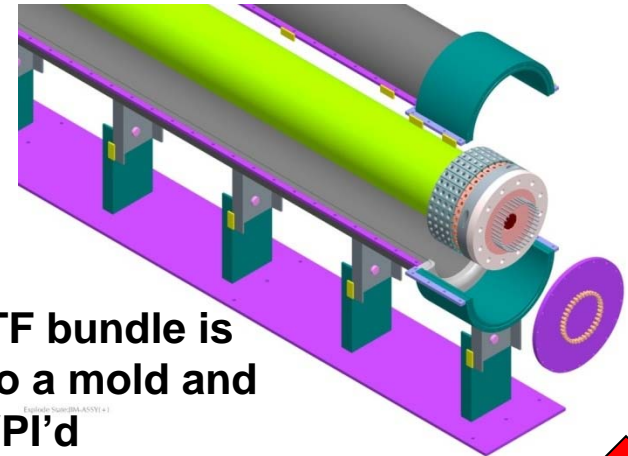
- The four VPI's quadrants are then assembled together to complete the full bundle.



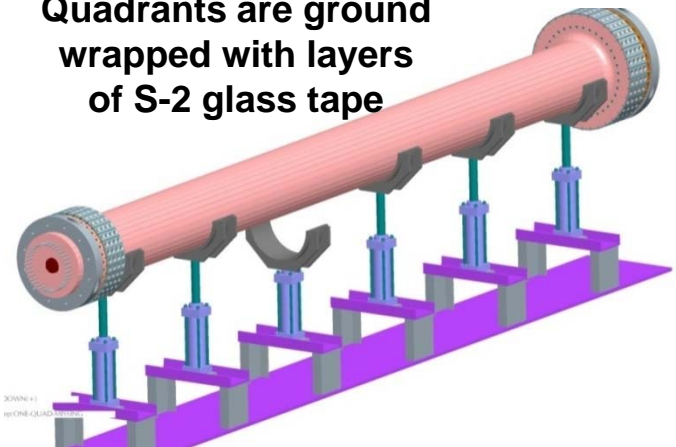
The quadrants will be assembled w/ S-2 between layers & pre-insulated G-10 core



The full TF bundle is placed into a mold and VPI'd

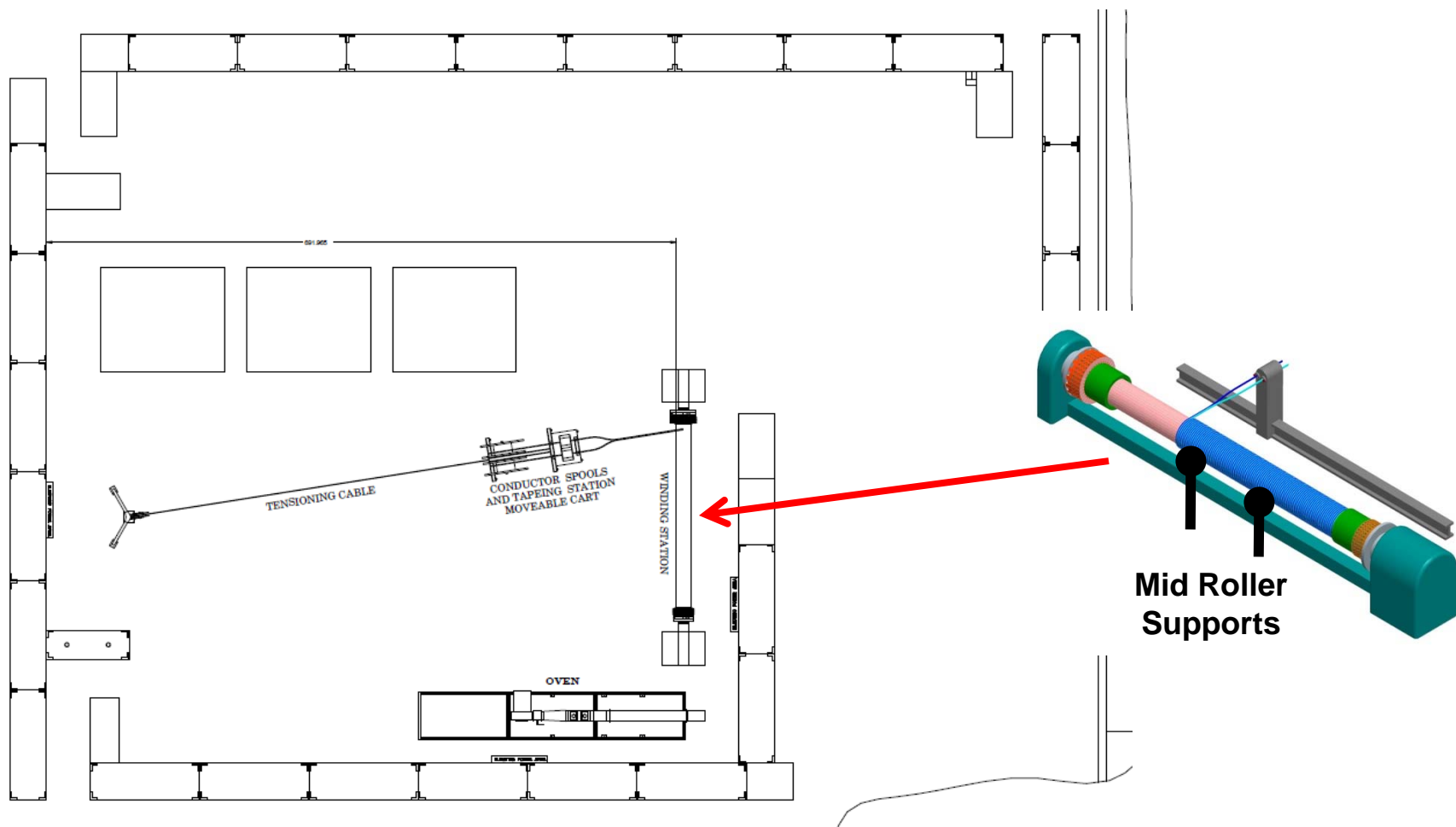


Quadrants are ground wrapped with layers of S-2 glass tape



# Fabrication of OH Solenoid

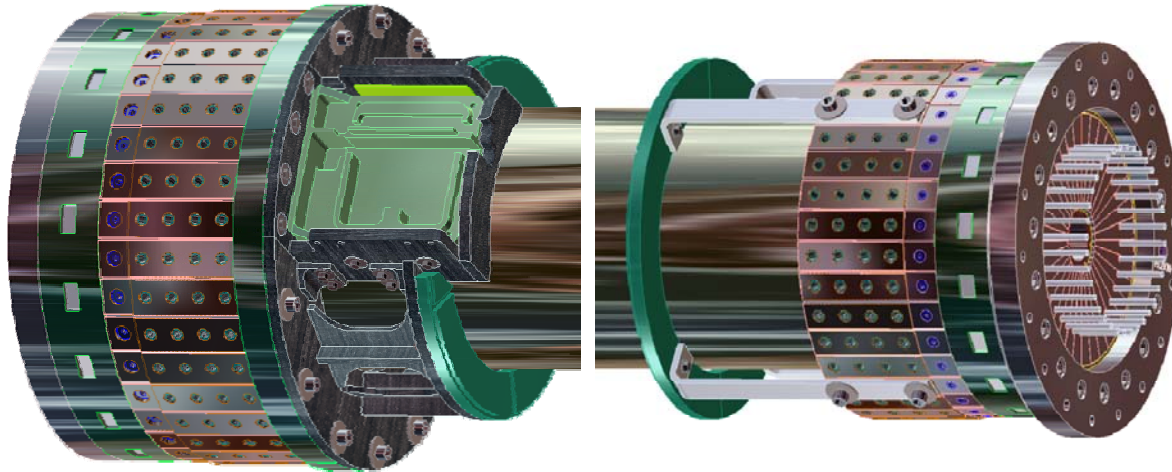
- The OH Solenoid will be wound onto the Inner TF Bundle
- The CS High Bay area will be reconfigured to wind the OH coil





# OH Fabrication- 1

- The OH solenoid will be tension wound onto the Inner TF bundle with a 0.100 gap between coils.
- A temporary mandrel using a product “Aquapour” will be used as a base for winding the OH solenoid.
  - The material provides a solid base for winding, and is easily removed with water once the coils have been completed to provide the necessary gap between coils. This material has been successfully tested in-house
  - An epoxy/glass layer will be applied over the cured mandrel, upon which the coil will be wound
  - Once the OH has be VPI'd the Aquapour will be removed

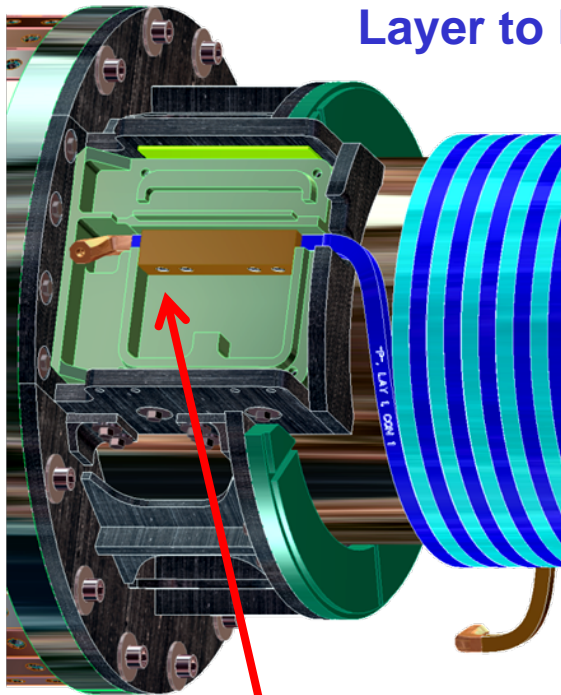


# OH Fabrication- 2

- The coil will be wound 2-conductors in hand
- Layer to layer joints will be Tig-Brazed
- Cooling fittings are torch brazed
- G-10 fillers will be used on either end to fill all voids and to improve the overall strength of the OH after VPI



## Layer to Layer Tig-Braze Joint



Lead Block



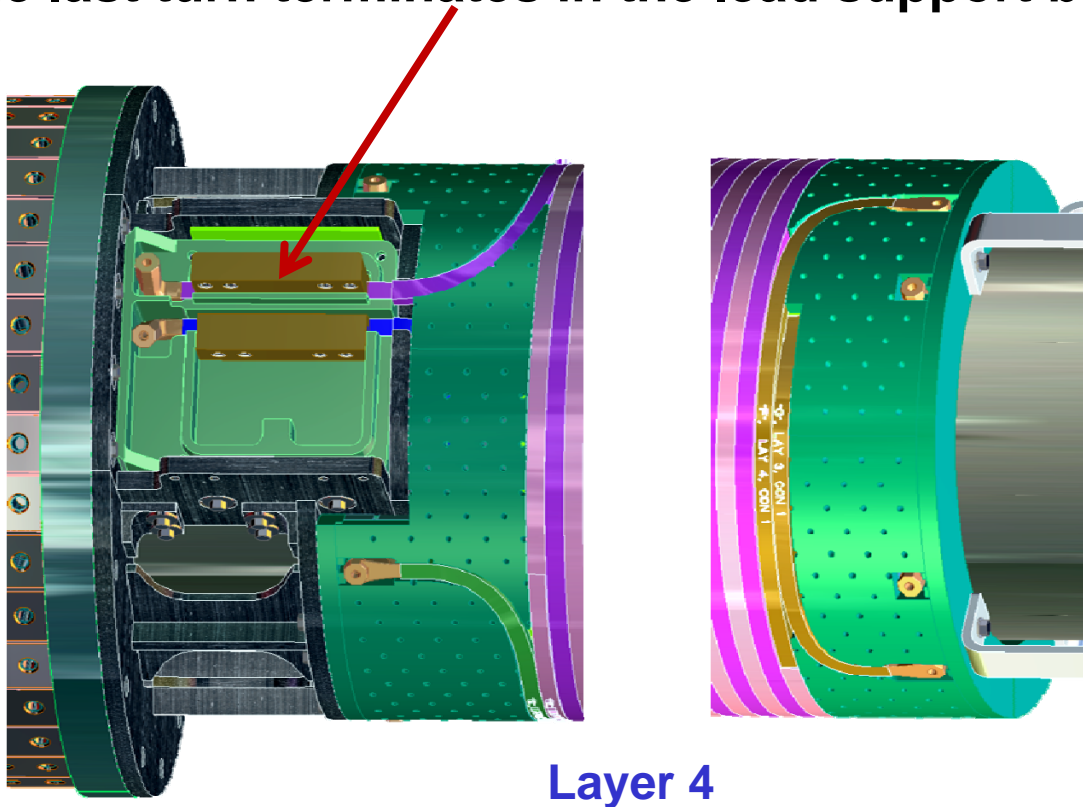
Cooling Fittings

- G-10 Fillers are custom fit to conform to cooling leads.
- S-2 glass mat is used between layer to layer levels of G-10
- The G-10 is perforated to enhance VPI and epoxy flow between layers



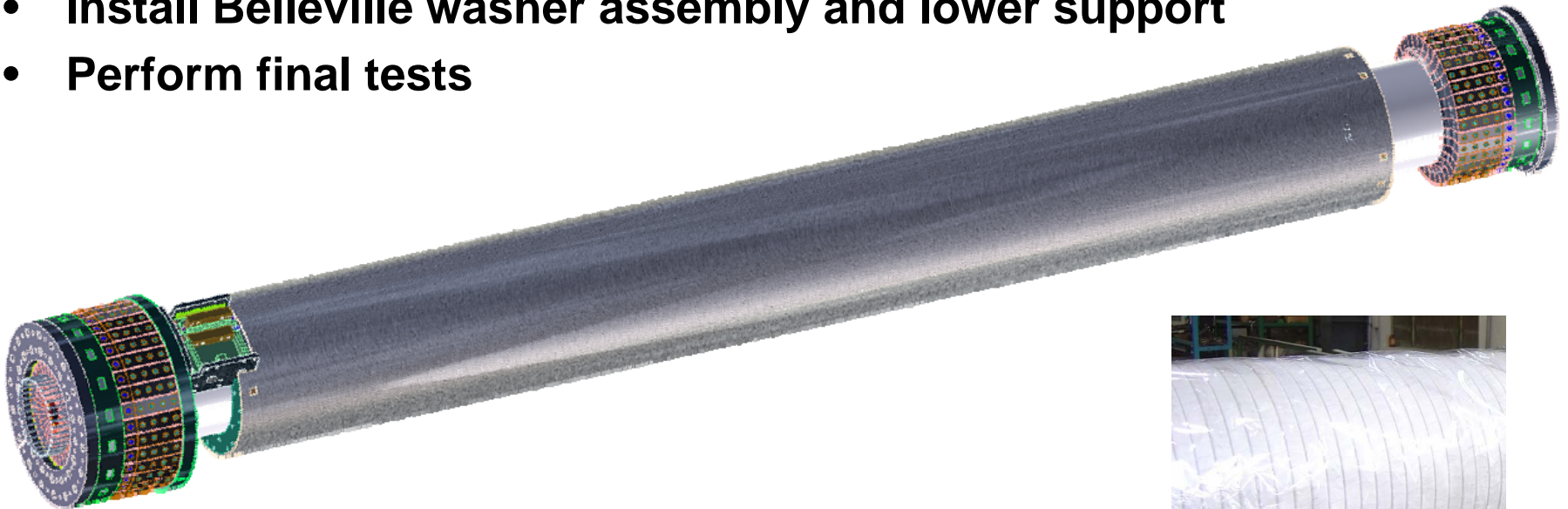
# OH Fabrication- 3

- Four (4) Layers are with layer to layer joints, cooling fittings and G-10 fillers
- The last turn terminates in the lead support block



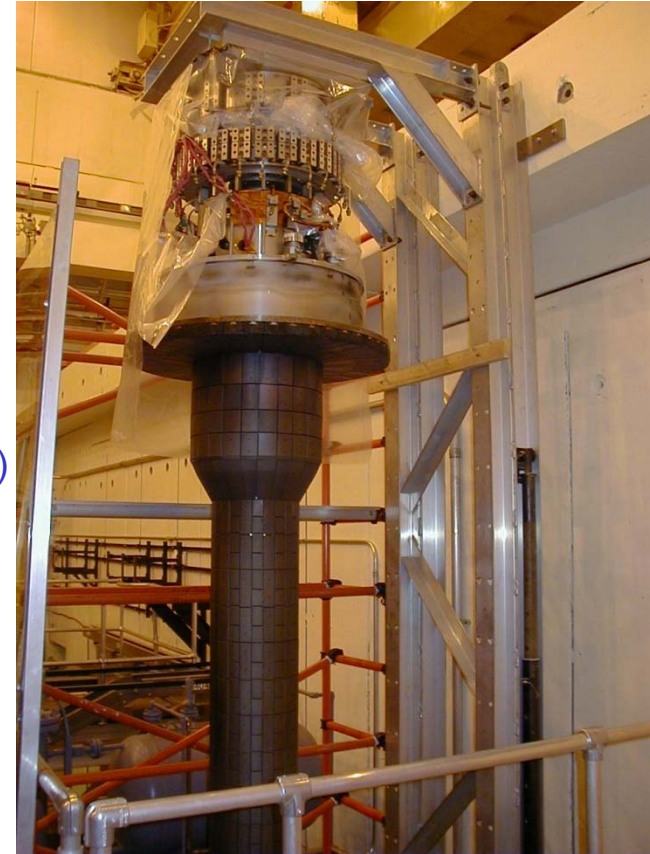
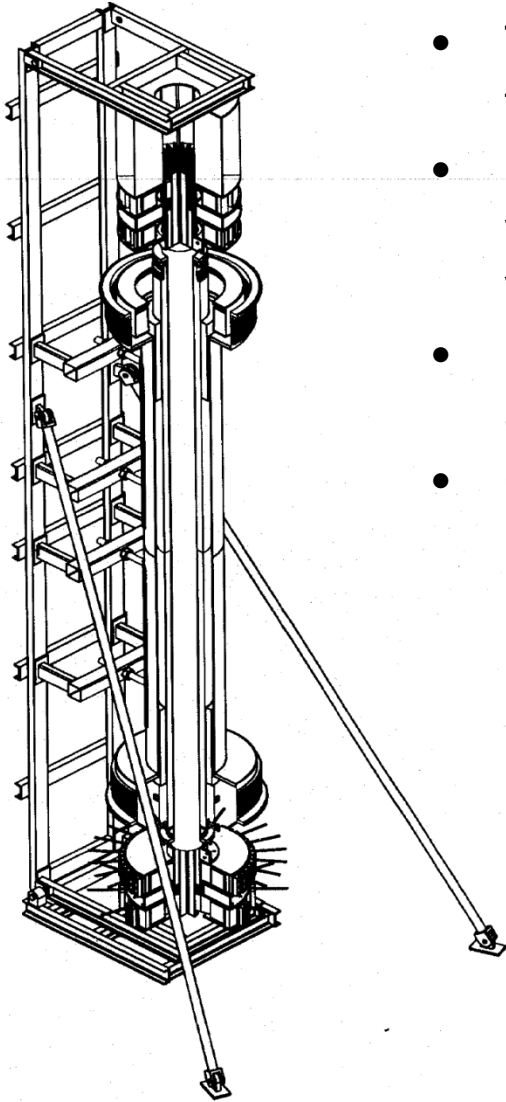
## OH Fabrication- 4

- The finished wound OH solenoid is then ground wrapped with S-2 glass tape.
- Install mold around the OH solenoid, and VPI using CTD101k
- Remove mold from OH then remove “Aquapour” filler material.
- Install silicone spacers between upper OH & TF bundle
- Install Belleville washer assembly and lower support
- Perform final tests



# General CS Assembly Notes

- The CS Assembly will occur in the C-site high bay area
- Most of the assembly activities will occur with the CS in the vertical position
- New fixture will be built for the assembly of new CS
- Components for assembly
  - OH/TF Assembly (In house fab)
  - Inner PF coils (outside procurement)
  - CS Inconel Casing (outside procurement)
  - Microtherm insulation (outside procurement)
  - PFC Tiles & hardware (outside procurement)
  - CS support structure (outside fabrication)

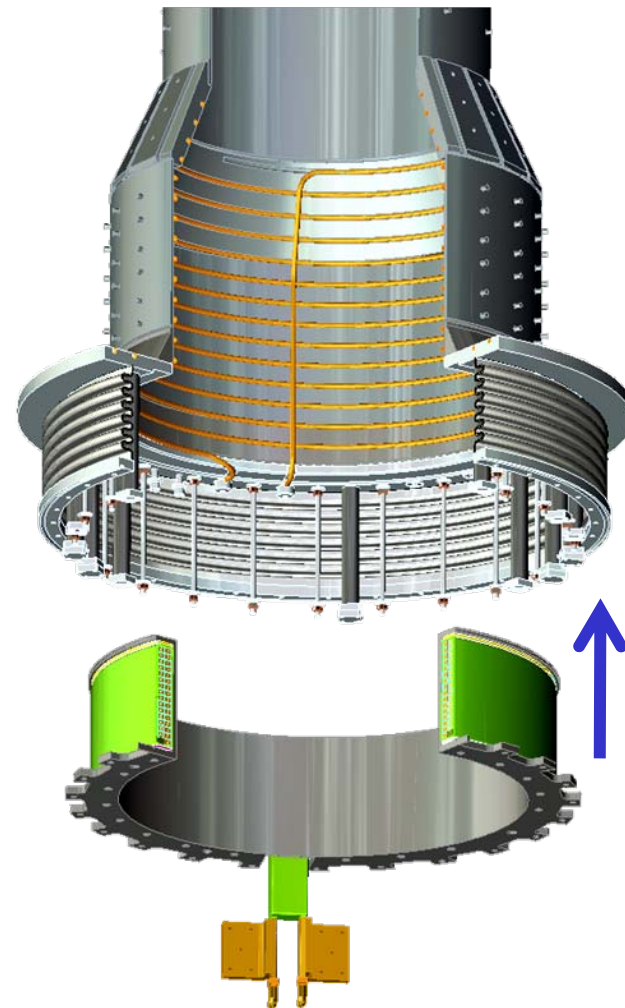
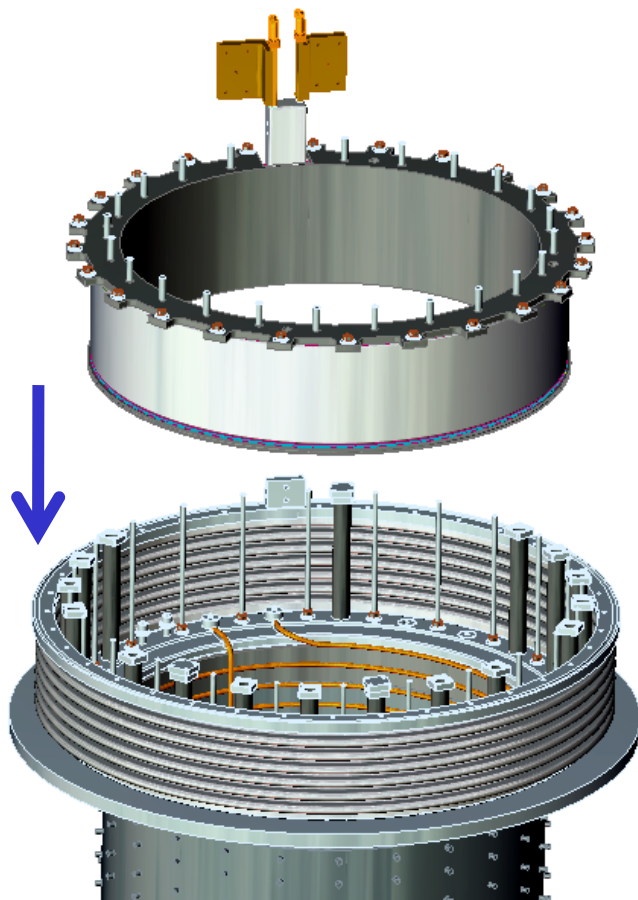


# Centerstack Assembly Sequence

- ***The next series of slides will identify the assembly sequence that will be used to complete the assembly of all the center stack components.***

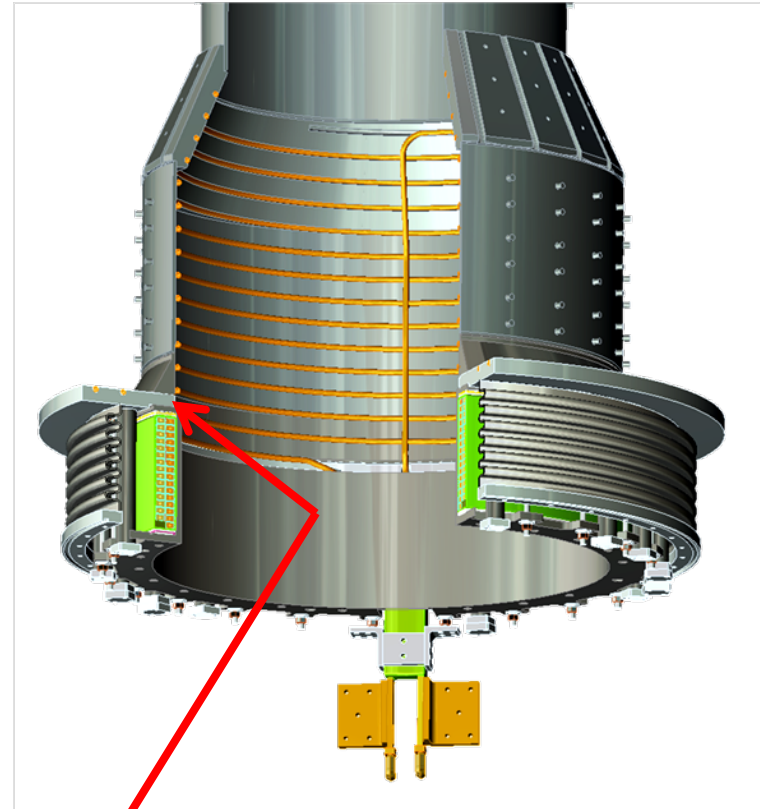
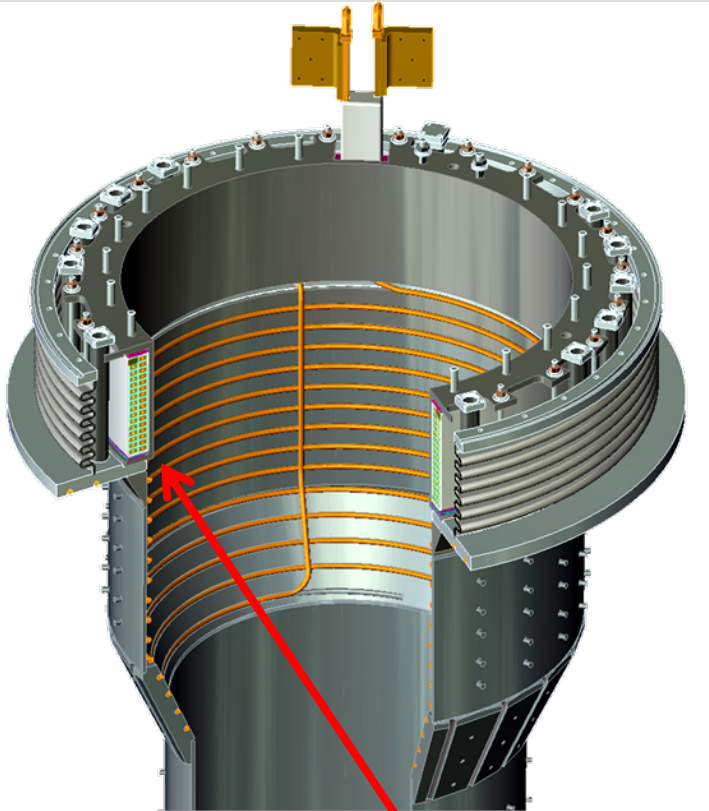
# Step 1- Install Upper & Lower PF1-B Coils

Mount the upper and lower PF-1B coils to the CS Casing.





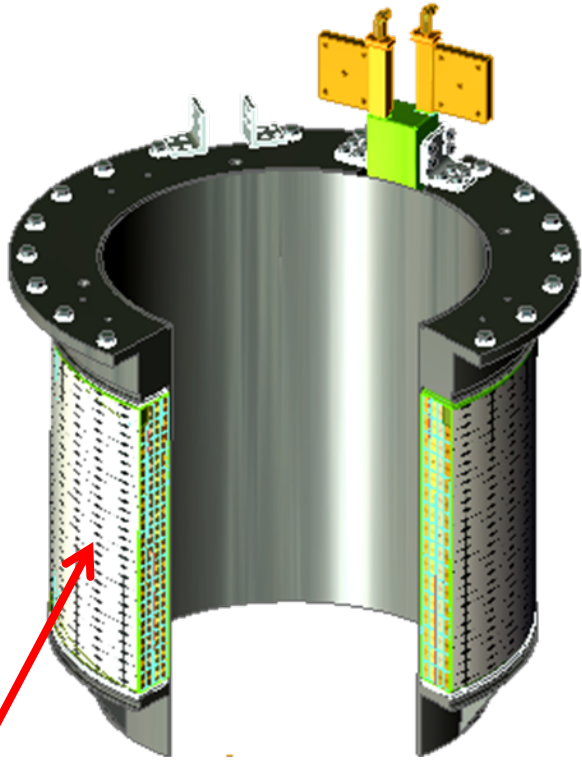
# Step 1b- PF-1B Coils in Position



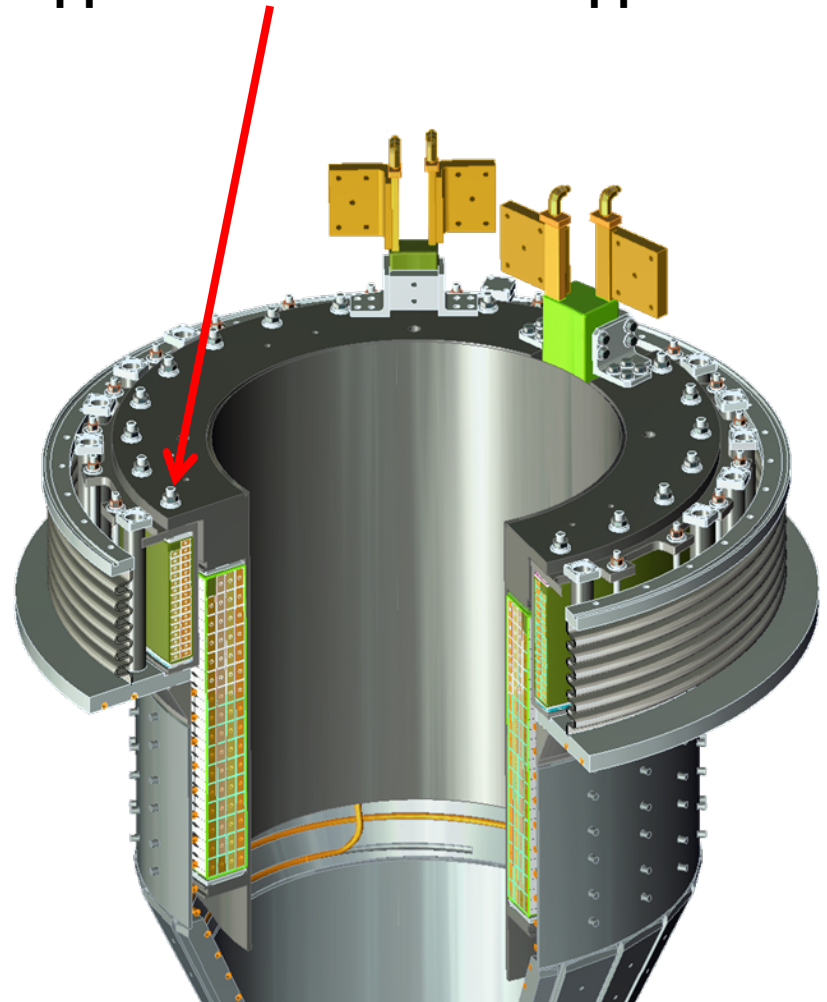
**Weld the PF-1B supports to CS Casing**

## Step 2- Install Upper PF-1A Coil

Mount Upper PF-1A to PF-1B support

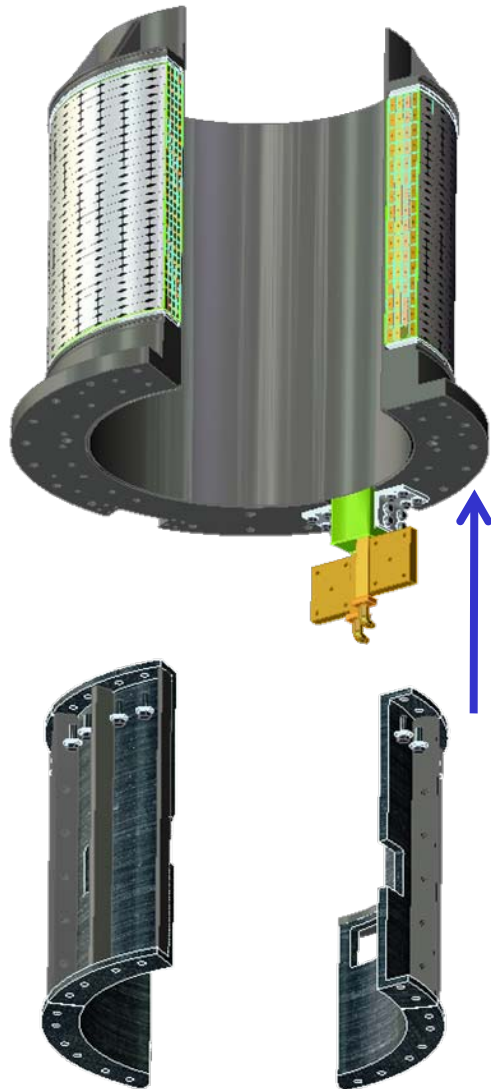


Install "Microtherm insulation around outside surfaces of "Upper PF1" Coil





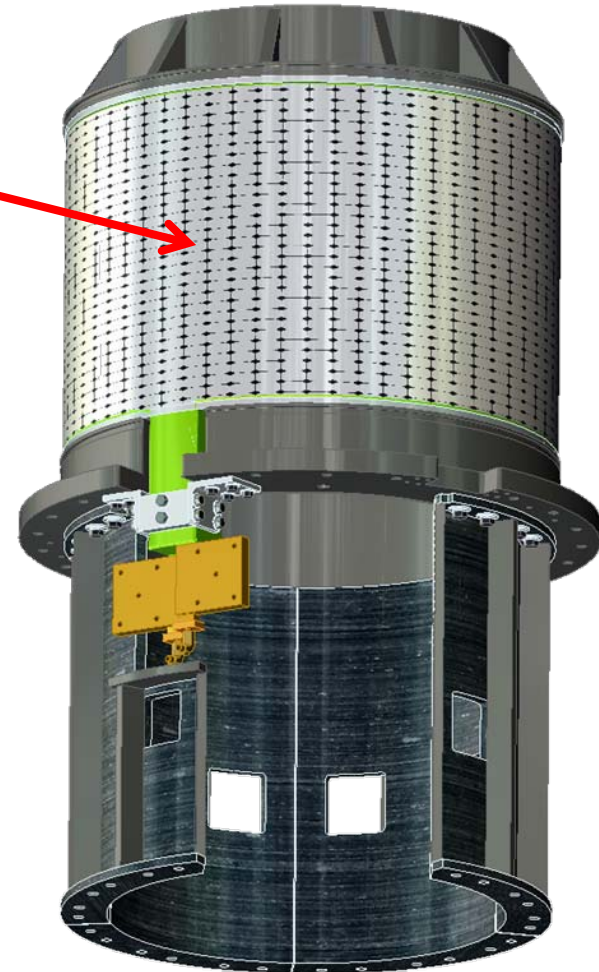
# Step 3- Assemble CS Support & Lower PF-1A Together



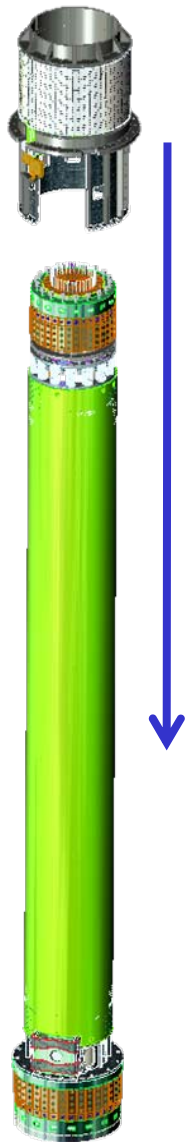
Install “Microtherm insulation around outside surfaces of “Upper PF1” Coil



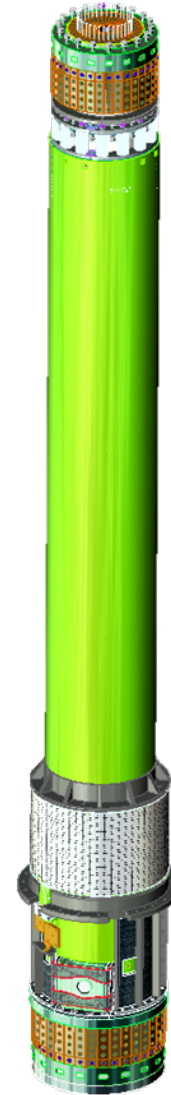
Mount the Center Stack Support Structure to Lower PF-1A Coil



# Step 4- Assemble Lower PF-1A Assy. To OH/TF Assy.

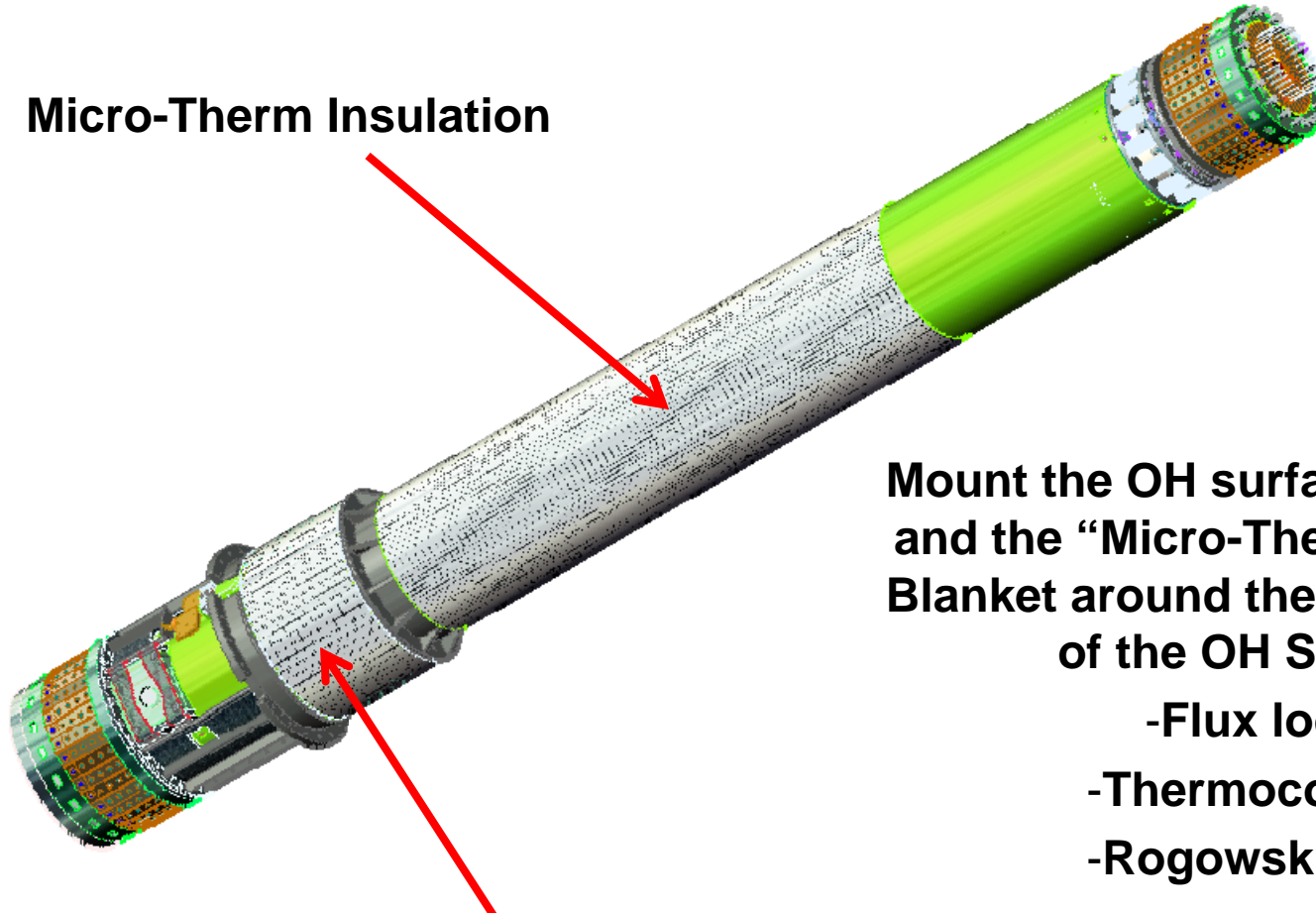


**Position the Lower  
PF-1A coil assembly  
over the OH/TF  
Assembly**



# Step 5 – OH Diagnostics & Thermal Blanket

**Micro-Therm Insulation**

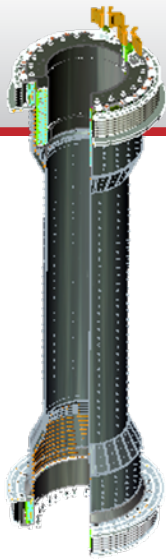


**Mount the OH surface diagnostics and the “Micro-Therm” Insulation Blanket around the outer surfaces of the OH Solenoid**

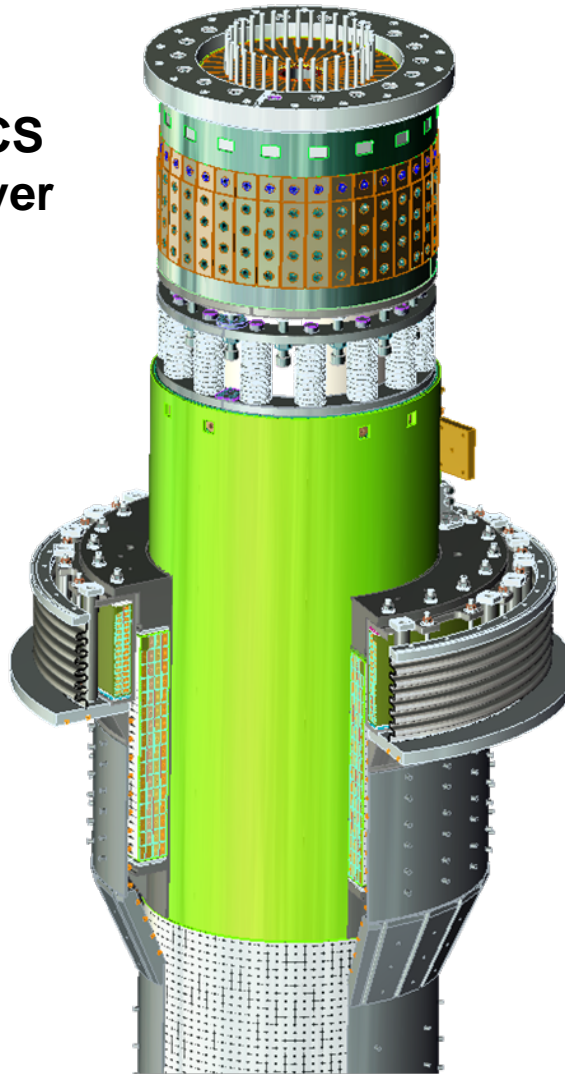
- Flux loops
- Thermocouples
- Rogowski Coils

**Lower PF-1A Coil Assy.**

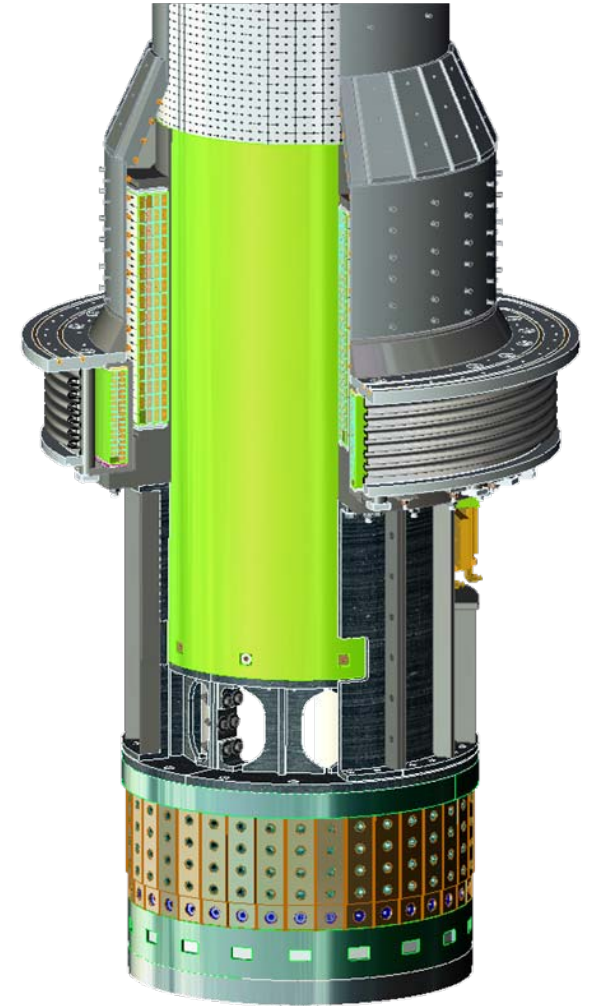
# Step 6 – Install CS Casing to CS Assembly



Lower the completed CS Assembly over the OH/TF Assembly



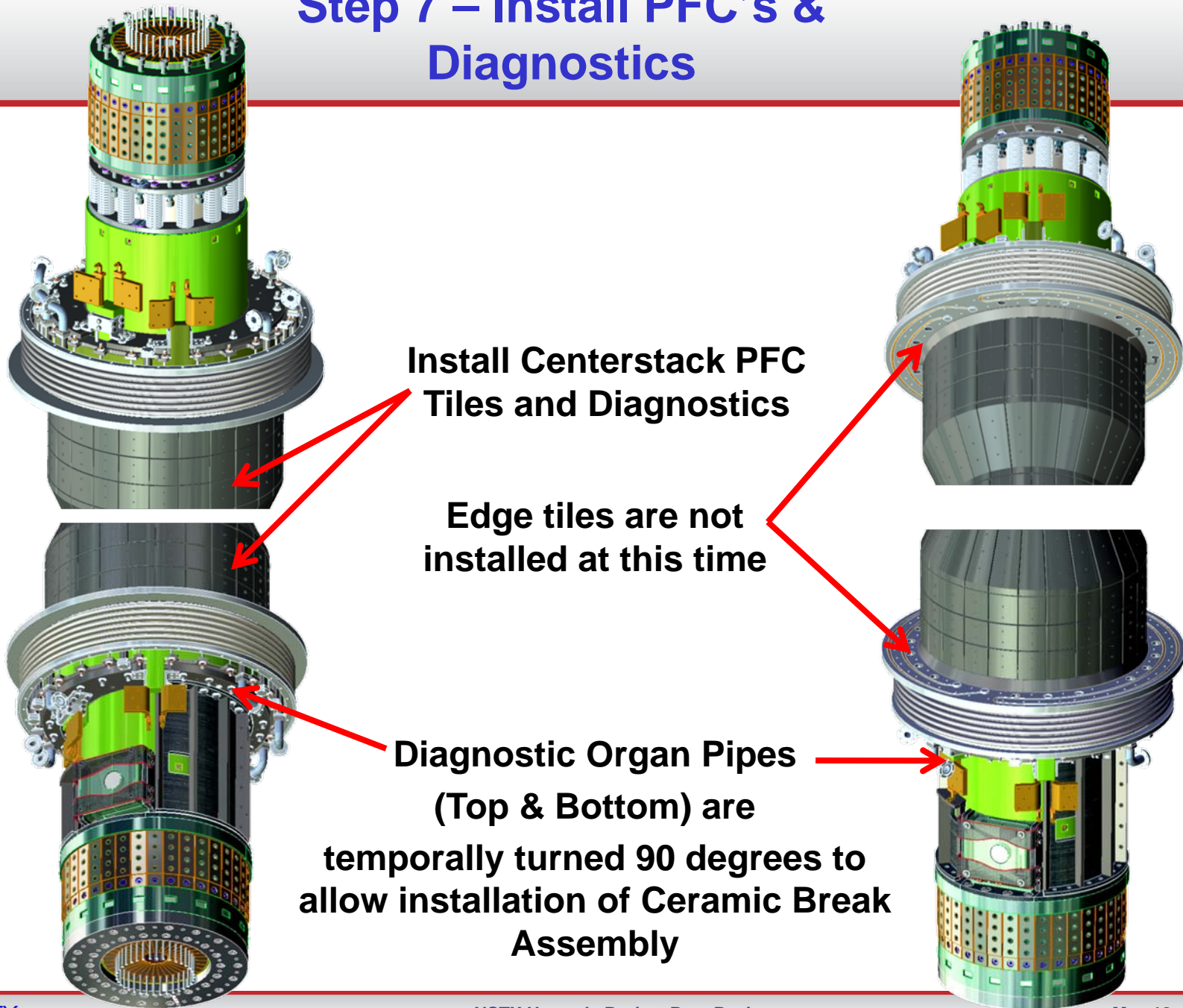
Upper Assembly



Lower Assembly



# Step 7 – Install PFC's & Diagnostics



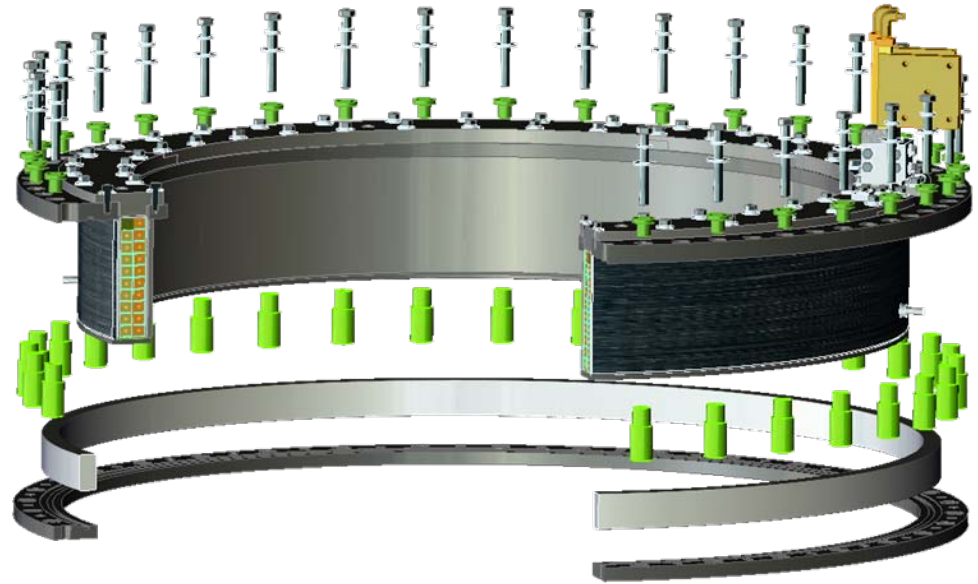
**Install Centerstack PFC Tiles and Diagnostics**

**Edge tiles are not installed at this time**

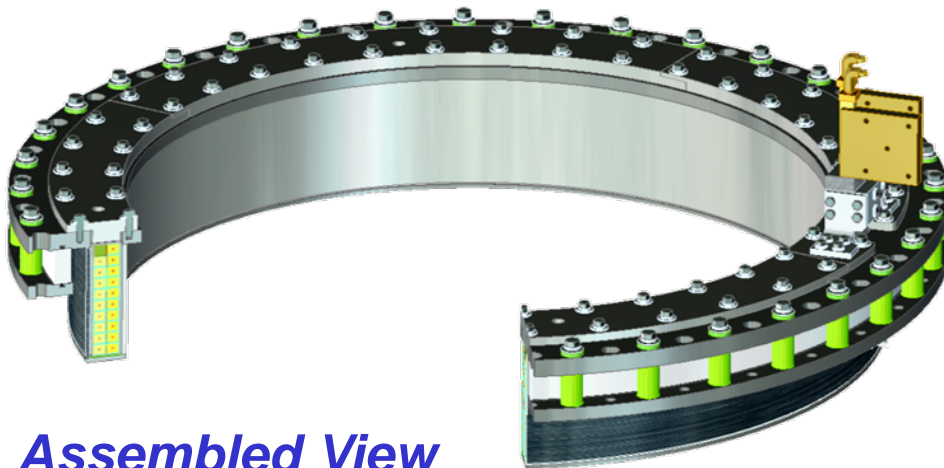
**Diagnostic Organ Pipes (Top & Bottom) are temporarily turned 90 degrees to allow installation of Ceramic Break Assembly**

# Step 8 – Sub-Assembly Complete Ceramic Break Assy.

Assemble the ceramic break components to the Upper and Lower PF-1C coil structures



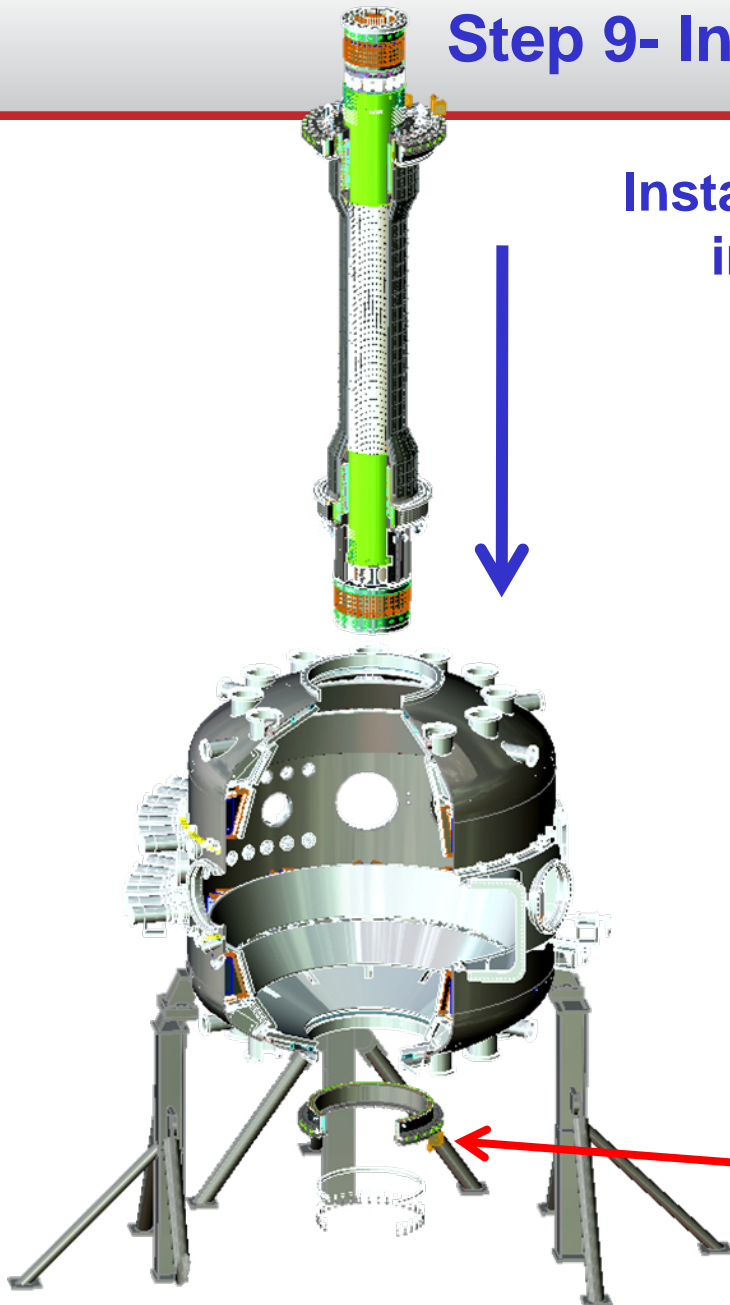
*Exploded View*



*Assembled View*

## Step 9- Install Completed CS Assy into VV

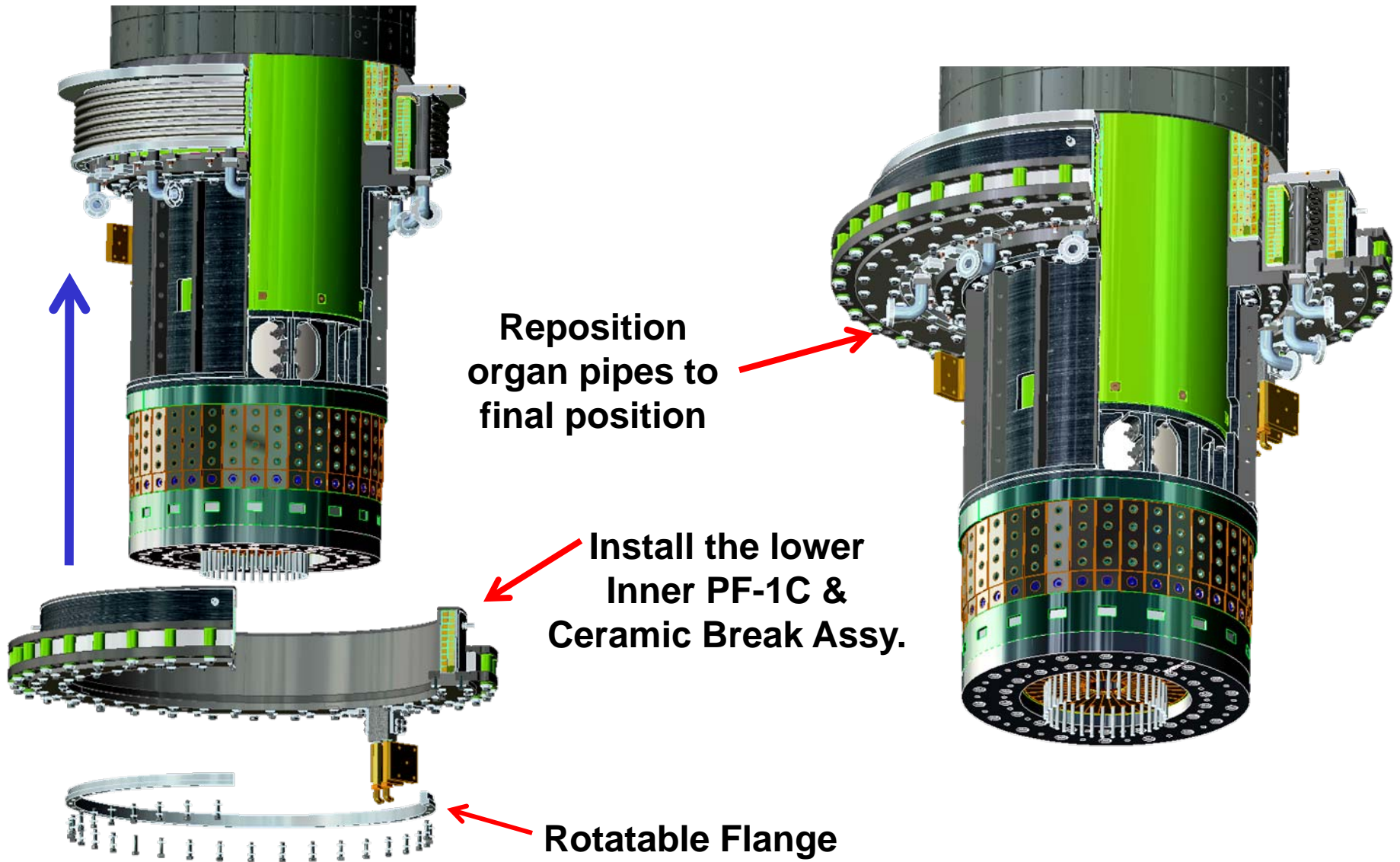
Install the completed Center Stack Assembly into the Vacuum Vessel (Spring 2014)



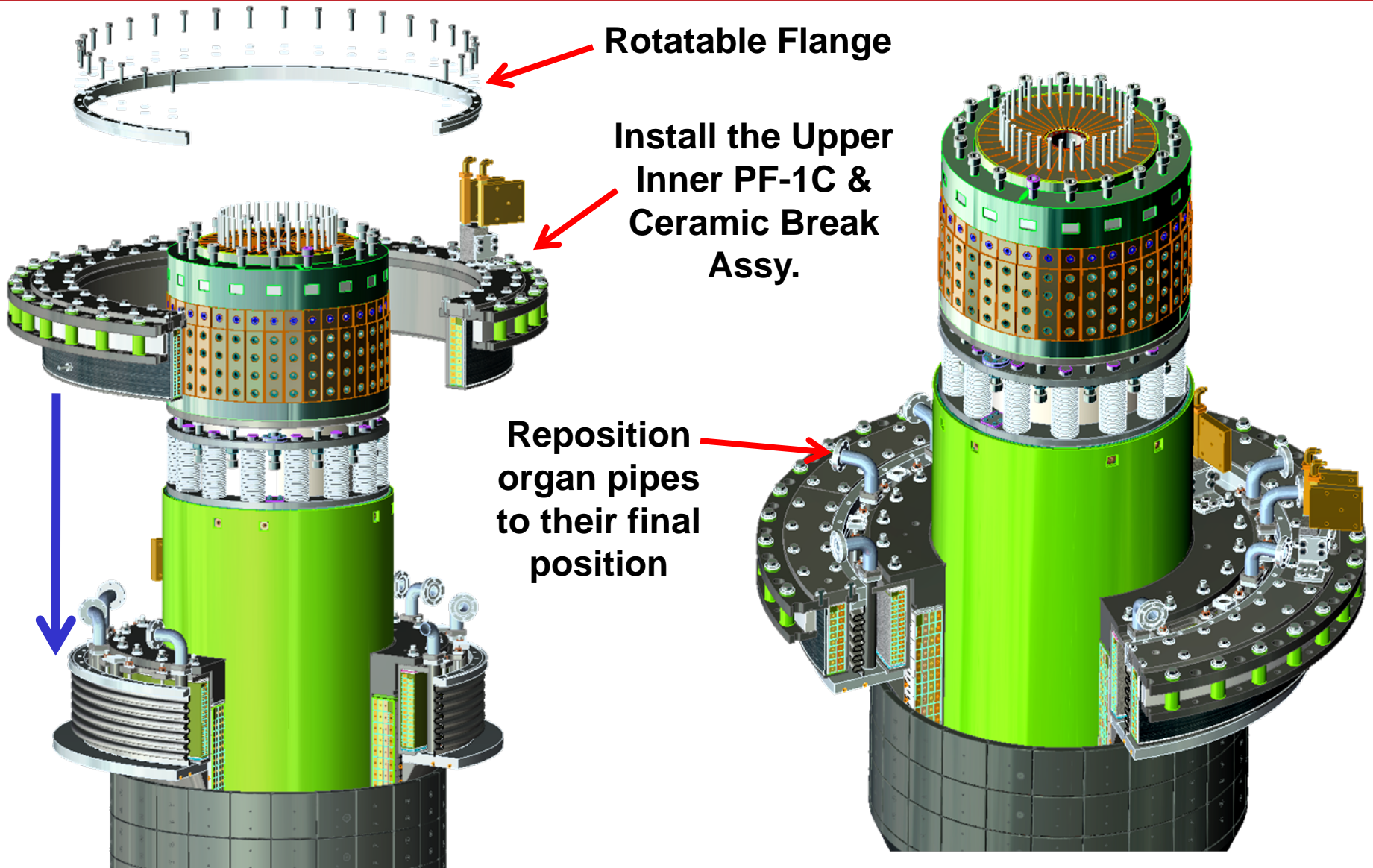
**Pre-position the lower Ceramic Break Assembly and Rotatable Flange prior to lower CS assembly into the VV**



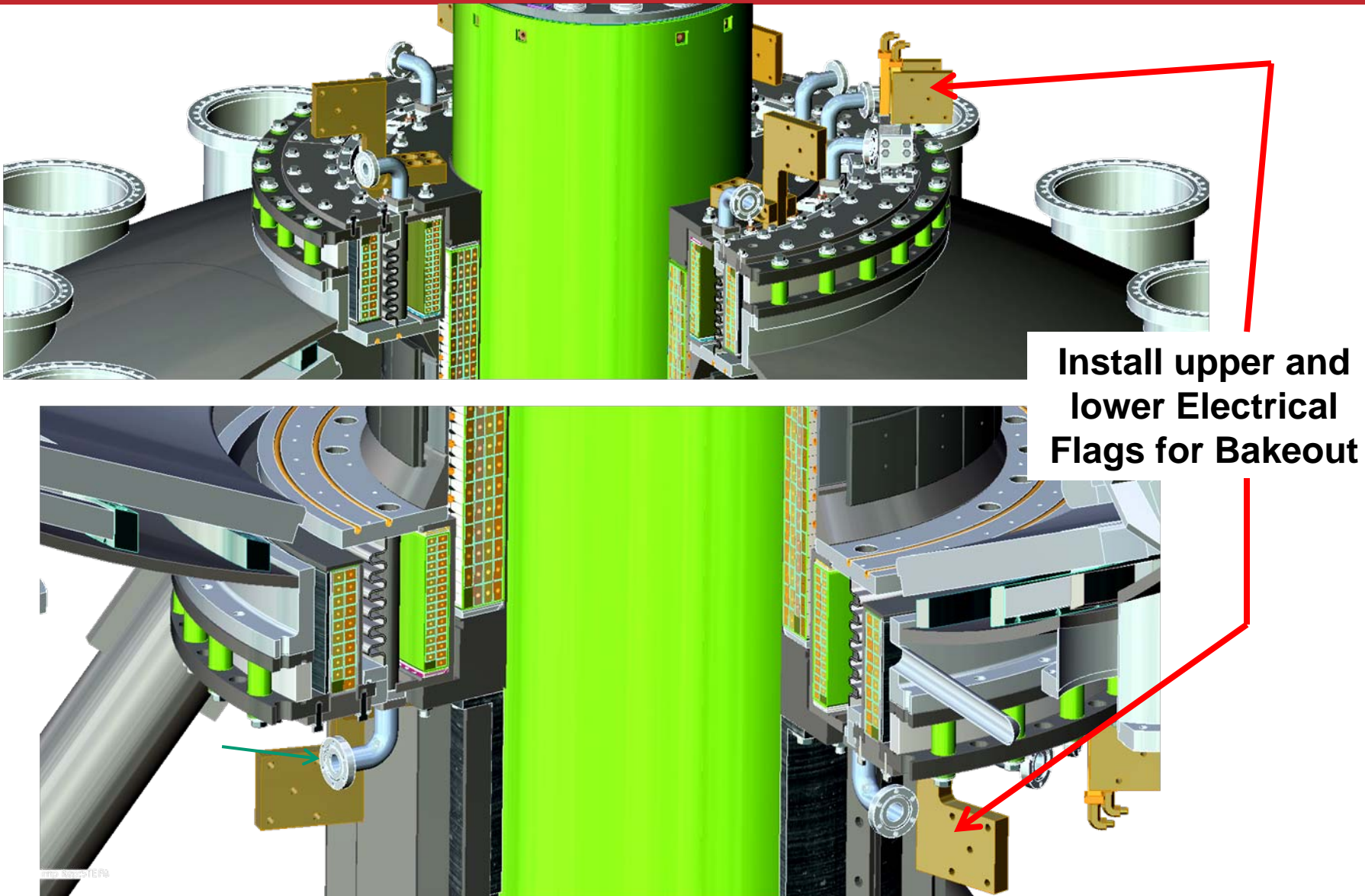
# Step 10- Install Lower Ceramic Break Assy.



# Step 11- Install Upper Ceramic Break Assy.

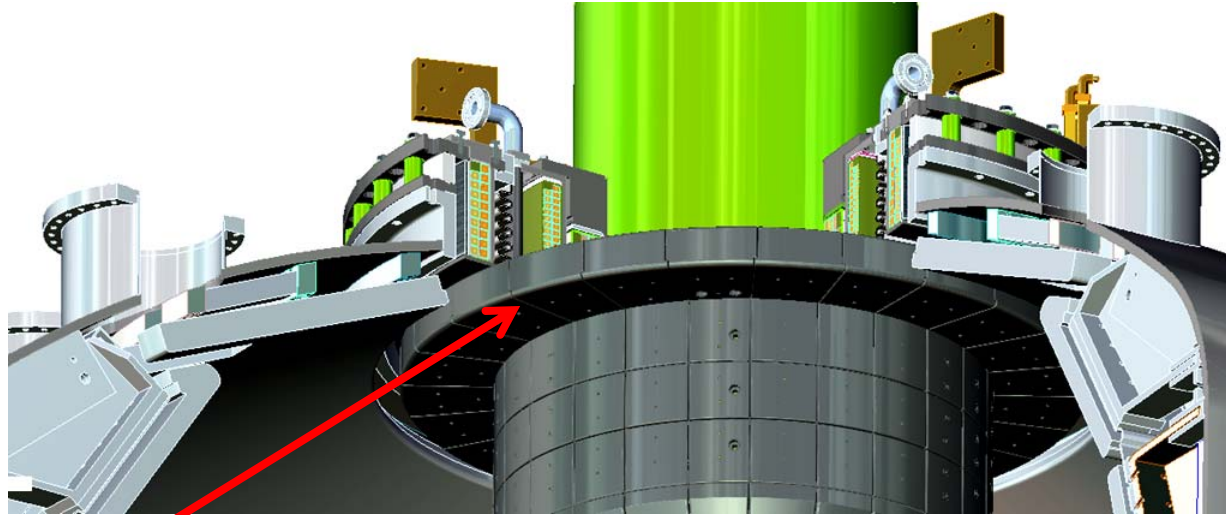


# Step 12- Center Stack in Final Position

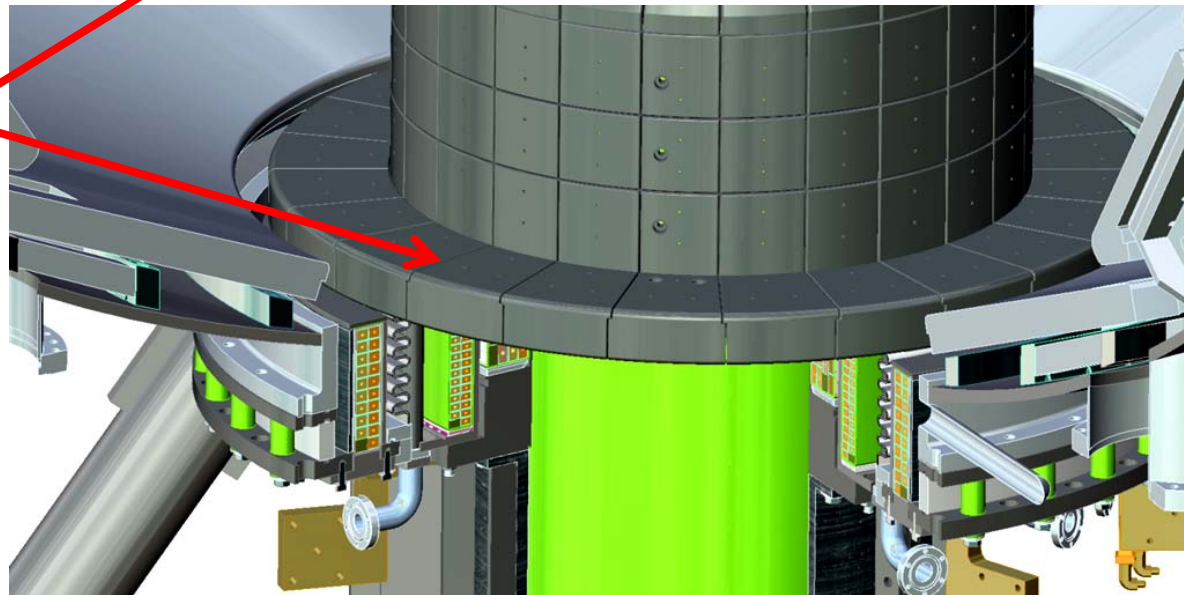




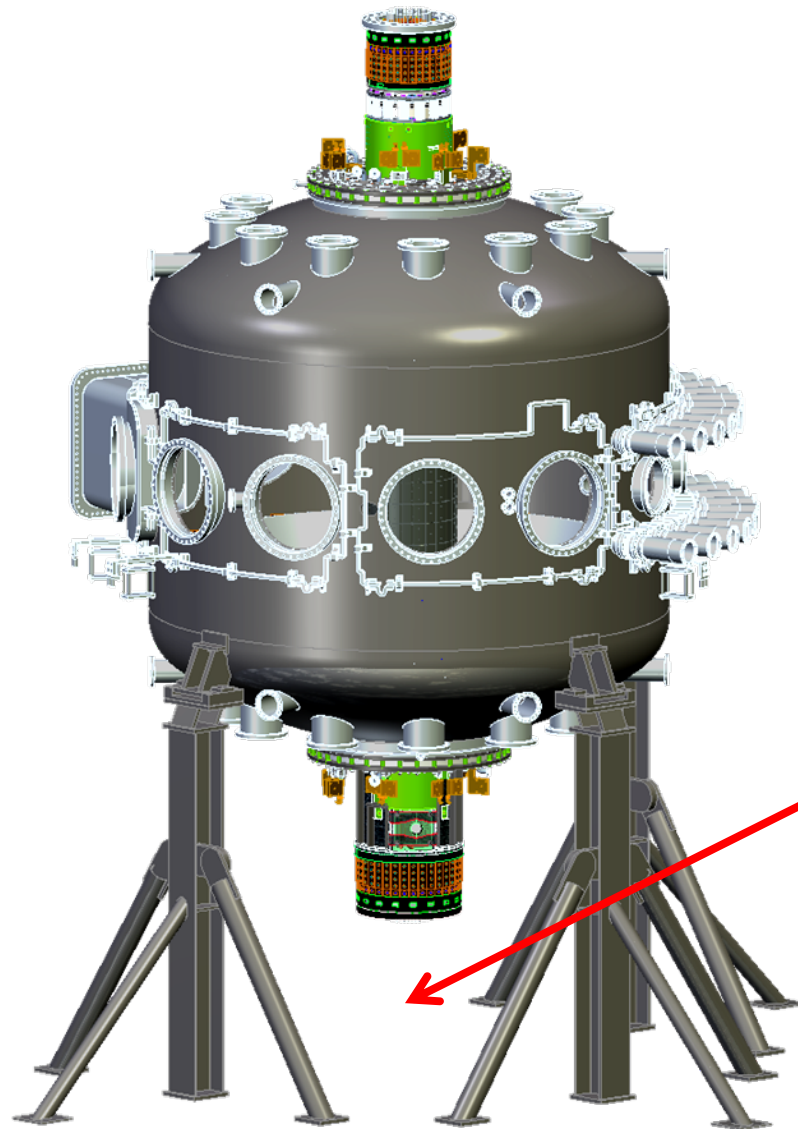
# Step 13- Install Upper & Lower PFC Edge Tiles



**Install upper  
and lower  
Edge Tiles**

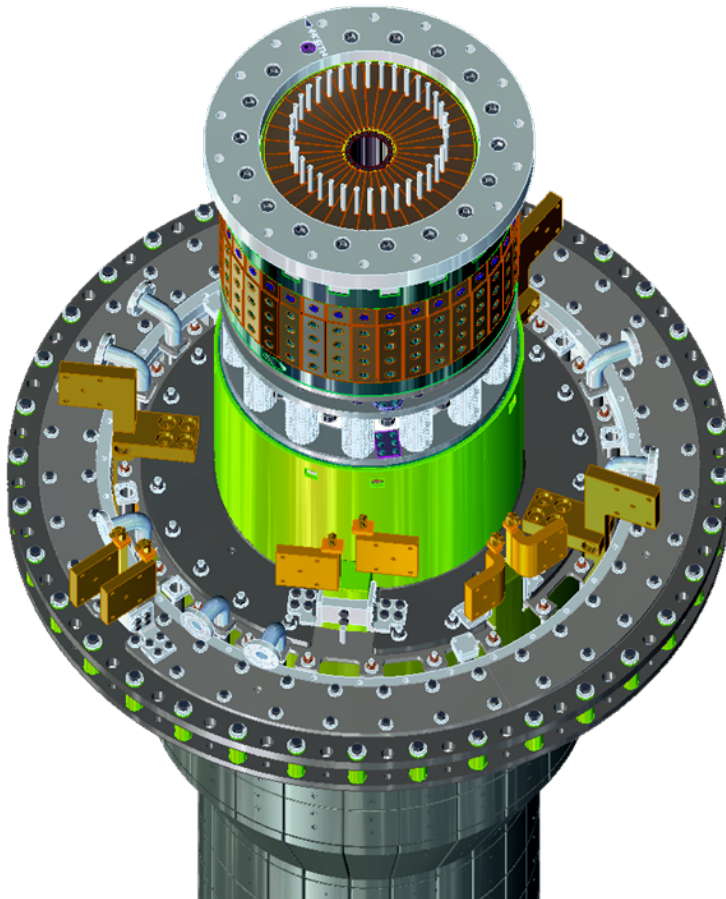


# Step 13- Center Stack Installation Complete

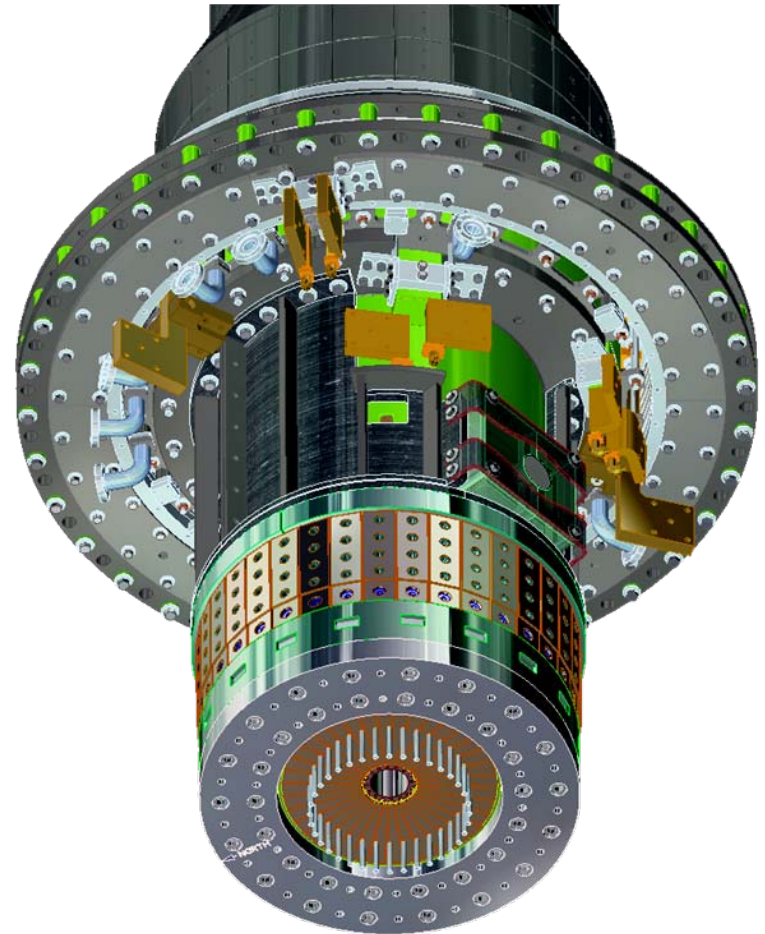


**Centerstack  
Assembly will be  
supported from  
pedestal (not shown  
in this view)**

# Center Stack- Upper and Lower Views



*Top View*



*Bottom View*

# Summary

- ***A Manufacturing Plan **NSTX-PLAN-MFG-1300** (preliminary) has been developed and will be the basis for our major procurements and manufacturing of CS components***
- ***The Inner TF Bundle, OH solenoid and Assembly of the Centerstack components will be performed at PPPL***
- ***The balance of major components will be procured from outside vendors and manufacturers***
- ***The Centerstack Assembly will be completed in **April 2014*****