Modular Coil Option

Machine Configuration and Assembly

David Williamson

NCSX Project Meeting
September 26-27, 2000

Presentation Outline

- Reference Plasma/Coil Parameters

- Configuration and Evaluation

  - Modular Coils and Structure
  - TF Coils
  - OH / PF Coils
  - Vacuum Vessel

- Fabrication and Assembly

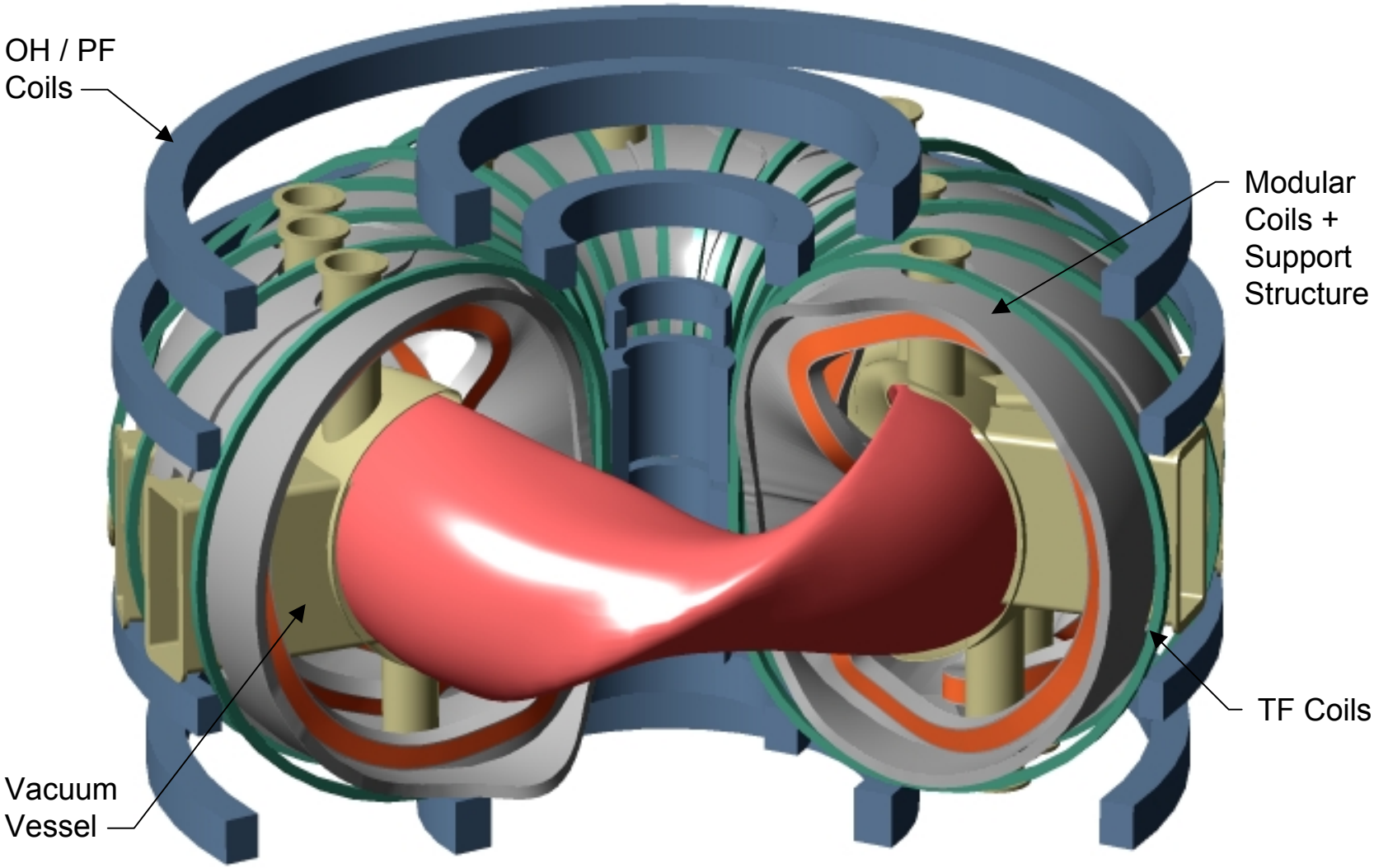
- Summary

Reference Parameters

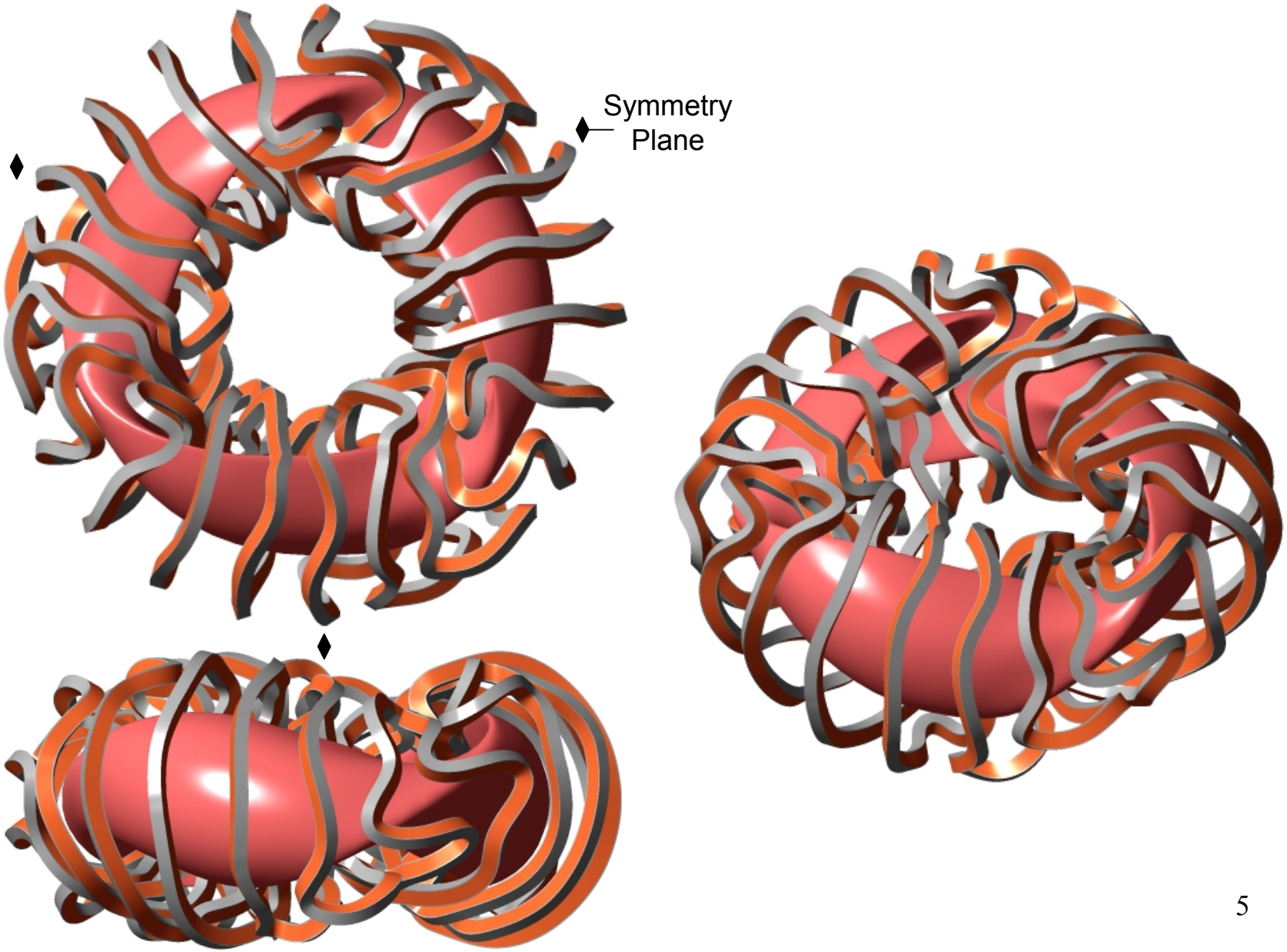
- Plasma Configuration LI-383
  - Major radius = 1.7-m
  - Aspect ratio = 4.4
  - Number of field periods = 3

- Coil Configuration #0907a1
  - Number of modular coils = 21
  - Number of coil types = 4
  - Minimum plasma-to-coil distance = 23.2-cm
  - Minimum coil-to-coil distance = 13.6-cm

Machine Configuration

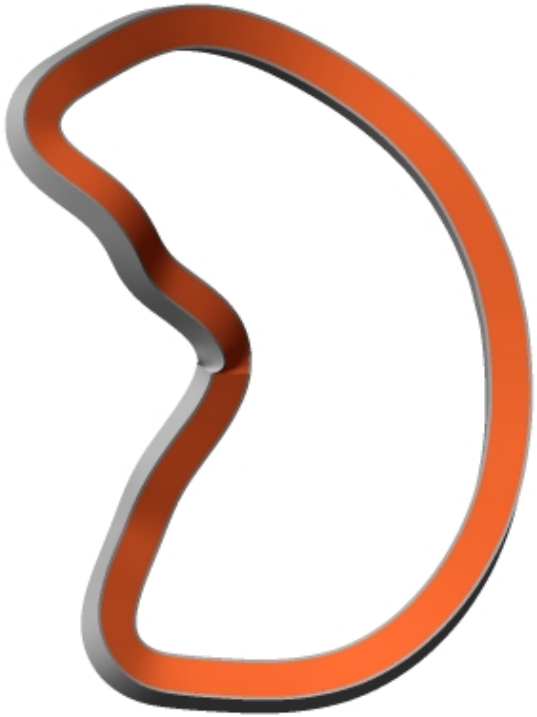


Modular Coil Configuration



Modular Coil Shapes

Coil #	1	2	3	4	Total
Quantity	6	6	6	3	21
Current, kA at 2-T	863.9	863.9	863.9	863.9	
Length, m	7.279	7.194	7.568	7.467	154.647
Minimum Coil-to-Coil Dist (cm)	13.6	13.6	14.4	15.6	
Min Bend Radius at Coil Center (cm)	10.5	7.5	11.1	13.7	
Total Current x Length = 134 MA-m					

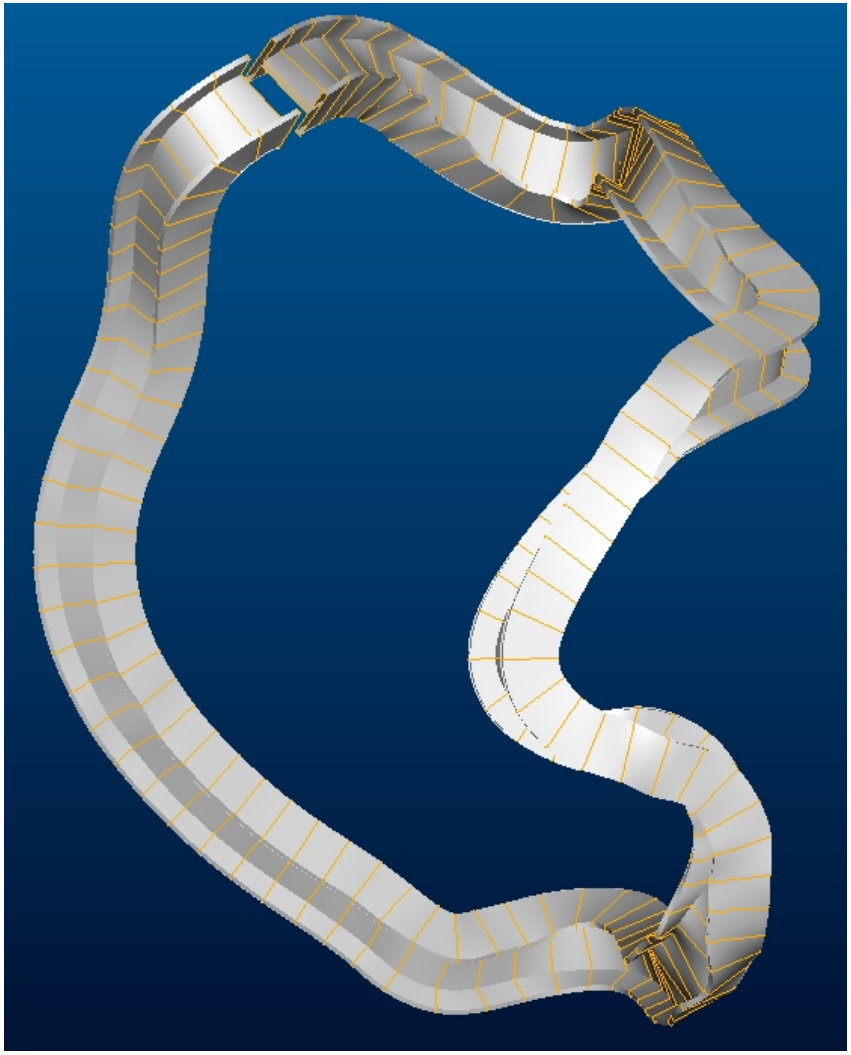


Coil #4

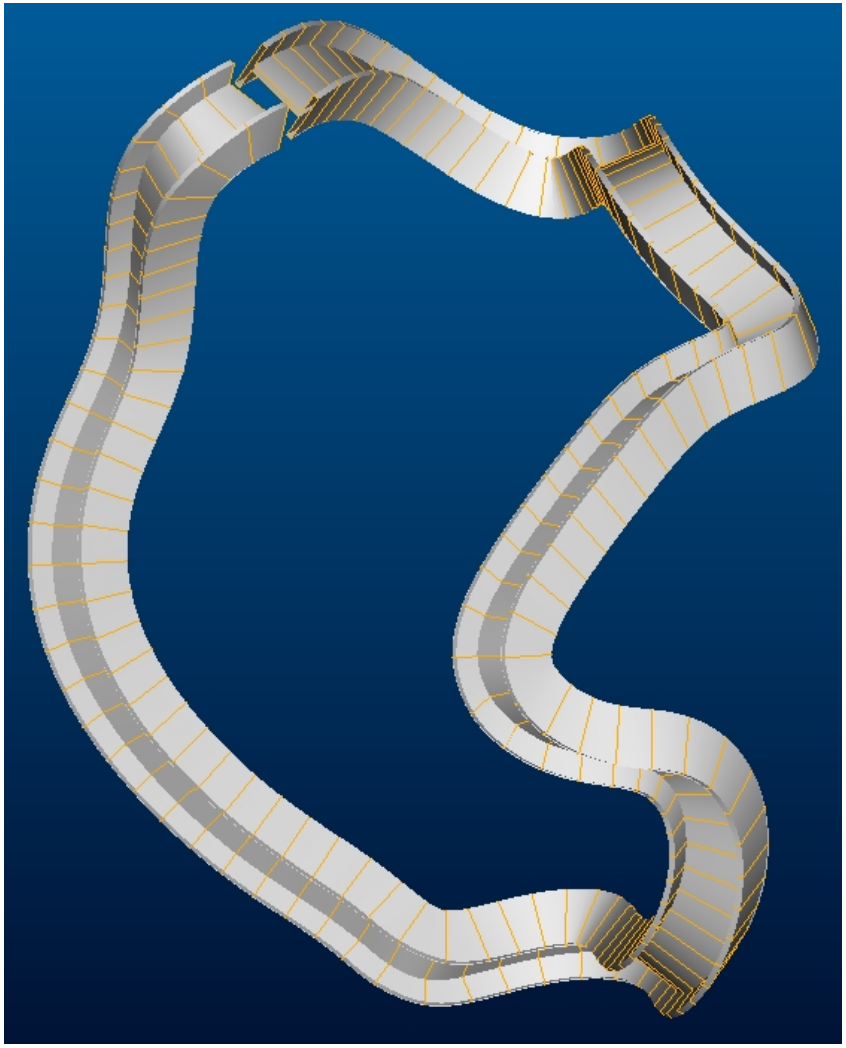
Coil #1

Method of Adjusting Coil Twist Has Been Implemented

- Section is normal to winding surface at start, then varies according to “intersecting frame method”

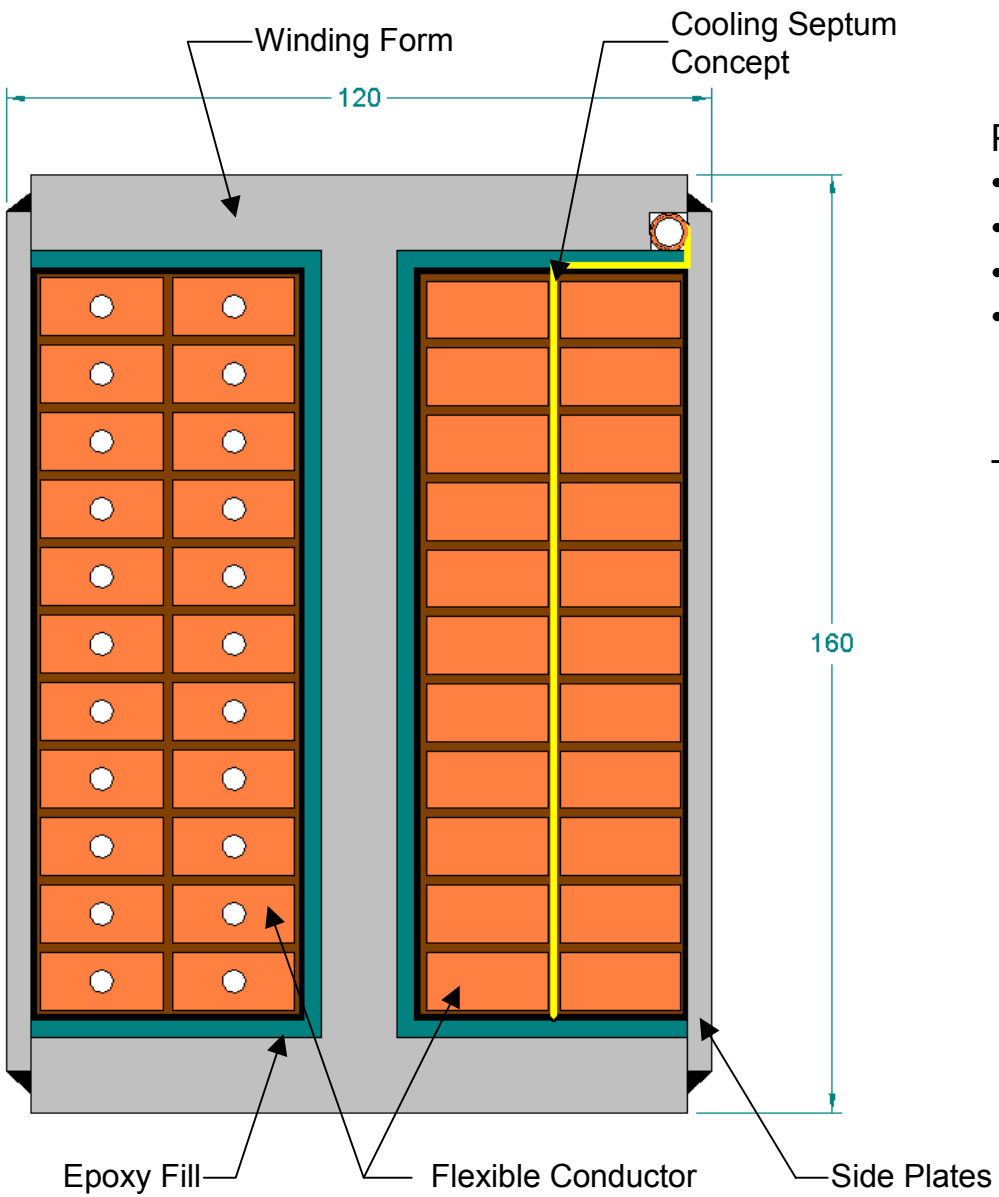


Normal to Surface



Smooth Shape

Winding Configuration



Parameters:
- Coil Envelope = 12 x 16-cm
- Current / Coil = 864-kA @ 2-T
- Number of Turns = 44
- Current / Turn = 19.6-kA

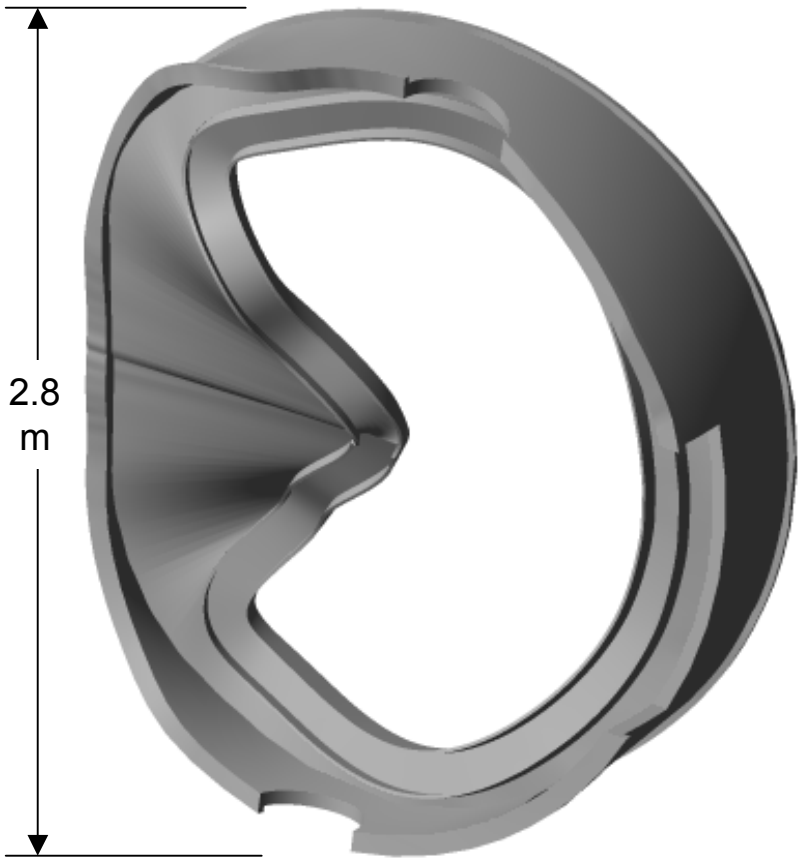
Two Winding Options:

Internal Passage:
- Conductor Size = 20.8 x 9.8-mm
- Hole Diameter = 4-mm
- Packing Factor = 75% (flexible cond)
- Net Current Density = 13.5-kA/cm2

Conduction to Septum:
- Conductor Size = 19.8 x 9.8-mm
- Septum Width = 2-mm
- Packing Factor = 75%
- Net Current Density = 13.4-kA/cm2

Structural Arrangement

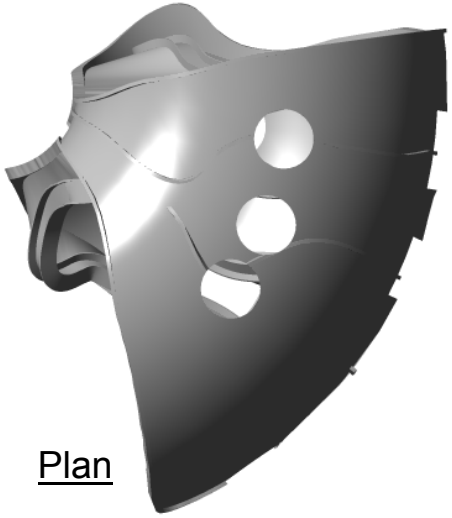
- Winding form and support structure are an integral casting (~6000-lb ea)



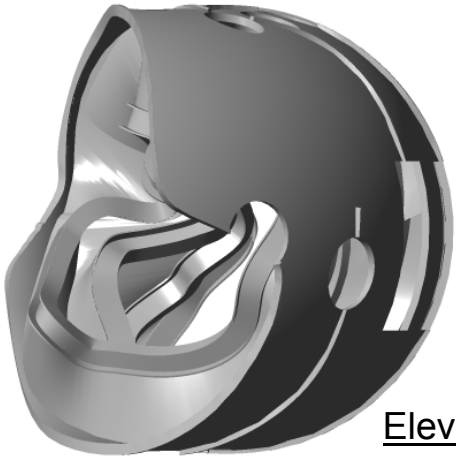
Coil #4

Structural Arrangement (2)

- Castings bolt together to form axisymmetric shell



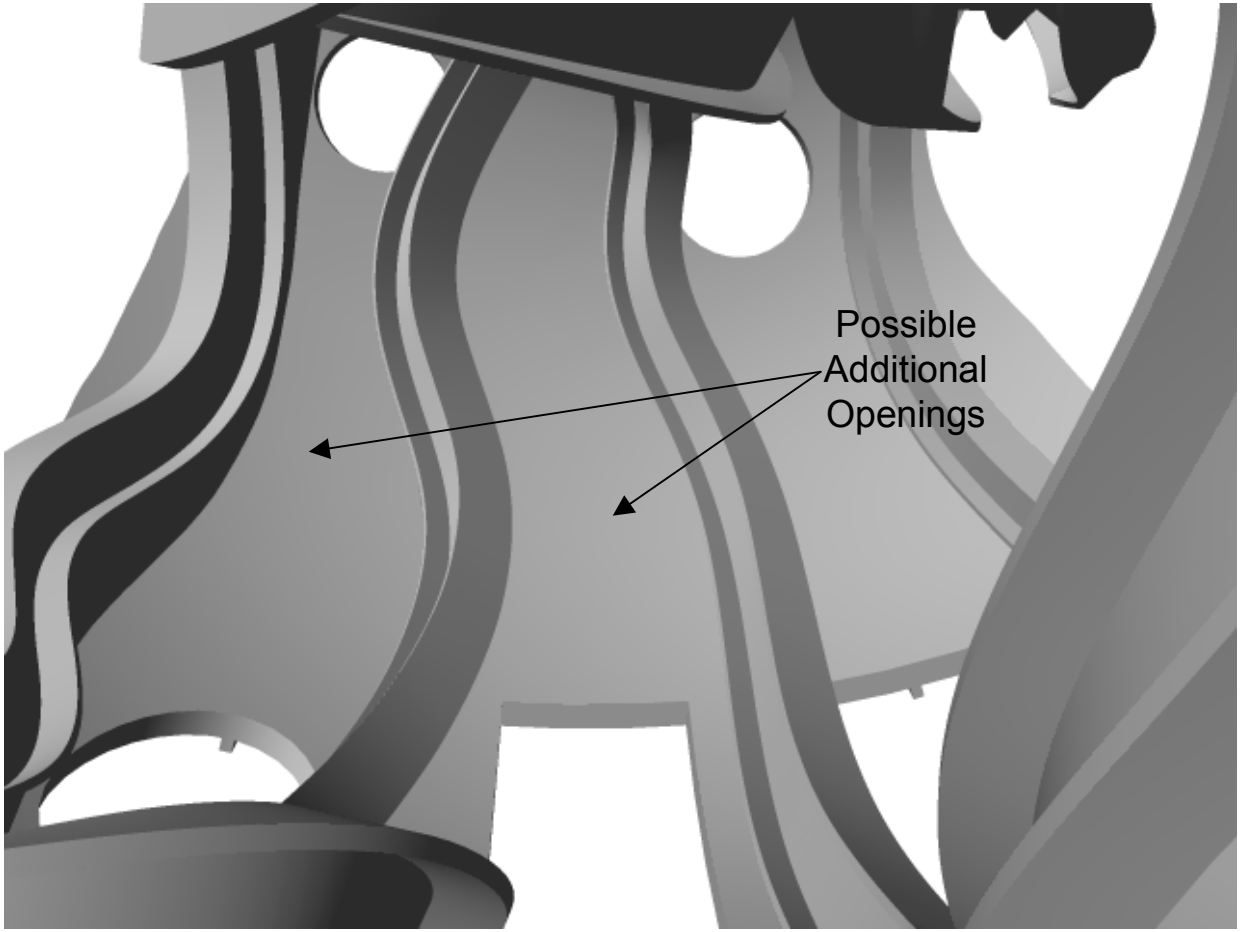
Plan



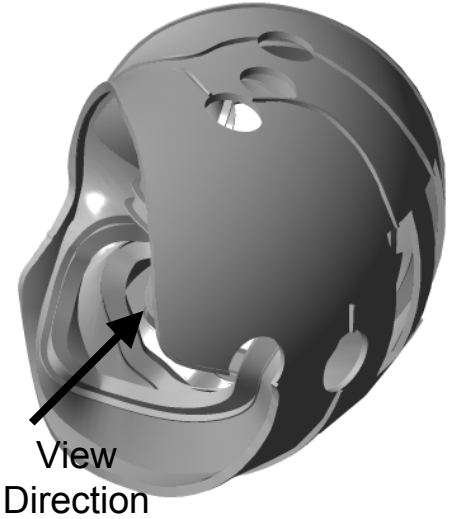
Elev

Structural Arrangement (3)

- The number and size of openings has not been optimized

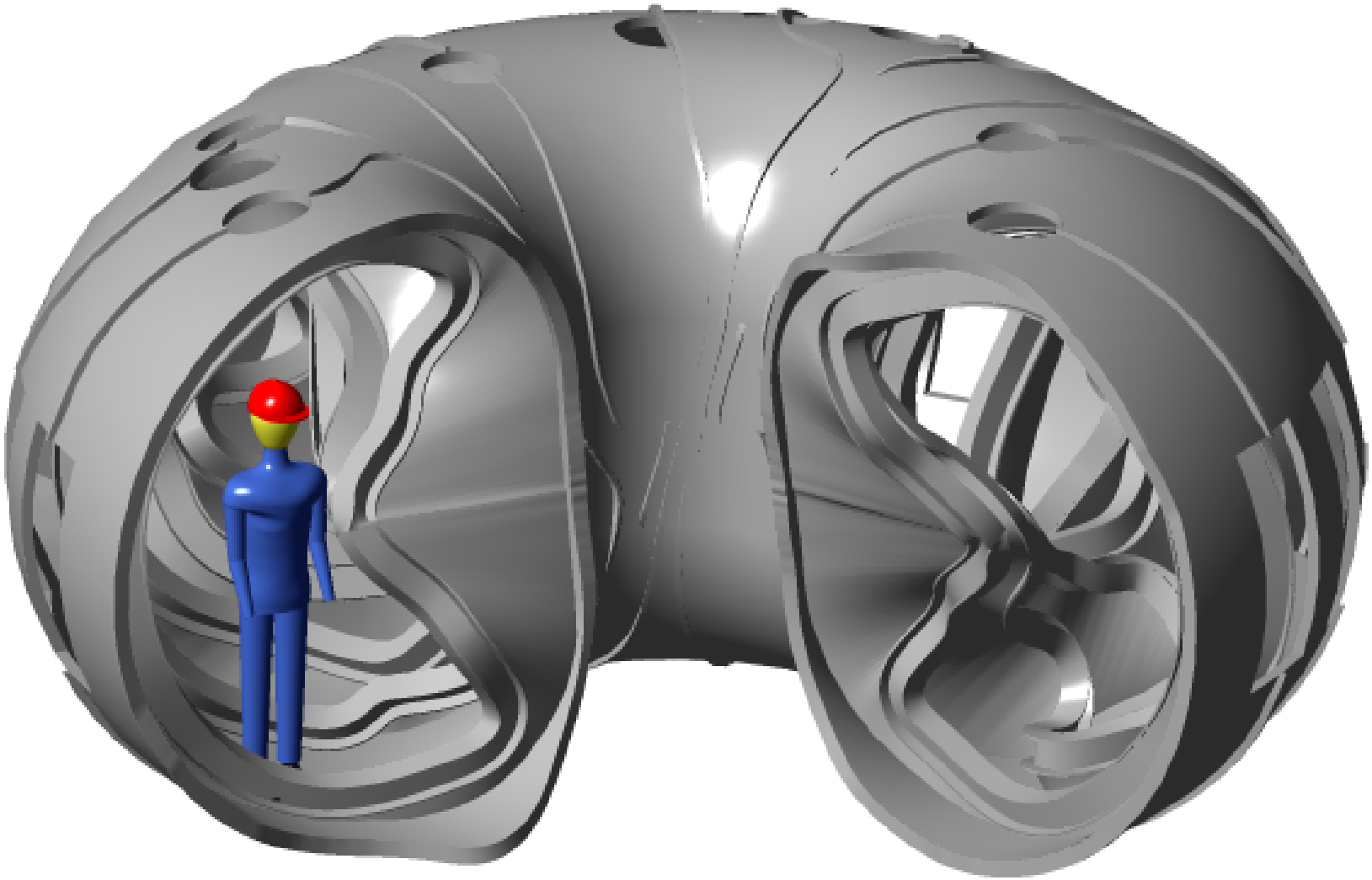


Perspective View from Inside of Shell



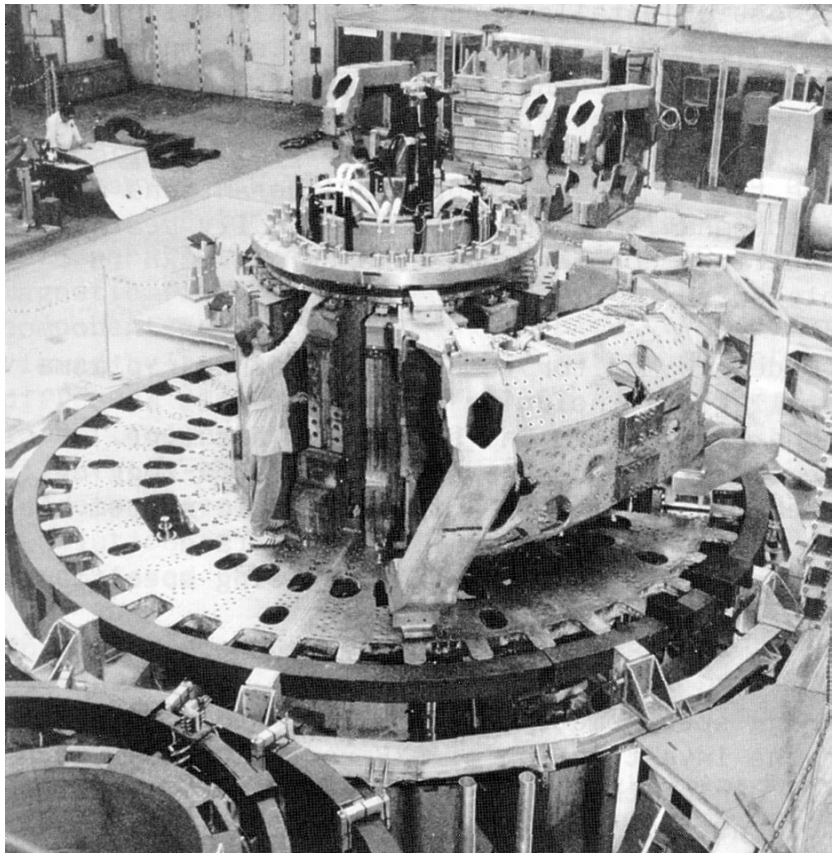
Structural Arrangement (4)

- Estimated weight of structural shell is 60-ton

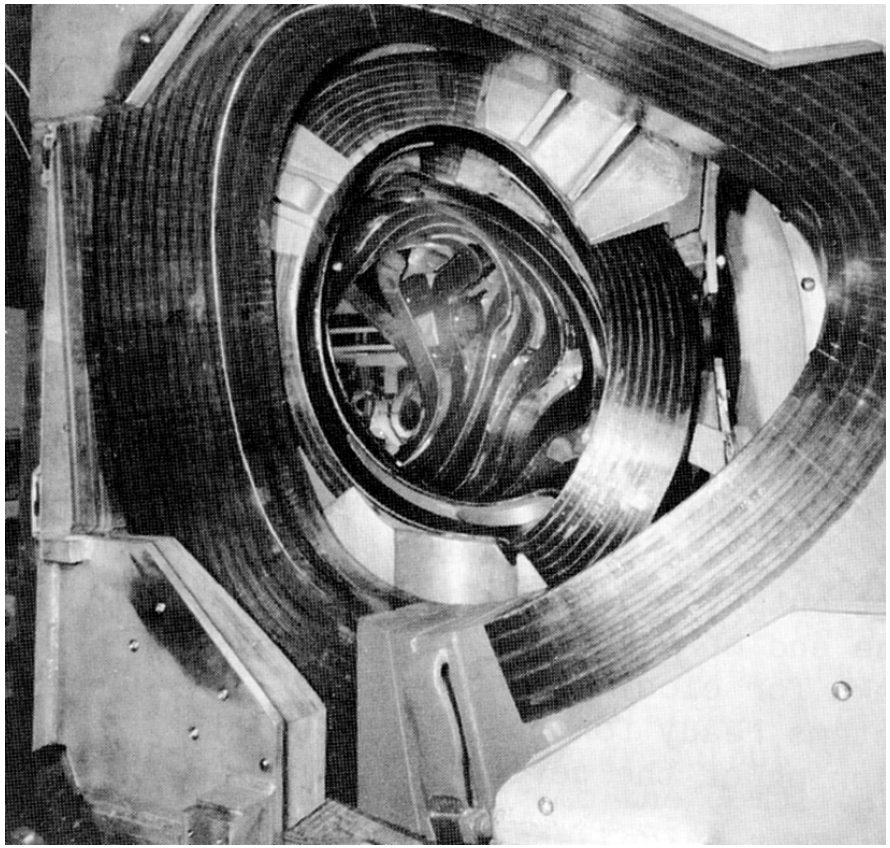


Structure Compared To W7-AS

- W7-AS uses external shell to support coils made from bundled solid copper conductor



Structural Shell Installation (1986)

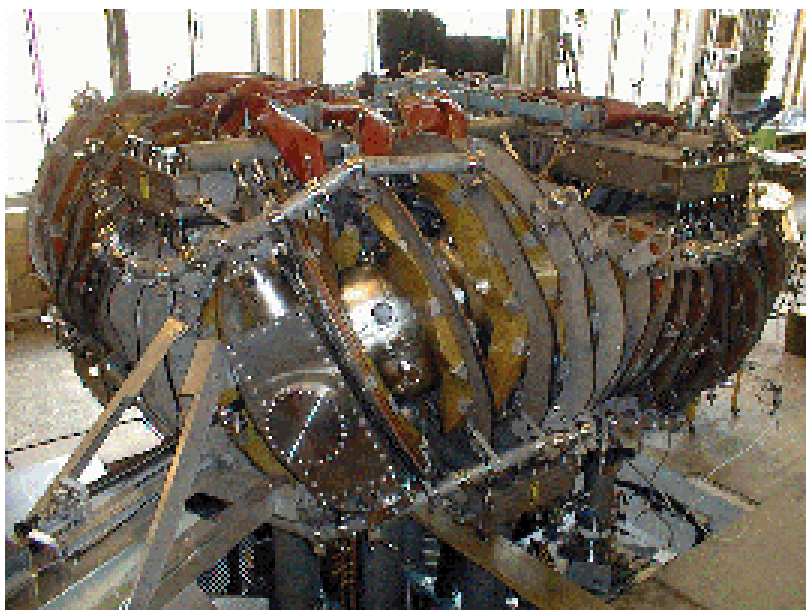


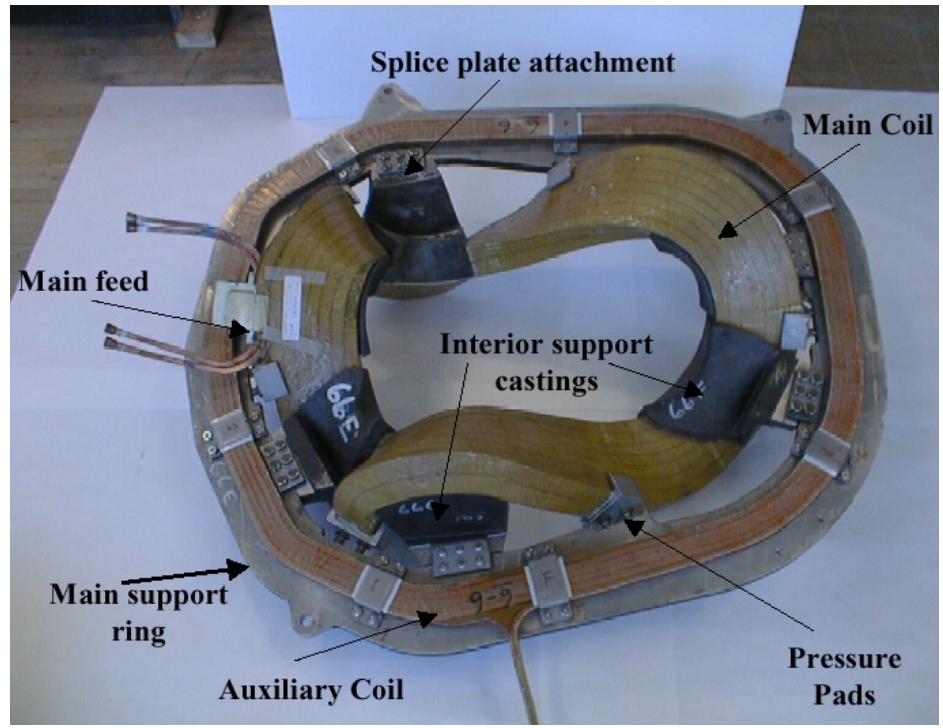
View into Bore of Assembly

Structure Compared To HSX

- HSX uses a flat external support plate with discrete coil supports

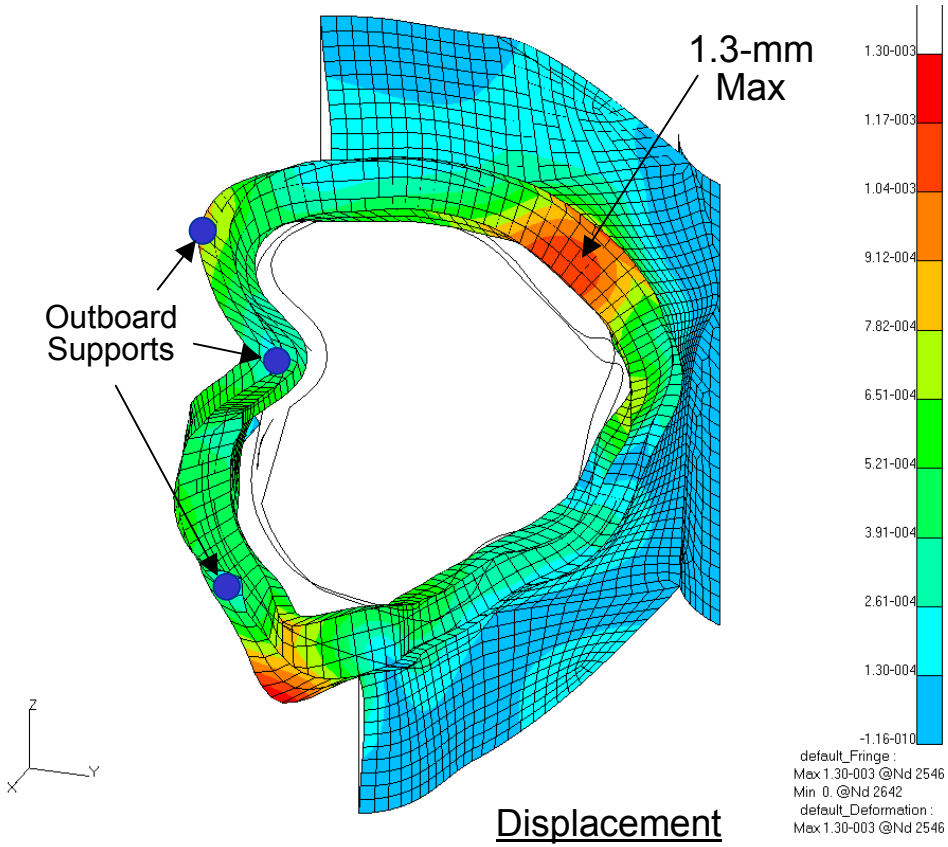
Major Radius	1.2 m
Average Plasma Minor Radius	0.15 m
Plasma Volume	~.44 m^3
Number of Field Periods	4
Helical Axis Radius	20 cm
Rotational Transform	
Axis	1.05
Edge	1.12
Number of Coils/period	12
Average Coil Radius	~ 30 cm
Number turns/coil	14
Coil Current	13.4 kA
Magnetic Field Strength (max)	1.37 T
Magnet Pulse Length (full field)	≤ 0.2 s
Auxiliary Coils (total)	48

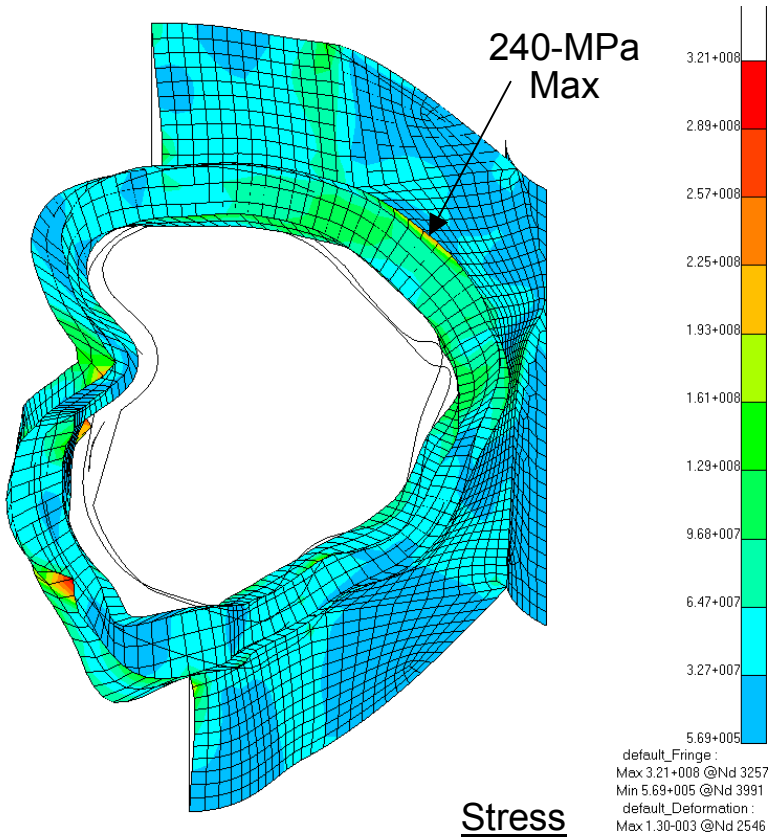




Response of Coil Structure to EM Loads

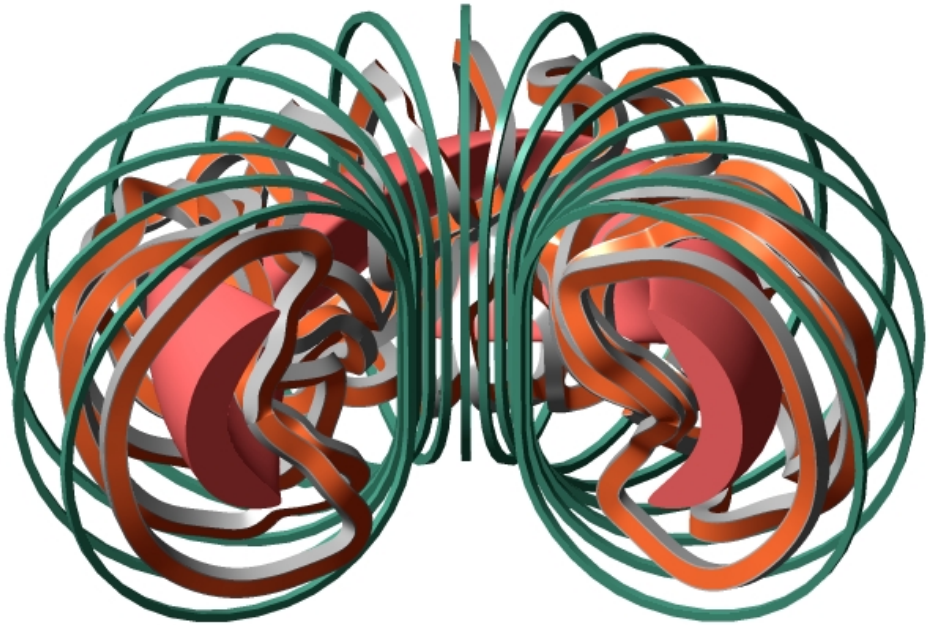
- EM and stress analysis has not been updated, but results should be improved due to additional structure

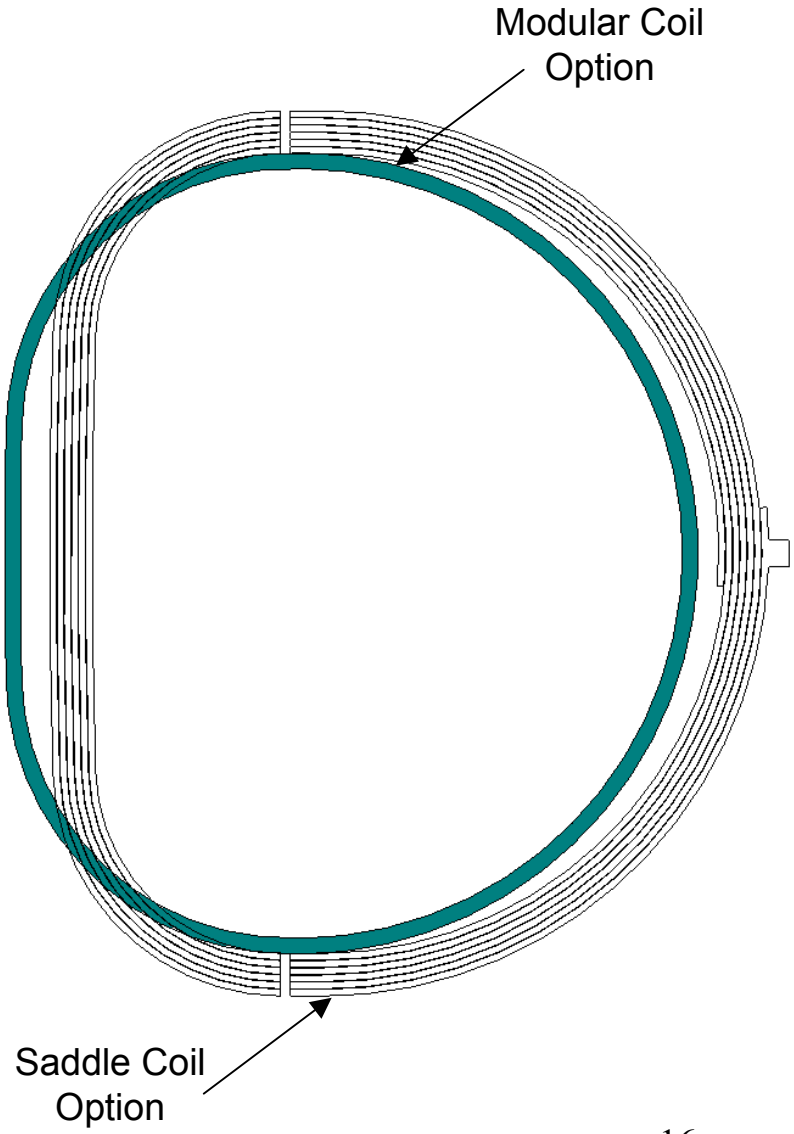




TF Coil Configuration

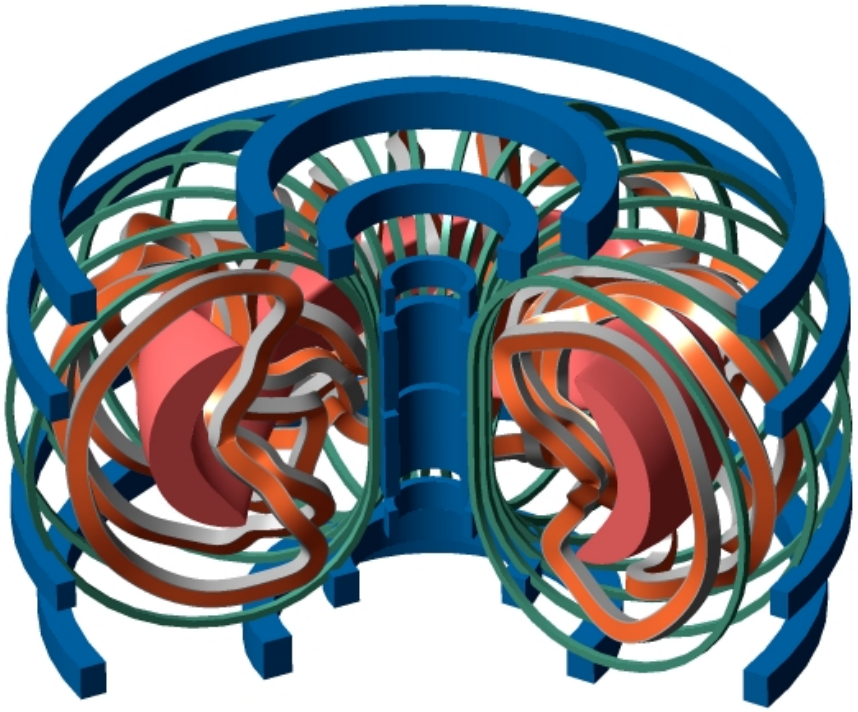
- Number of Coils = 21
- Field = 0.2-T @ 1.7-m
- Current / coil = 81-kA
- Number of turns = 4
- Coil x-section = 6 x 6-cm
- Coil perimeter = 9-m



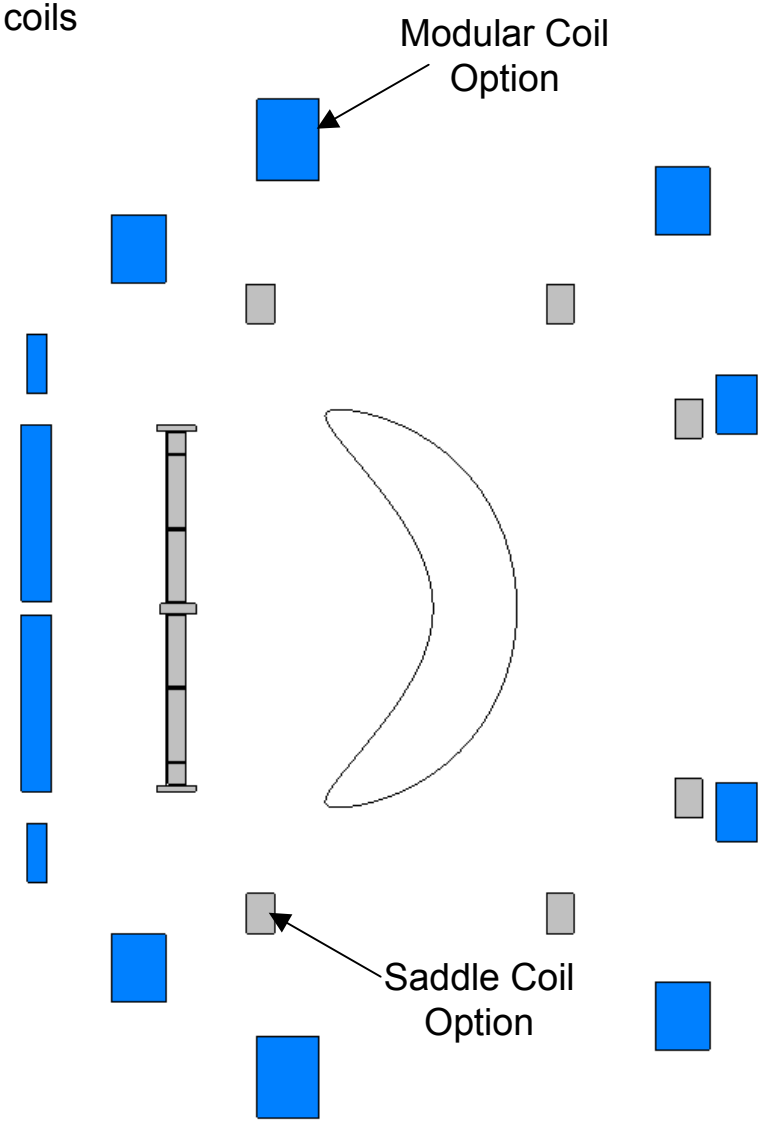


PF Coil Configuration

- OH / return and VF windings are positioned outside the TF coils

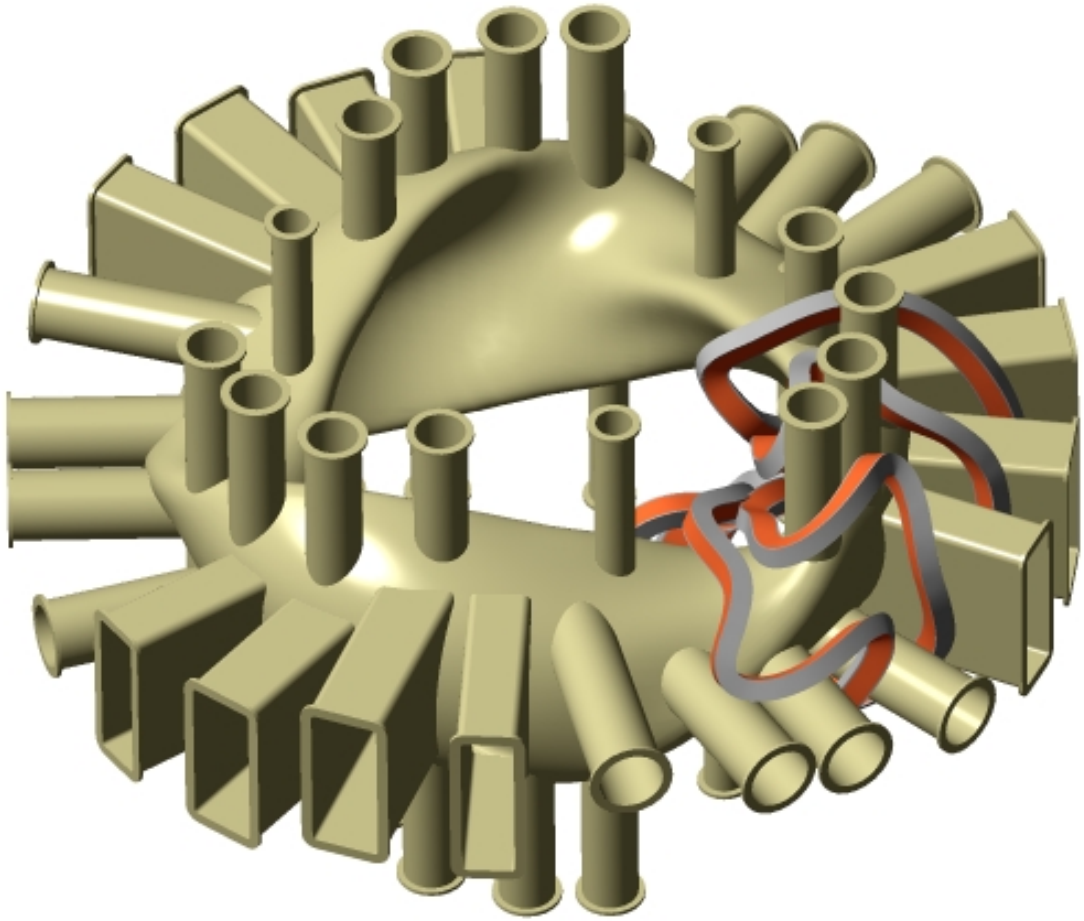


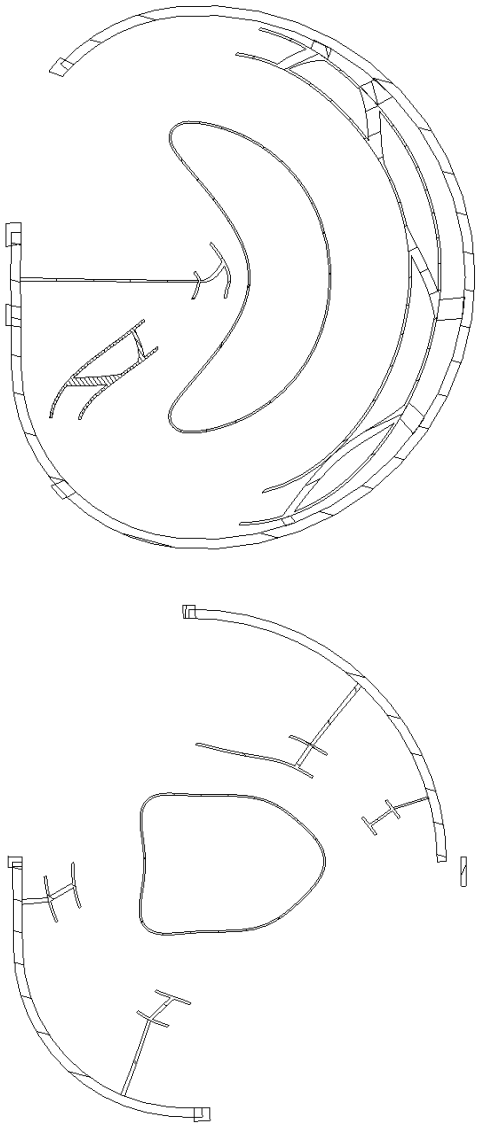
	INCHES					
	r1	dr	rc	z1	dz	zc
PF1	9.75	4.5	12	1	13	7.5
PF2	9.75	4.5	12	14	13	20.5
PF3	10.5	3	12	31.65	8.7	36
PF4	23	8	27	48	10	53
PF5	44.5	9	49	63	12	69
PF6	103	8	107	55	10	60
PF7	112	6	115	25.65	8.7	30



Vacuum Vessel Configuration

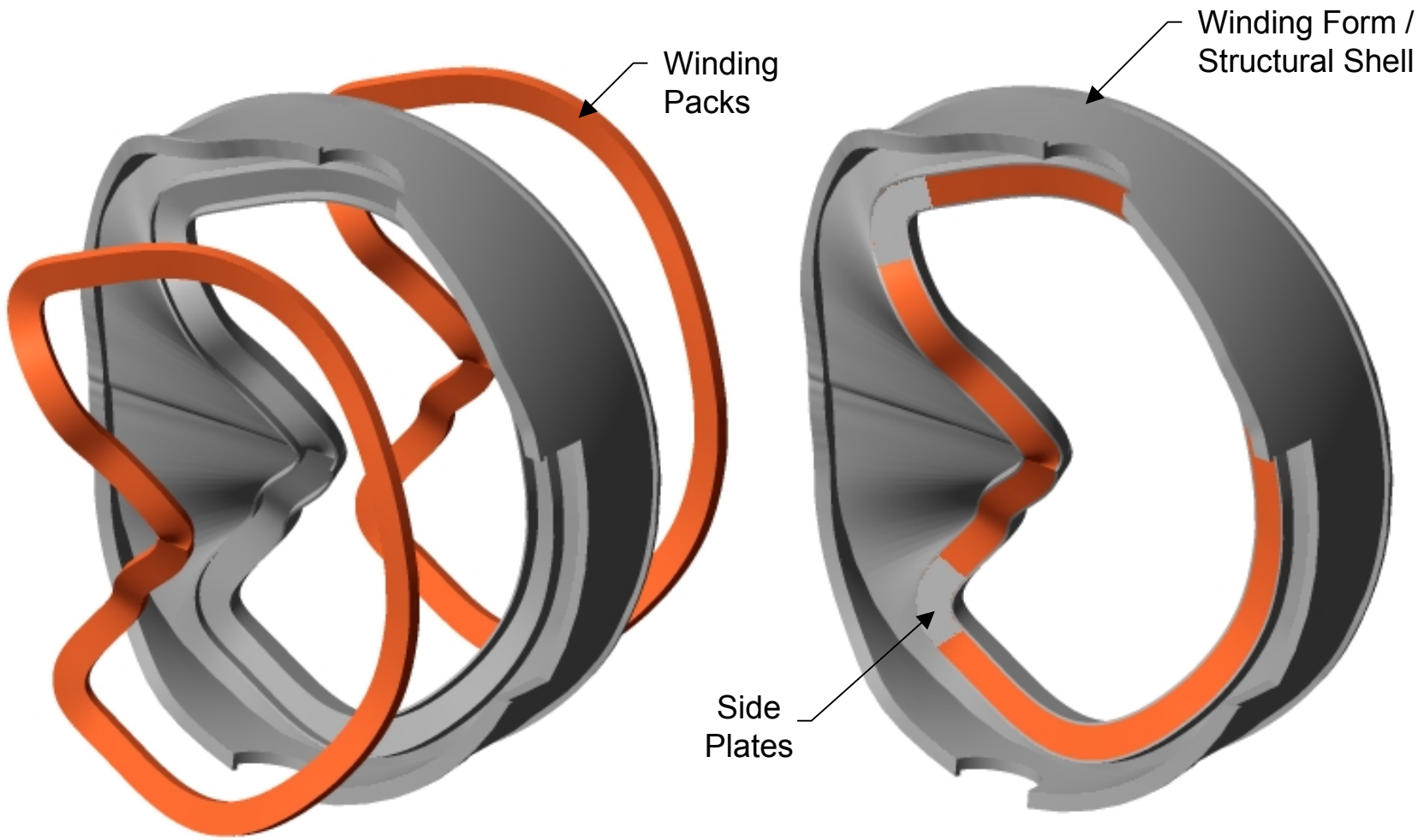
- Thin conformal vessel with 5.2-cm offset from plasma
- Ports as shown vary from 15x36-in to ~14-in dia
- Estimated weight is 7.8-ton





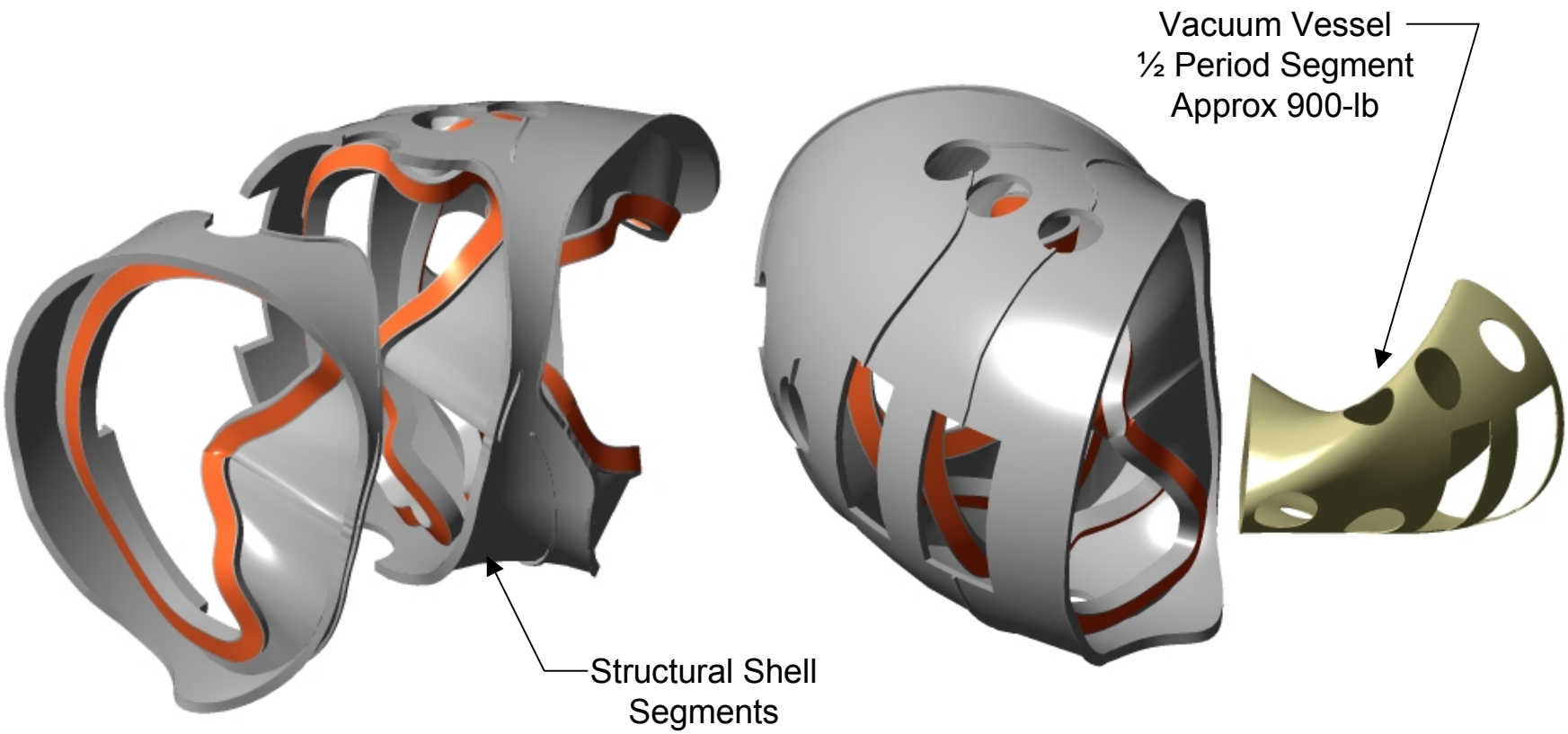
Fabrication and Assembly

- Wind conductor into 21 structural shell segments
- Install side plates for local lateral support



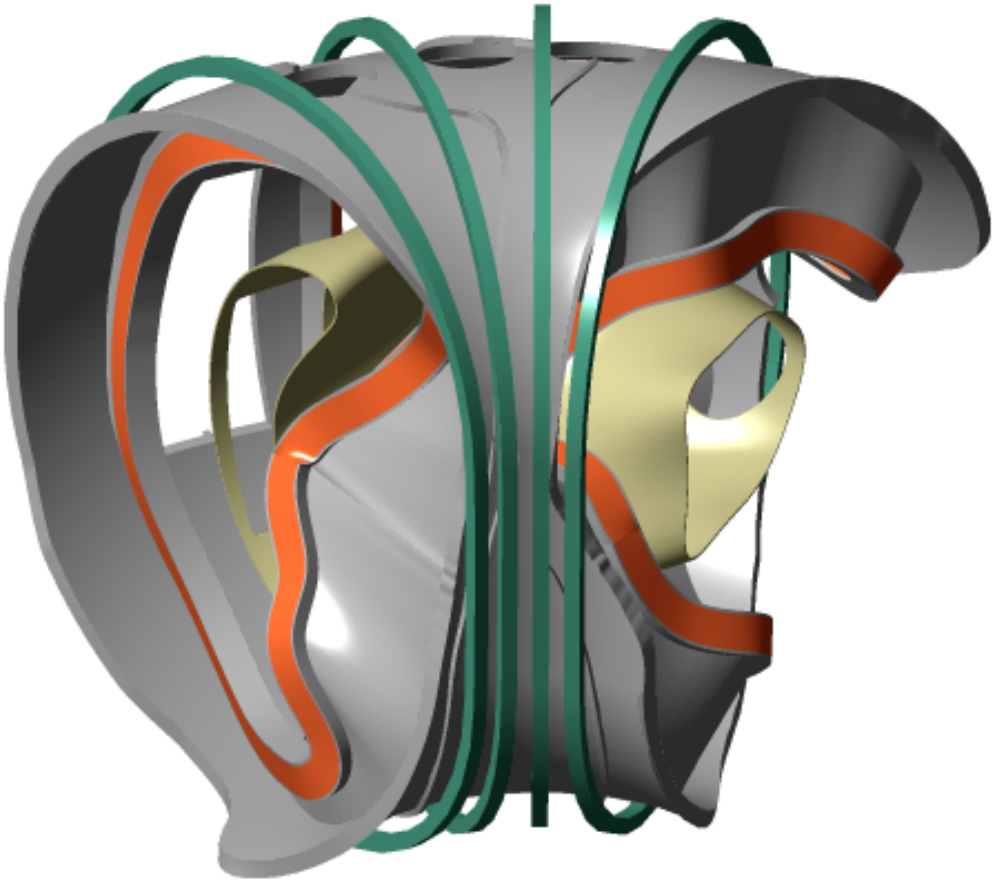
Fabrication and Assembly (2)

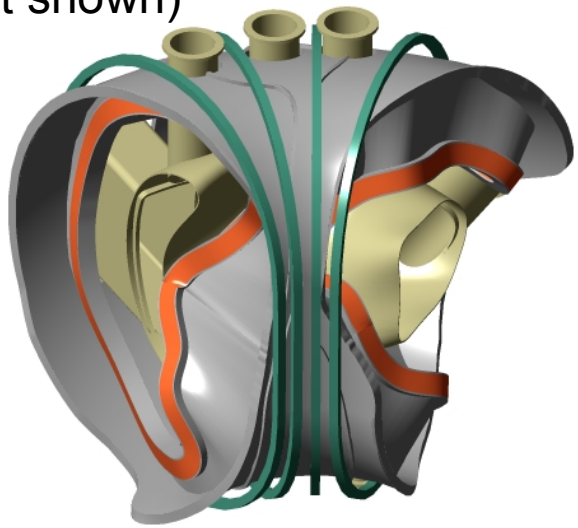
- Assemble 4 shell segments for one half-period of structure
- Install vacuum vessel segment without ports

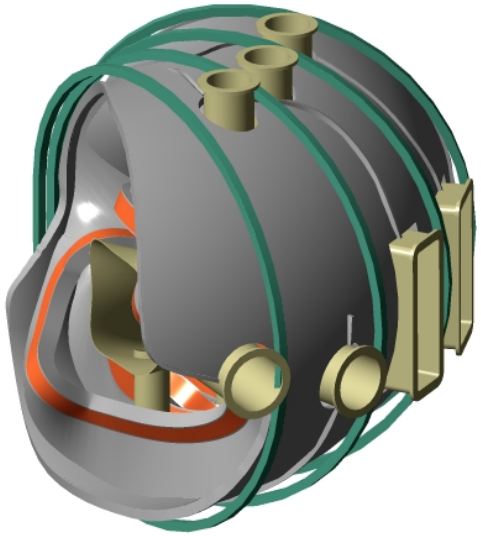


Fabrication and Assembly (3)

- Place TF coils and attach to shell (supports not shown)
- Install vacuum vessel port extensions

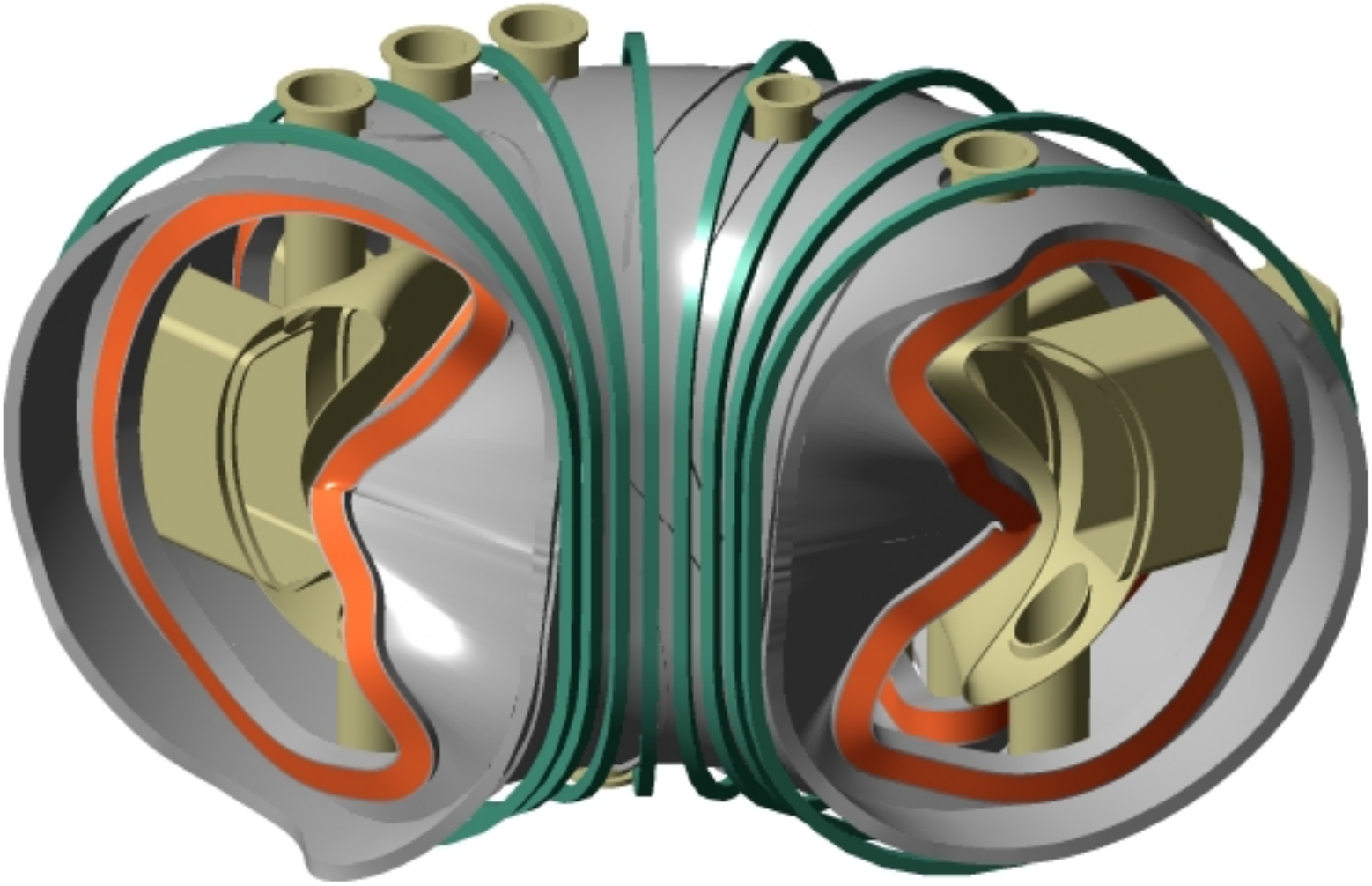






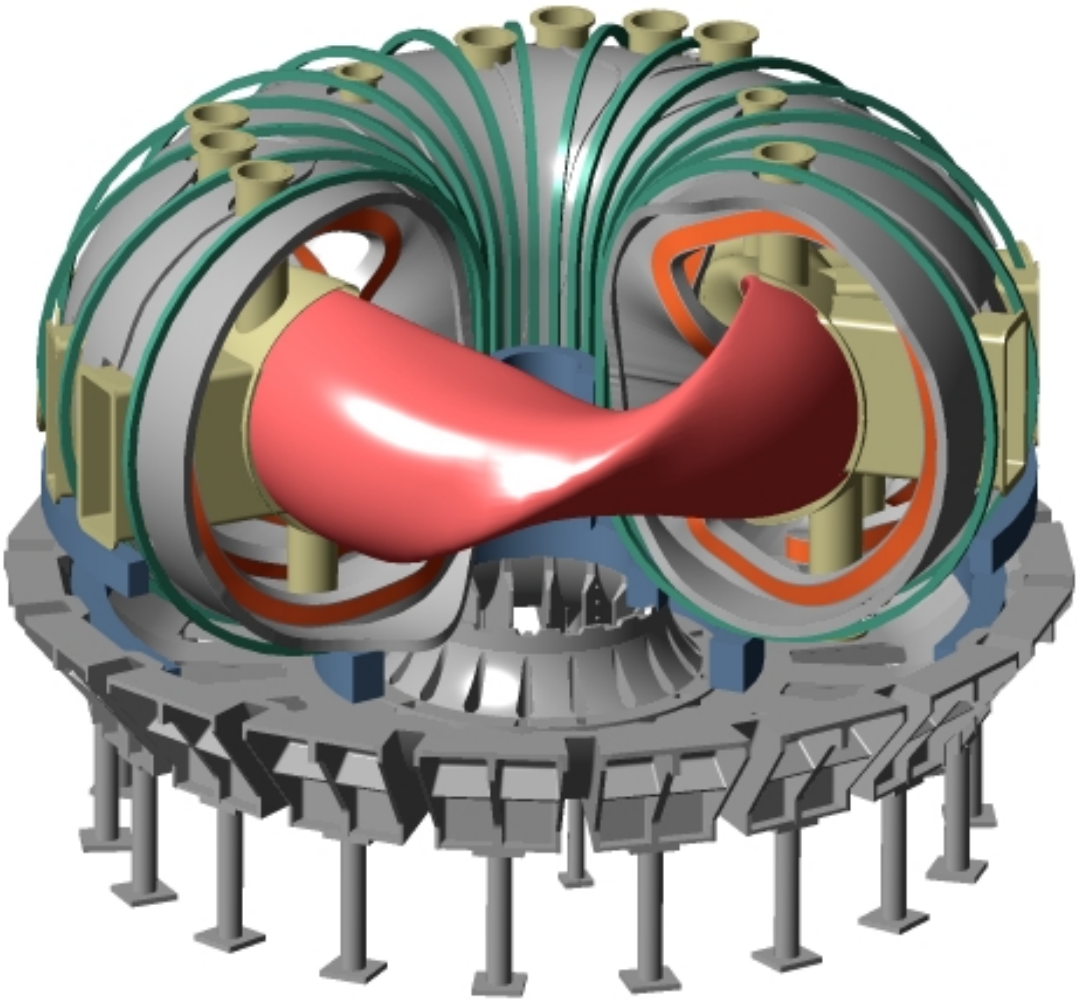
Fabrication and Assembly (4)

- Attach half-period sub-assemblies by welding (vessel) and bolting (shell)



Fabrication and Assembly (5)

- Attach OH / PF coils directly to the modular coil support structure
- Support base would be similar in size to saddle coil option



Summary and Conclusions

- A modular coil configuration has been developed, though not in as much detail as the saddle coil option

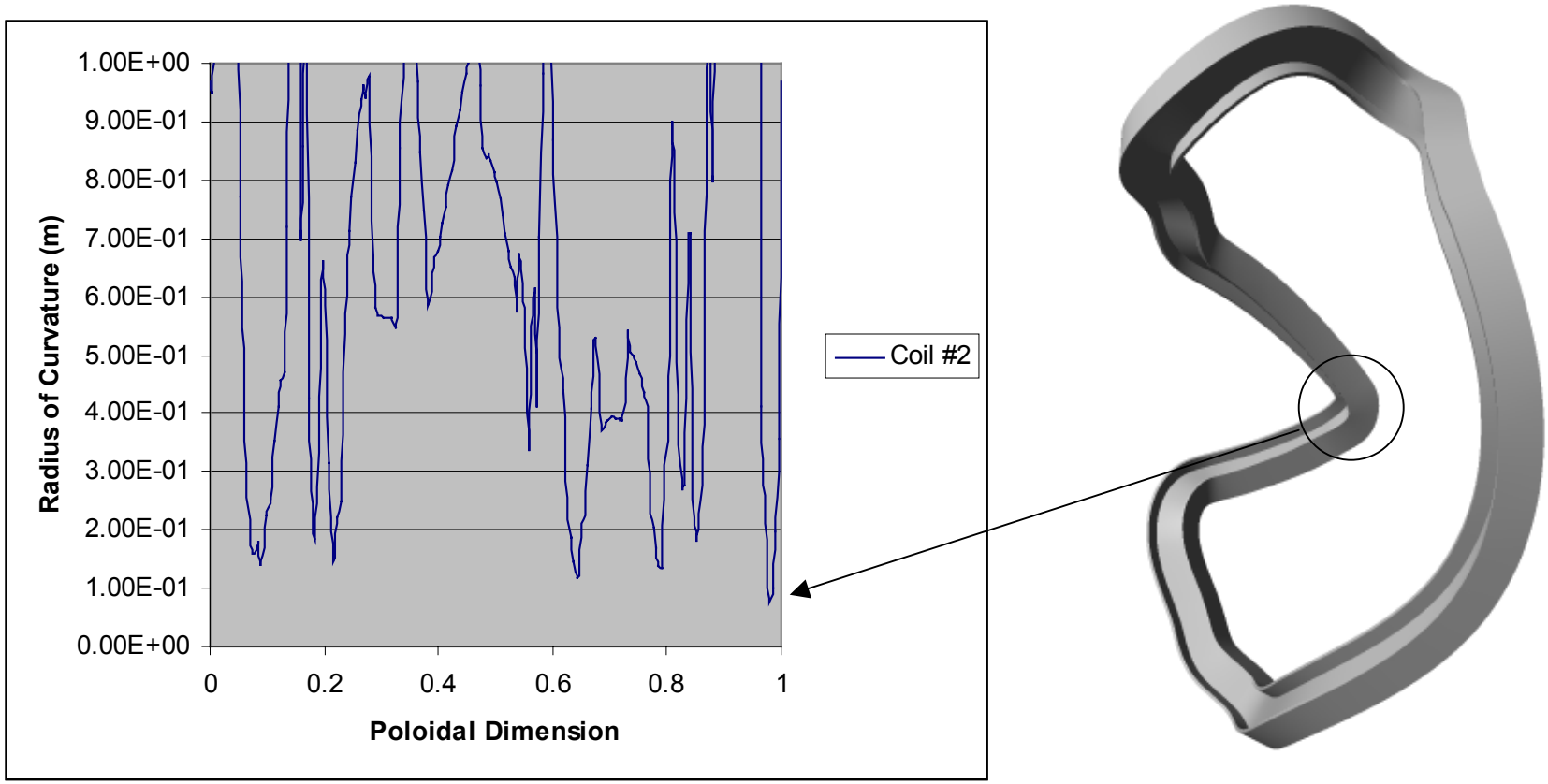
- Issues include:
  - Coil geometry (bend radius, twist, coil-to-coil spacing)
  - Current density
  - Access for heating and diagnostics

- Fabrication appears to have same level of complexity as the saddle coil option, except winding form castings are larger

- Assembly operations are similar, except for vacuum vessel which requires more in-field welding

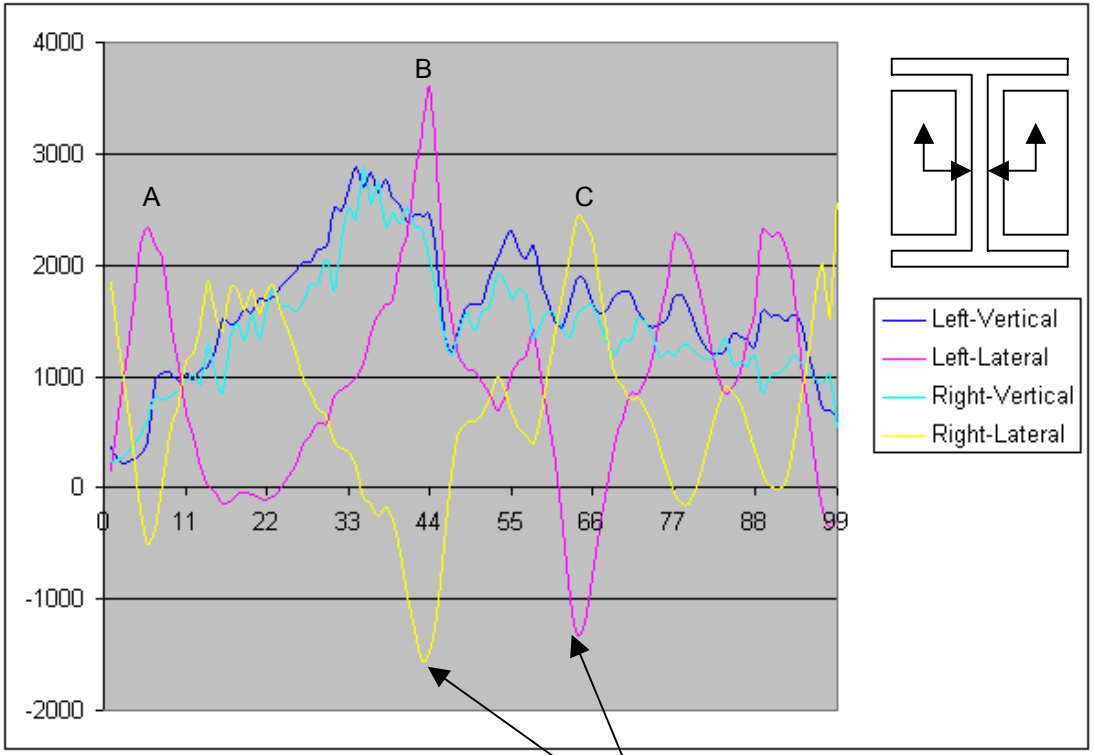
- With modular configuration, it may be possible to wind coils using bundled solid copper turns instead of cable conductor

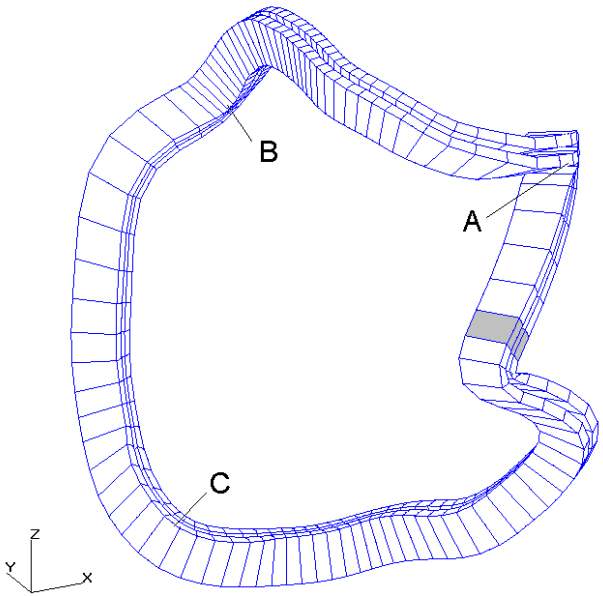
Backup Slide – Radius of Curvature



Backup Slide – EM Force Distribution

- EM Force (lb/in) for Coil #1 in Coil Local Coordinate System





Lateral force direction is away from structure