NSTX Upgrade

Vessel Rework for the Neutral Beam and Thomson Scattering

NSTXU-CALC-24-01-00

Rev 0

February 1, 2011

Prepared By:

Thomas Willard Digitally signed by Thomas Willard
DN: cn=Thomas Willard, o=Engineering, ou=PPPL, email=twillard@pppl.gov, c=US
Date: 2011.02.02 13:45:19 -05'00'

Tom Willard

Reviewed By:

Ali Zolfaghari Digitally signed by Ali Zolfaghari
DN: cn=Ali Zolfaghari, o=PPPL, ou=Engineering, email=azolfagh@pppl.gov, c=US
Date: 2011.02.02 15:58:09 -05'00'

Ali Zolgfahari

Approved By:

Mark Smith Digitally signed by Mark Smith
DN: cn=Mark Smith, o=PPPL, ou=FOM, email=msmith@pppl.gov, c=US
Date: 2011.02.02 16:49:16 -05'00'

Marc Smith, Cognizant Engineer

George Labik Digitally signed by George Labik
DN: cn=George Labik, o=PPPL, ou, email=glabik@pppl.gov, c=US
Date: 2011.02.04 17:27:43 -05'00'

George Labik, Cognizant Engineer

Craig Priniski Digitally signed by Craig Priniski
DN: cn=Craig Priniski, o=Princeton Plasma Physics Lab, ou=FOM, email=cpriniski@pppl.gov, c=US
Date: 2011.02.15 09:01:37 -05'00'

Craig Priniski, Cognizant Engineer

PPPL Calculation Form

Calculation # NSTXU-CALC-24-01 Revision # 00 _____ WP #, if any (ENG-032) ________

Purpose of Calculation: (Define why the calculation is being performed.)

To qualify the NSTX upgrade changes to the vacuum vessel midsection, required to accommodate: 1.) the addition of a second Neutral Beam at Port J; and 2.) the larger diameter port at Port L to prevent an optical interference with the Thomson Scattering laser beam. Specifically, to determine the maximum stress in the vacuum vessel midsection and port extensions under the worst-case simulataneously applied load condition: 1.) vacuum/ atmospheric pressure load; 2.) magnetostatic Toroidal Field coil torsional load; and 3.) electromagnetic transient plasma disruption load.

References (List any source of design information including computer program titles and revision levels.)

[1] NSTX Structural Design Criteria Document, I. Zatz[2] NSTX Design point, June 2010 http://www.pppl.gov/~neumeyer/NSTX_CSU/Design_Point.html[3] Hicks, C.M.: "Shock and Vibration Handbook", McGraw-Hill, New York, NY, 1995.

Assumptions (Identify all assumptions made as part of this calculation.)The combination of Current Scenario #79 and the Centered Plasma Disruption Scenario was assumed worst-case for the vacuum vessel, since it results in the maximum out-of-plane torque and the largest induced eddy currents in the vessel wall. Several other current and disruption scenario combinations should be run to confirm this assumption.

Calculation (Calculation is either documented here or attached)
See attached

Conclusion (Specify whether or not the purpose of the calculation was accomplished.)

The results of the one-way coupled electromagnetic-static structural analysis shows the maximum stress occurs at the intersection of vessel wall and the J-K port cap extension, along the perimeter weld seam, and is below the maximum allowed by the NSTX Structural Design Criteria. A detailed fatigue analysis of the weld, submodeled from the global model with the full inventory of loads for the worst-case current scenario, is required to fully qualify the NSTX upgrade changes.

Cognizant Engineer’s printed name, signature, and date

Mark Smith

Digitally signed by Mark Smith
DN: cn=Mark Smith, o=PPPL, ou=FOM, email=msmith@pppl.gov, c=US
Date: 2011.02.02 16:49:33 -05'00'

Marc Smith

George Labik

Digitally signed by George Labik
DN: cn=George Labik, o=PPPL, ou, email=glabik@pppl.gov, c=US
Date: 2011.02.16 15:58:56 -05'00'

George Labik

Craig Priniski

Digitally signed by Craig Priniski
DN: cn=Craig Priniski, o=Princeton Plasma Physics Lab, ou=FOM, email=cpriniski@pppl.gov, c=US
Date: 2011.02.15 09:02:29 -05'00'

Craig Priniski

I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct.

Checker’s printed name, signature, and date

Ali Zolfaghari

Digitally signed by Ali Zolfaghari
DN: cn=Ali Zolfaghari, o=PPPL, ou=Engineering, email=azolfagh@pppl.gov, c=US
Date: 2011.02.02 16:01:22 -05'00'

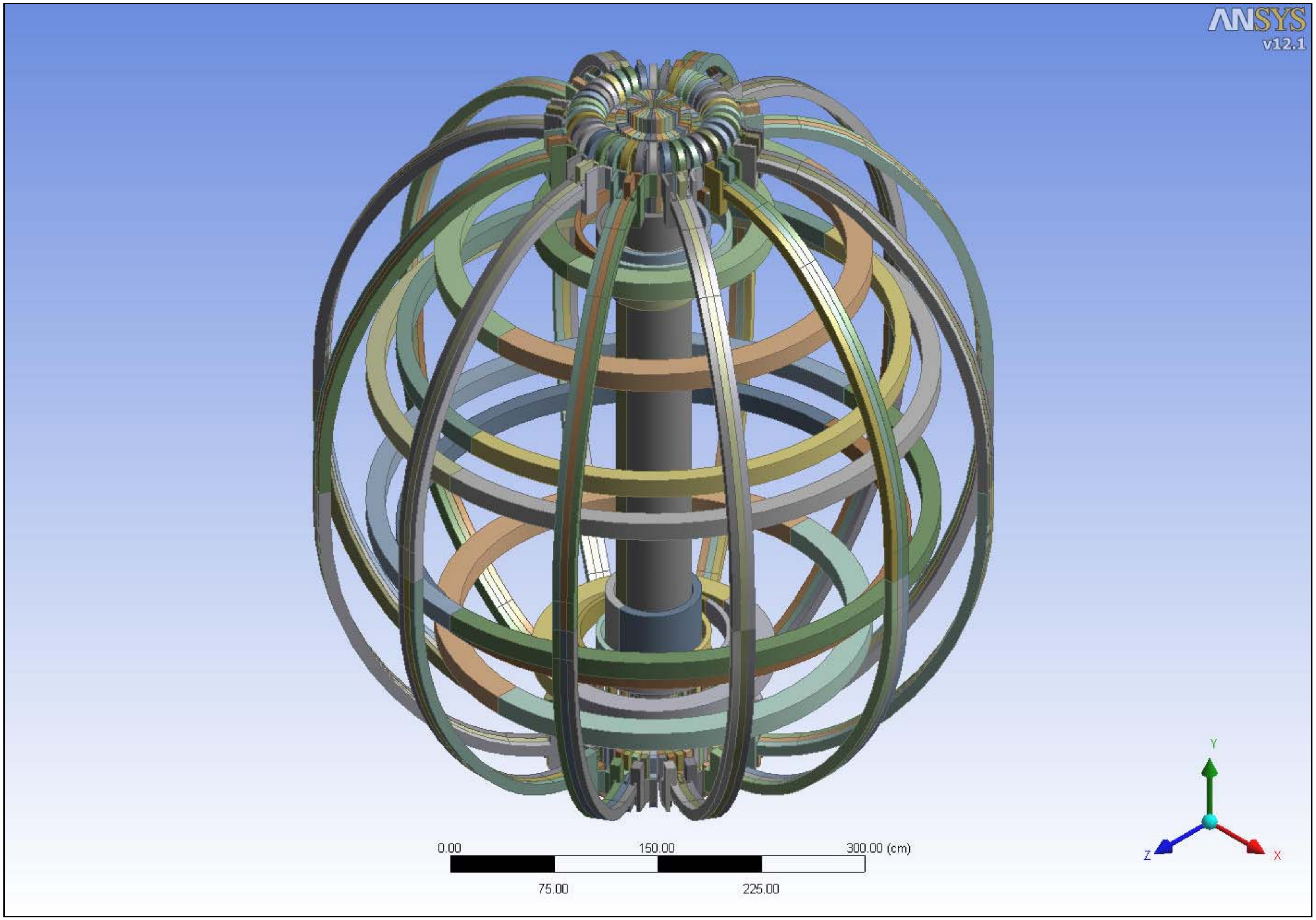
Ali Zolgfahari

NSTXU-CALC-24-01-00
Vessel Port Rework for NB and Thomson Scattering

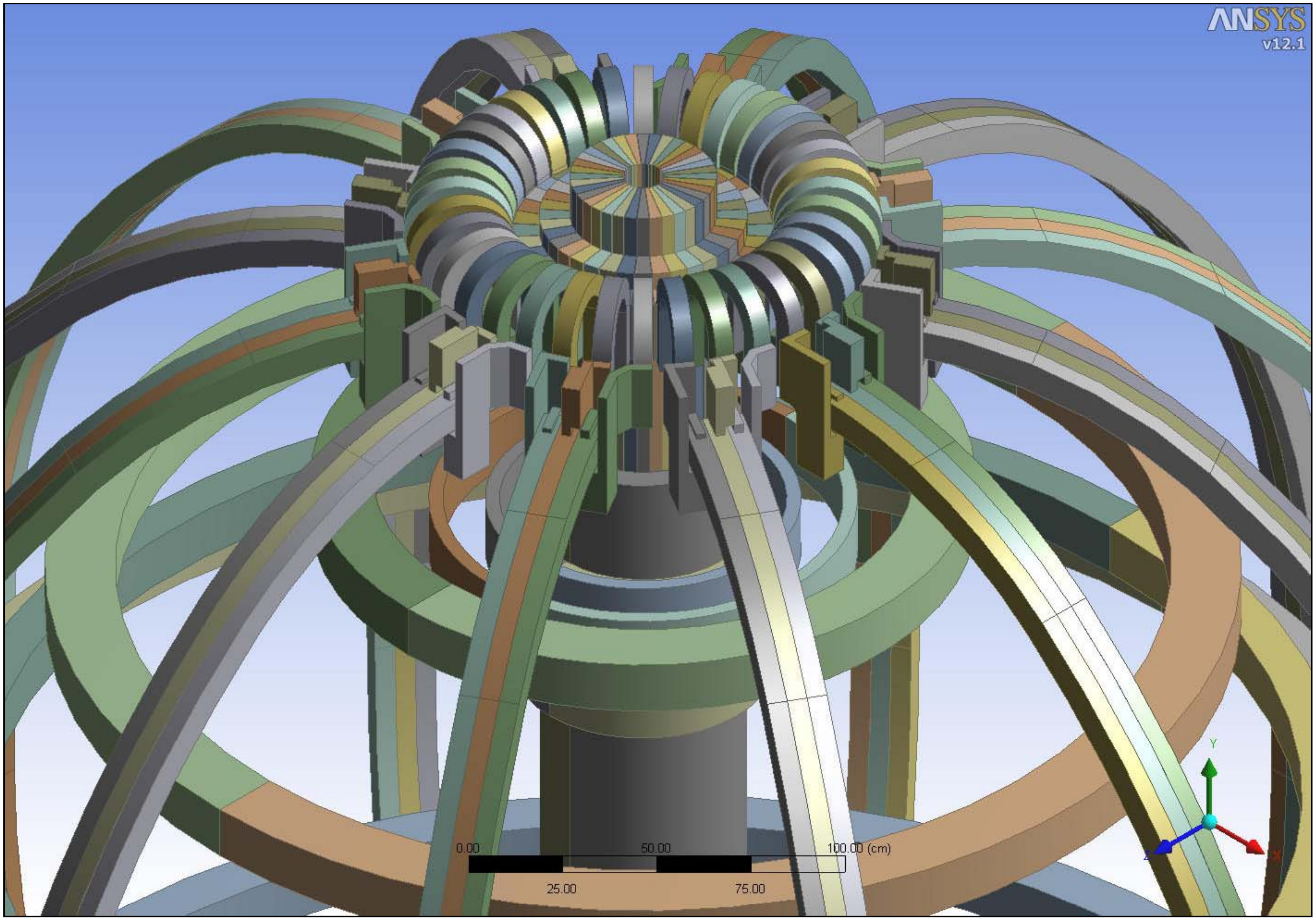
02-01-11

Steady-State Maxwell EM Analysis:
PF and TF Coil Loads:

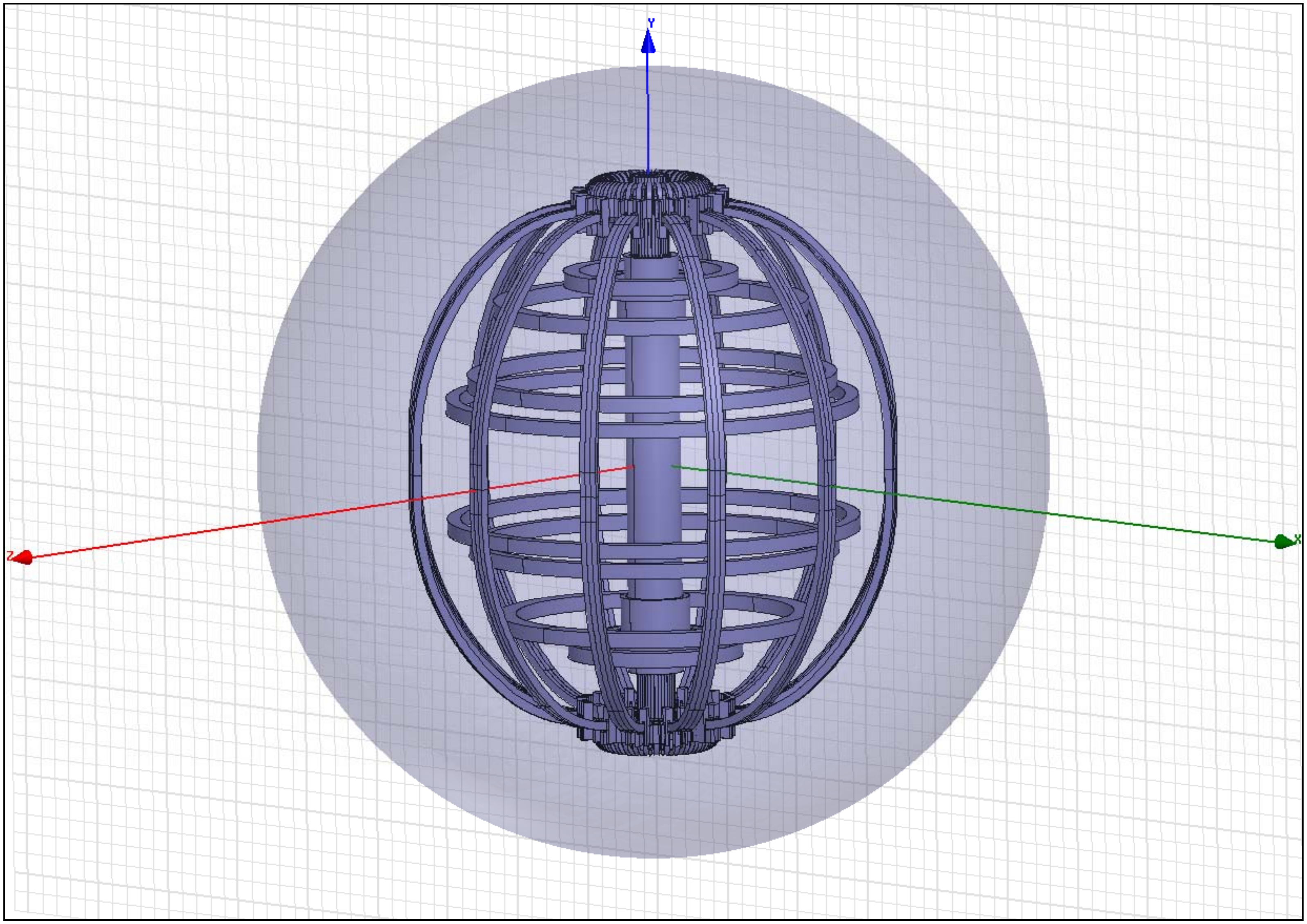
Current Scenario #79 with 10% Headroom



ANSYS WB Solid Model of Simplified Coil Assembly Exported to Maxwell



ANSYS WB Solid Model of Simplified Coil Assembly Exported to Maxwell (2)

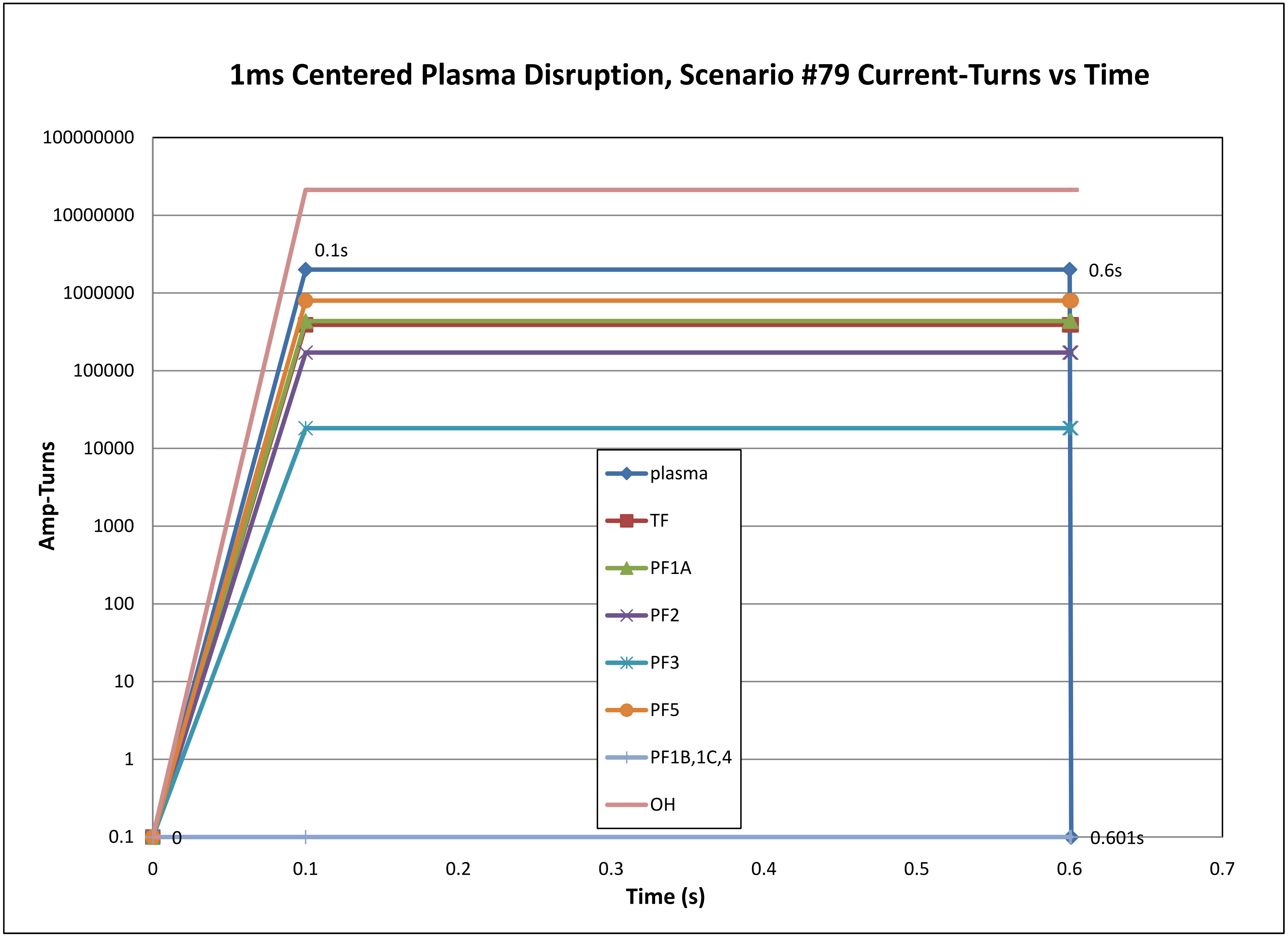


Maxwell Solid Model with Vacuum Enclosure

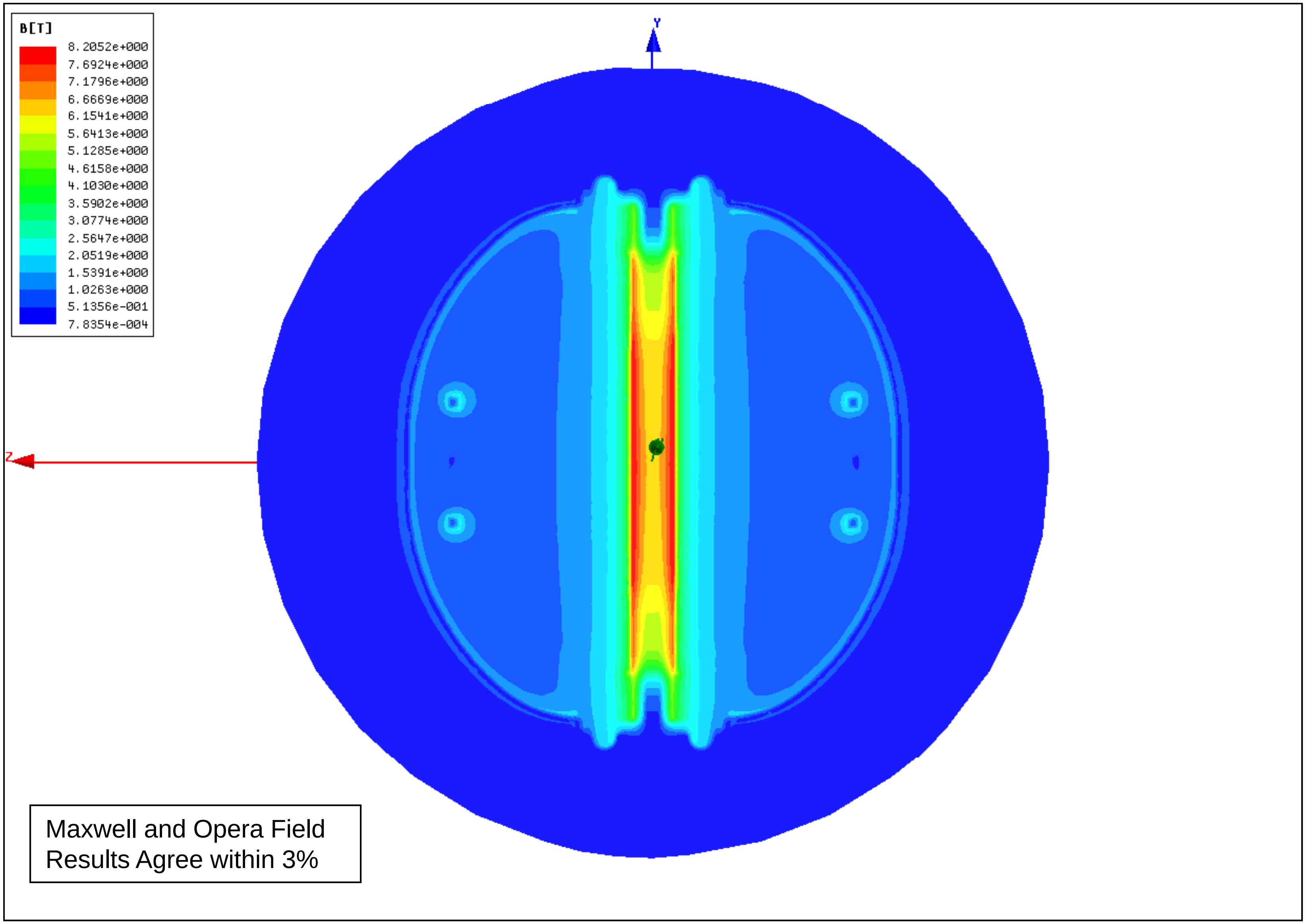
Current Scenario # 79

	# turns	Current (kA)	Current-turns	Current-turns with10% Headroom	Direction*
PF1aU	64	6.1999	3.9679E+05	4.3647E+05	CCW
PF1bU	32	0.0000	0.0000E+00	0.0000E+00	CCW
PF1cU	20	0.0000	0.0000E+00	0.0000E+00	CCW
PF2U	28	-5.5545	-1.5553E+05	-1.7108E+05	CW
PF3U	30	0.5531	1.6593E+04	1.8252E+04	CCW
PF4U	17	0.0000	0.0000E+00	0.0000E+00	CCW
PF5U	24	-30.1771	-7.2425E+05	-7.9668E+05	CW
PF5L	24	-30.1771	-7.2425E+05	-7.9668E+05	CW
PF4L	17	0.0000	0.0000E+00	0.0000E+00	CCW
PF3L	30	0.5531	1.6593E+04	1.8252E+04	CCW
PF2L	28	-5.5545	-1.5553E+05	-1.7108E+05	CW
PF1cL	20	0.0000	0.0000E+00	0.0000E+00	CCW
PF1bL	32	0.0000	0.0000E+00	0.0000E+00	CCW
PF1aL	64	6.1999	3.9679E+05	4.3647E+05	CCW
OH	884	-24.0000	-2.1216E+07	-2.1216E+07	CW
TF	3	130.0000	3.9000E+05	3.9000E+05	--
Plasma	1	2.00E+03	2.0000E+06	2.0000E+06	CCW

* As viewed from the top

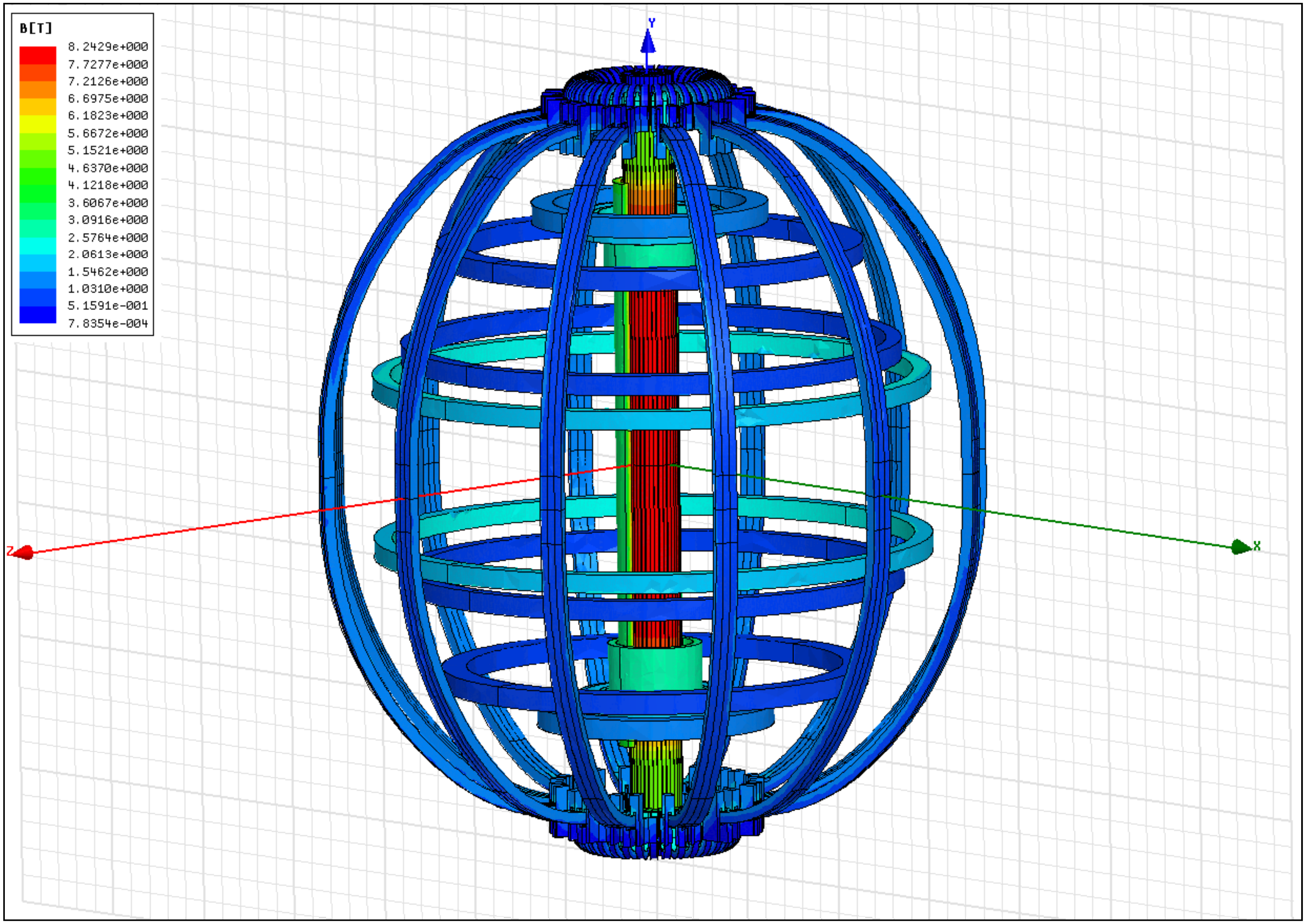


1ms Centered Plasma Disruption, Scenario #79 Current-Turns vs Time
100000000
10000000
1000000
100000
10000
1000
100
10
1
0.1
Amp-Turns
0.1s
0.6s
0
0.601s
plasma
TF
PF1A
PF2
PF3
PF5
PF1B,1C,4
OH
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Time (s)



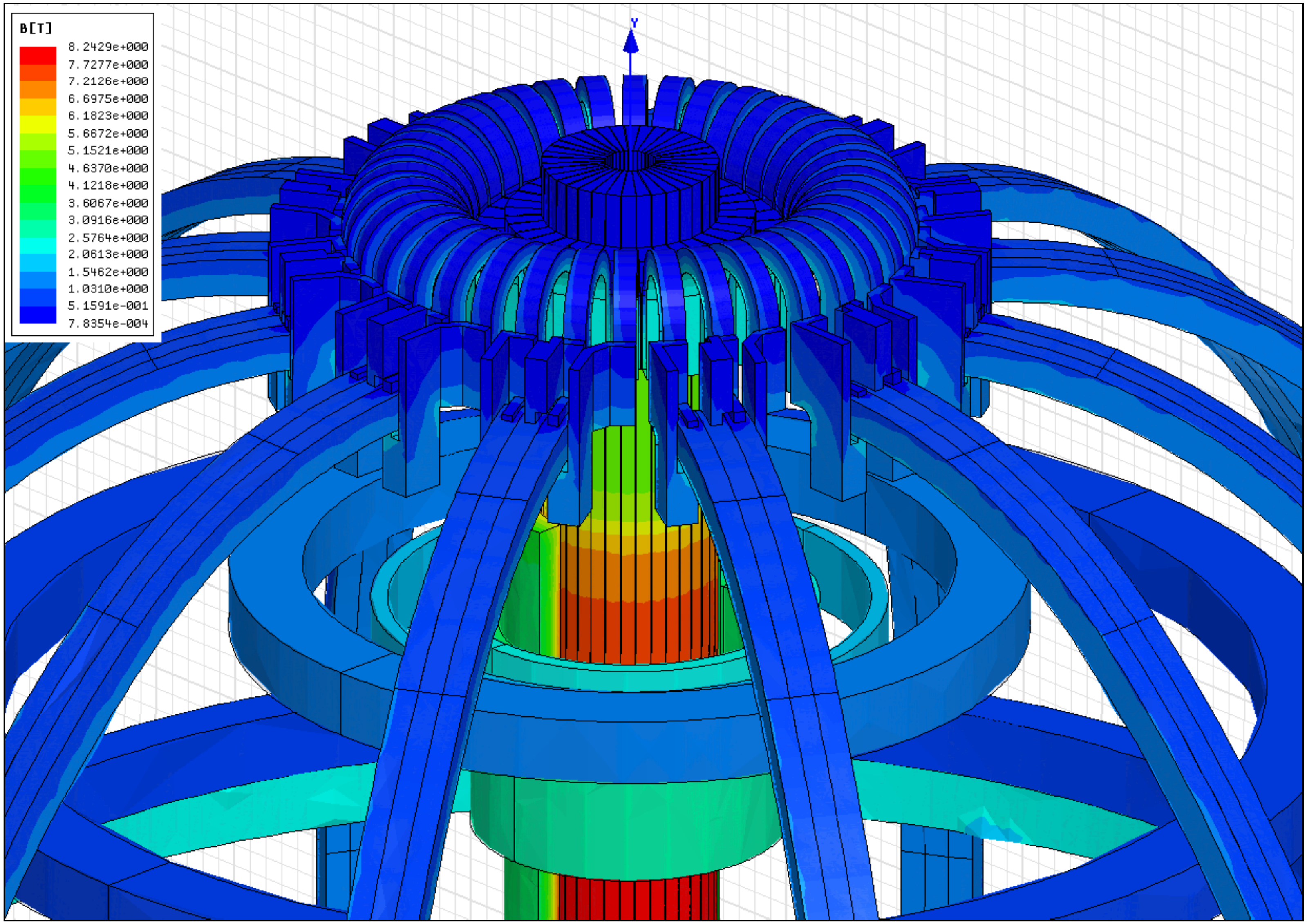
Maxwell Results: Magnetic Flux Density on Y-Z Plane

Current Scenario #79 w/ Headroom



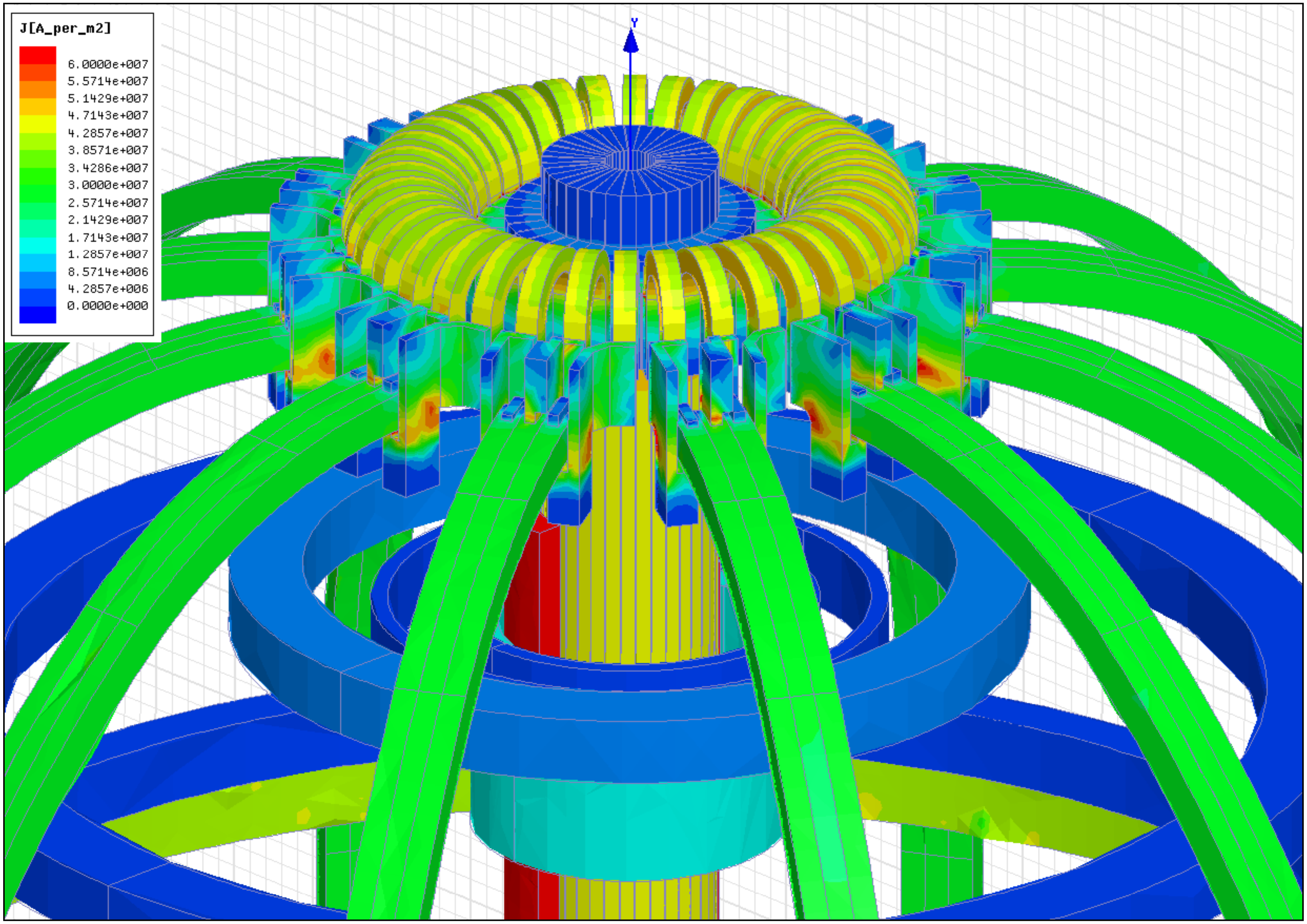
Maxwell Results: Magnetic Flux Density on Coil Surfaces

Current Scenario #79 w/ Headroom



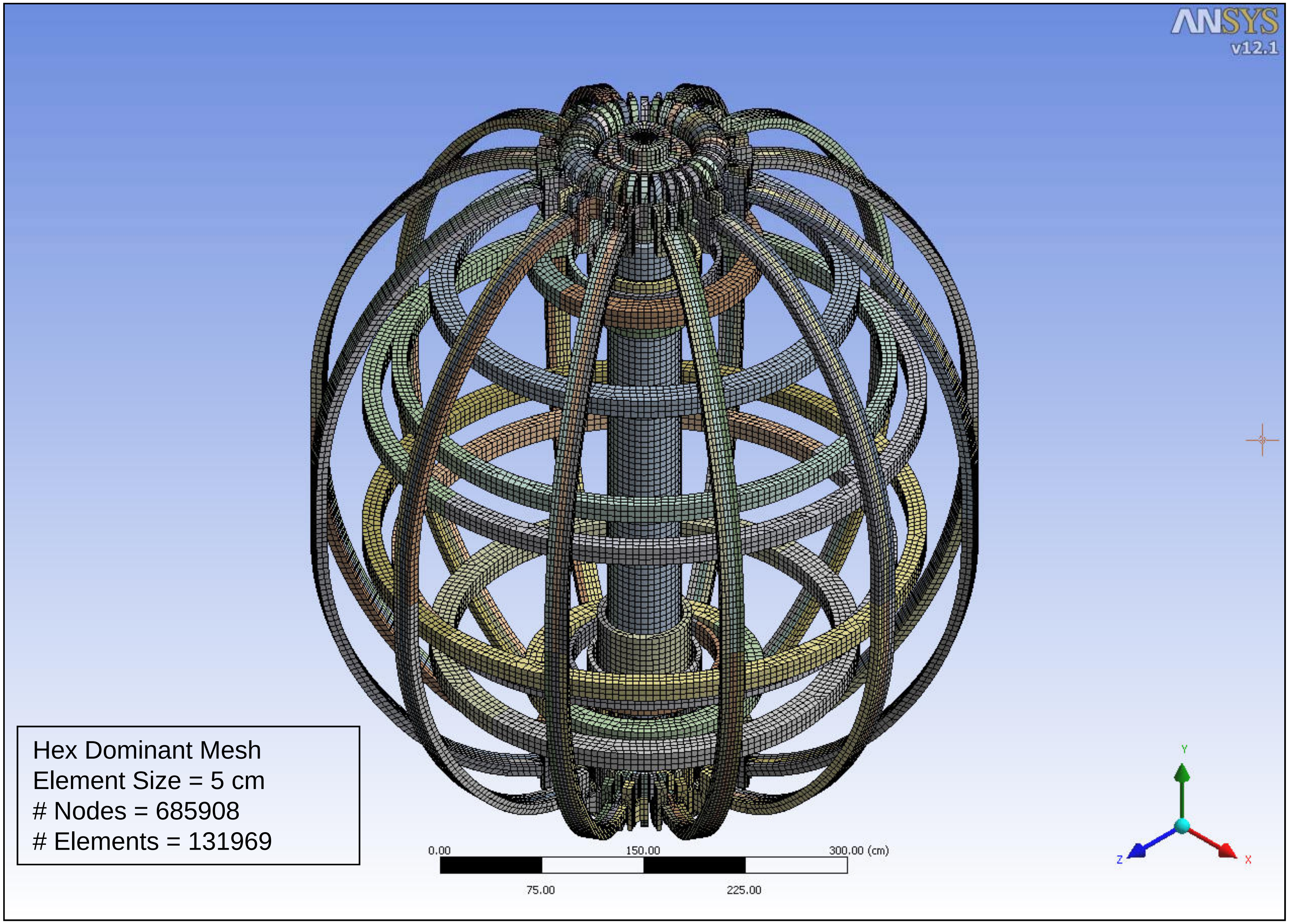
Maxwell Results: Magnetic Flux Density on Coil Surfaces(2)

Current Scenario #79 w/ Headroom

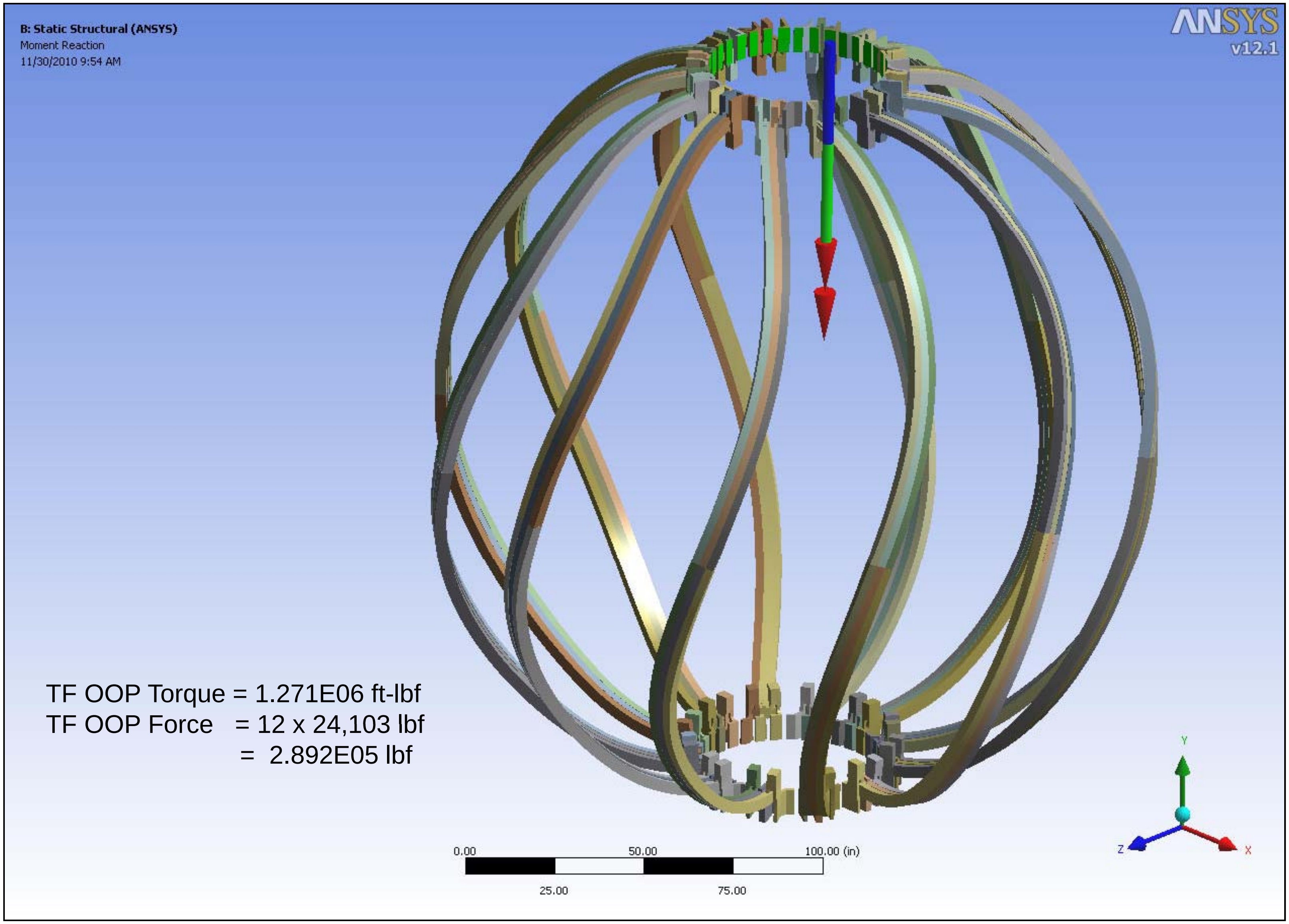


Maxwell Results: Current Density on Coil Surfaces

Current Scenario #79 w/ Headroom

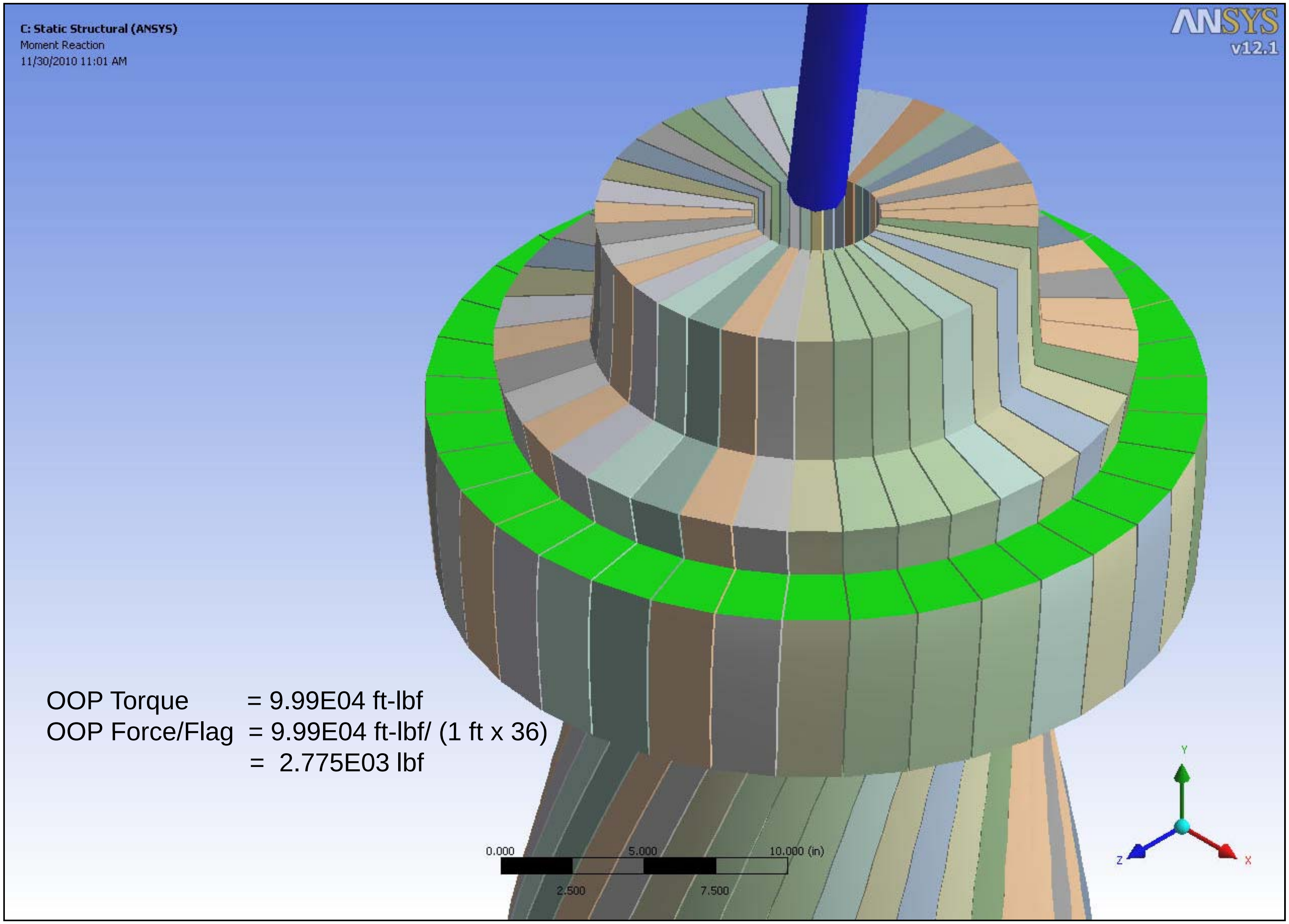


ANSYS WB Full Model Mesh



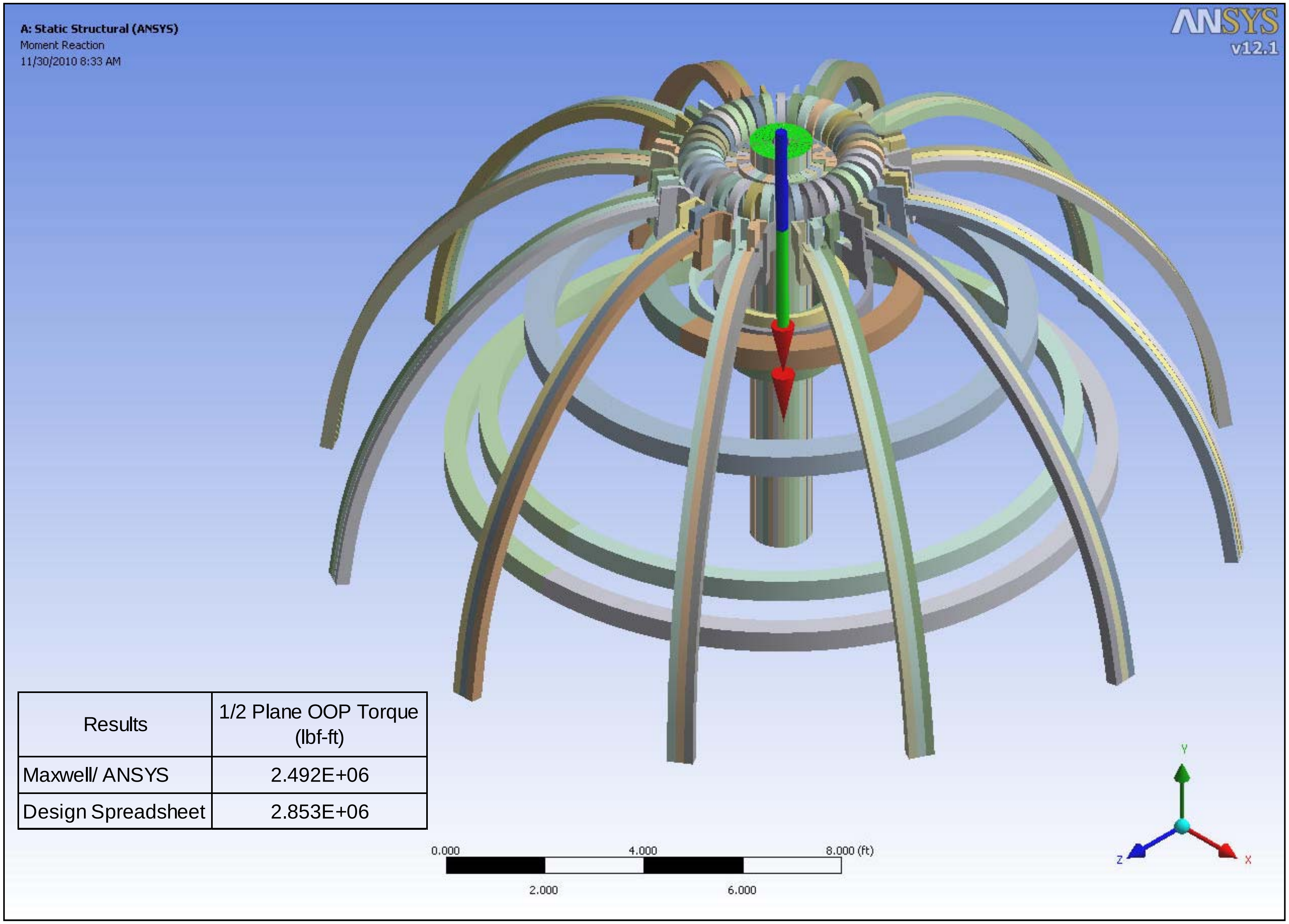
TF Outer Leg OOP Torque and Force, Fixed Ends, No Clevis Load

Current Scenario #79 w/ Headroom



TF Inner Leg OOP Torque, OOP Force/ Flag: Fixed Ends

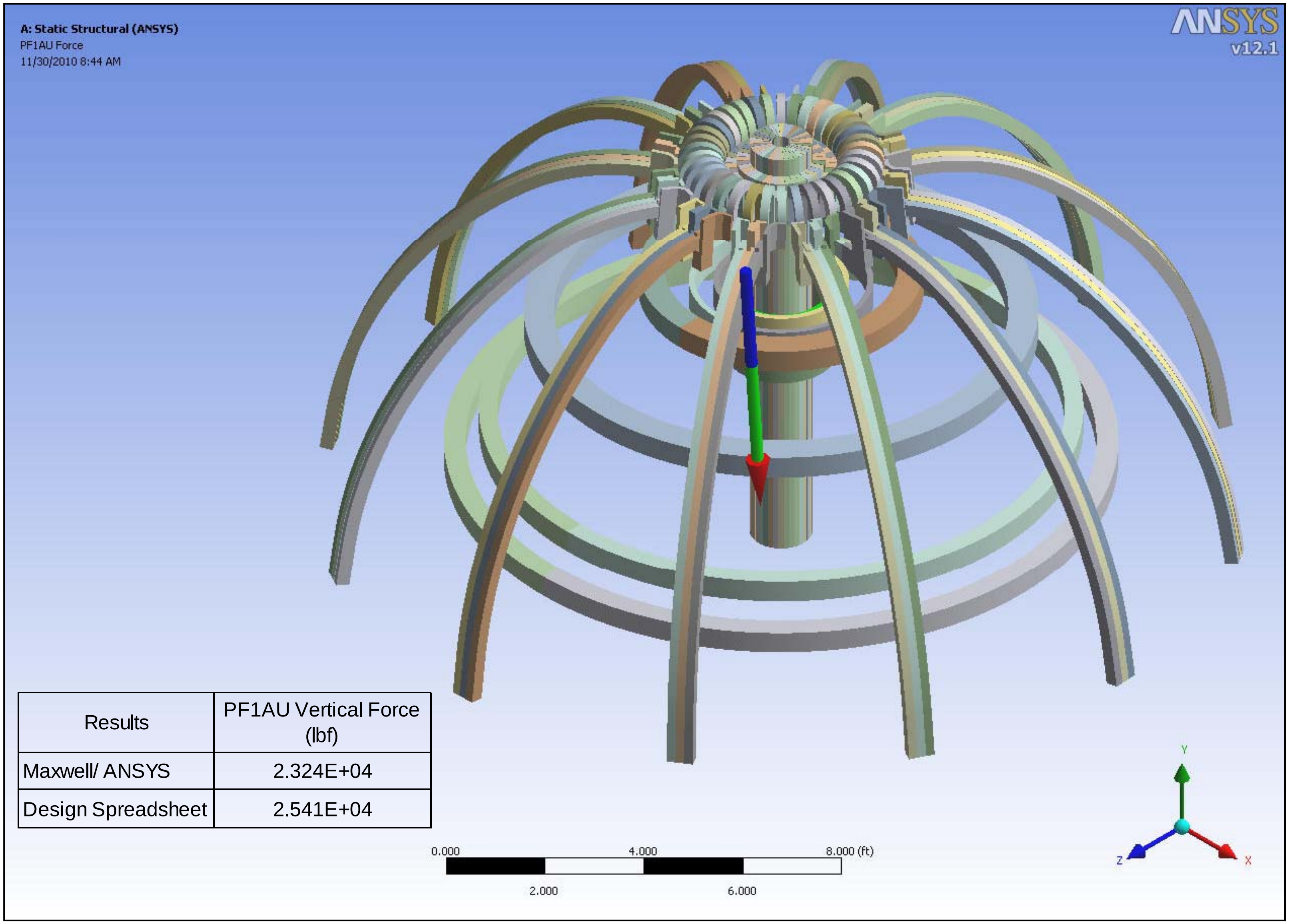
Current Scenario #79 w/ Headroom



Results	1/2 Plane OOP Torque (lbf-ft)
Maxwell/ ANSYS	2.492E+06
Design Spreadsheet	2.853E+06

Maxwell/ANSYS WB EM Generated Loads: Half Plane TF OOP Torque

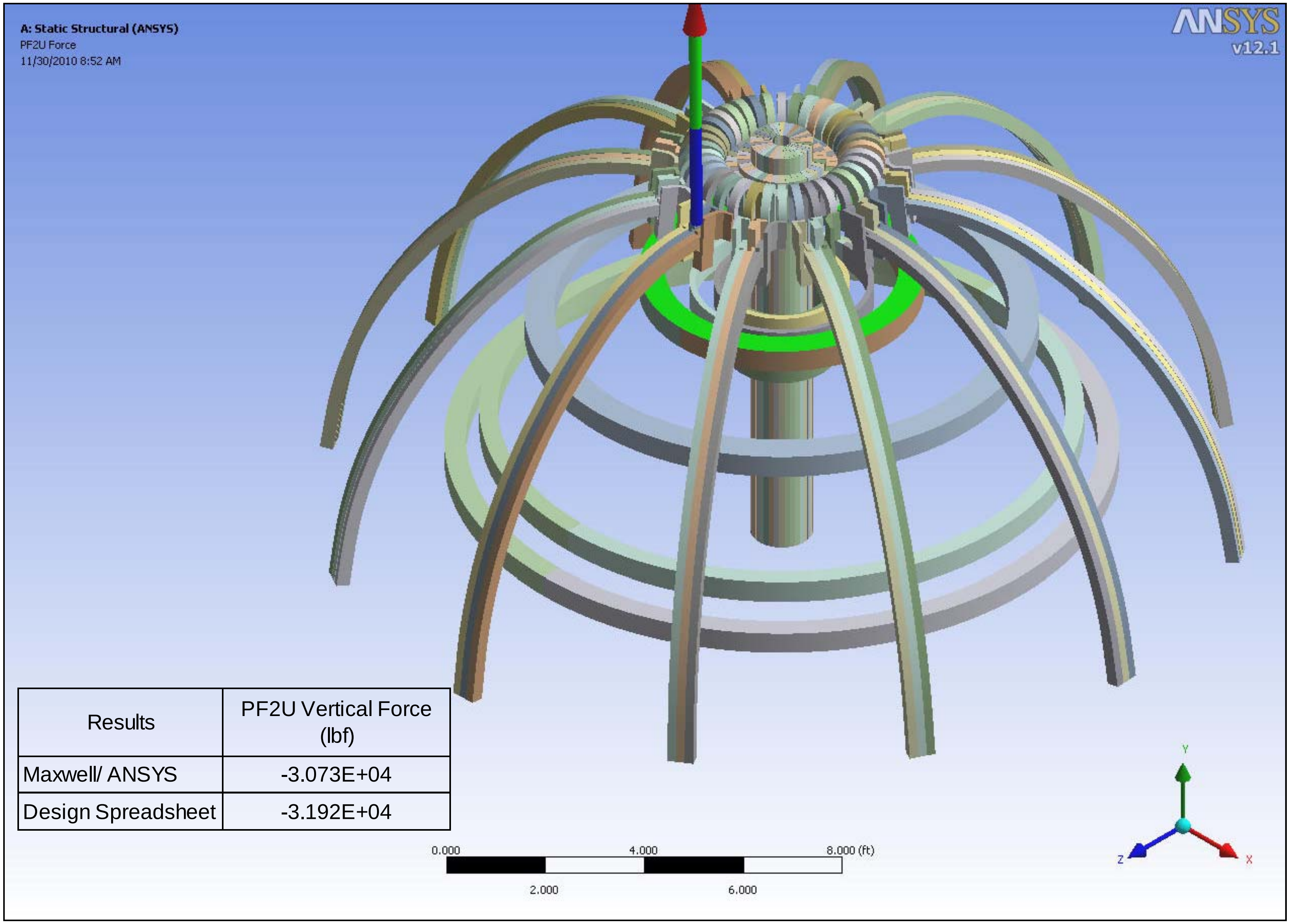
Current Scenario #79w/ Headroom



Results	PF1AU Vertical Force (lbf)
Maxwell/ ANSYS	2.324E+04
Design Spreadsheet	2.541E+04

Maxwell/ANSYS WB EM Generated Loads: PF1AU Vertical Force

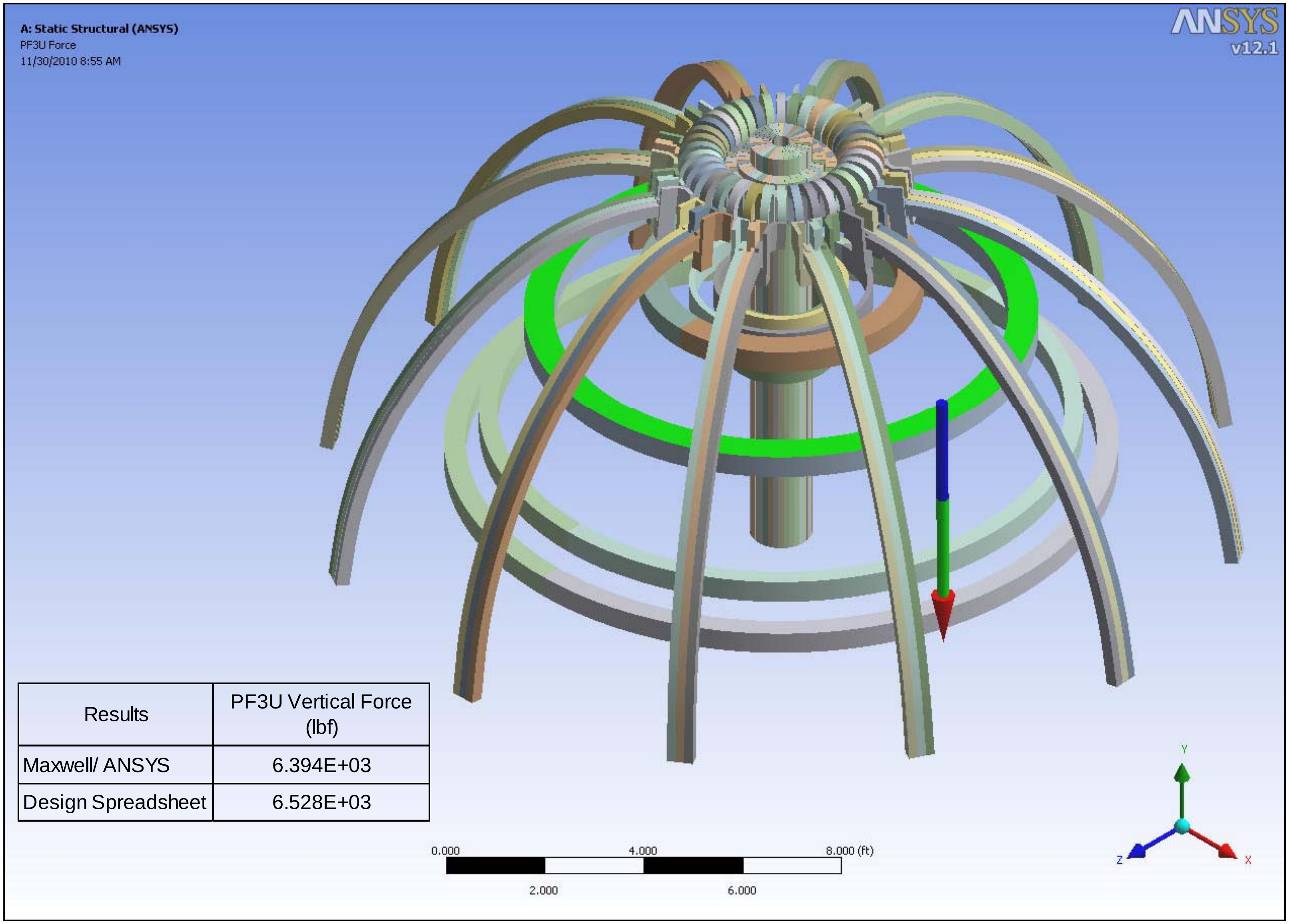
Current Scenario #79 w/ Headroom



Results	PF2U Vertical Force (lbf)
Maxwell/ ANSYS	-3.073E+04
Design Spreadsheet	-3.192E+04

Maxwell/ANSYS WB EM Generated Loads: PF2U Vertical Force

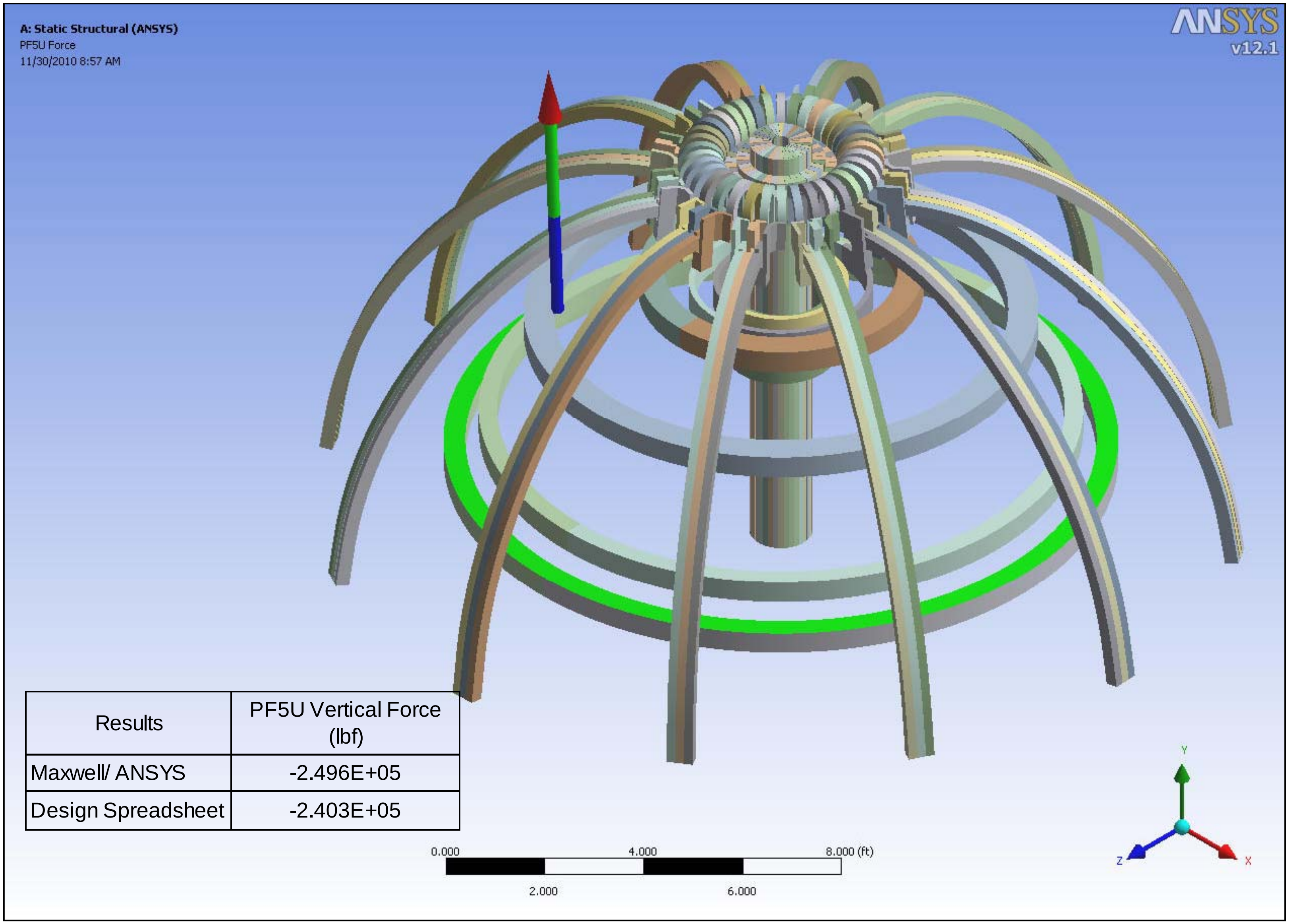
Current Scenario #79 w/ Headroom



Results	PF3U Vertical Force (lbf)
Maxwell/ ANSYS	6.394E+03
Design Spreadsheet	6.528E+03

Maxwell/ANSYS WB EM Generated Loads: PF3U Vertical Force

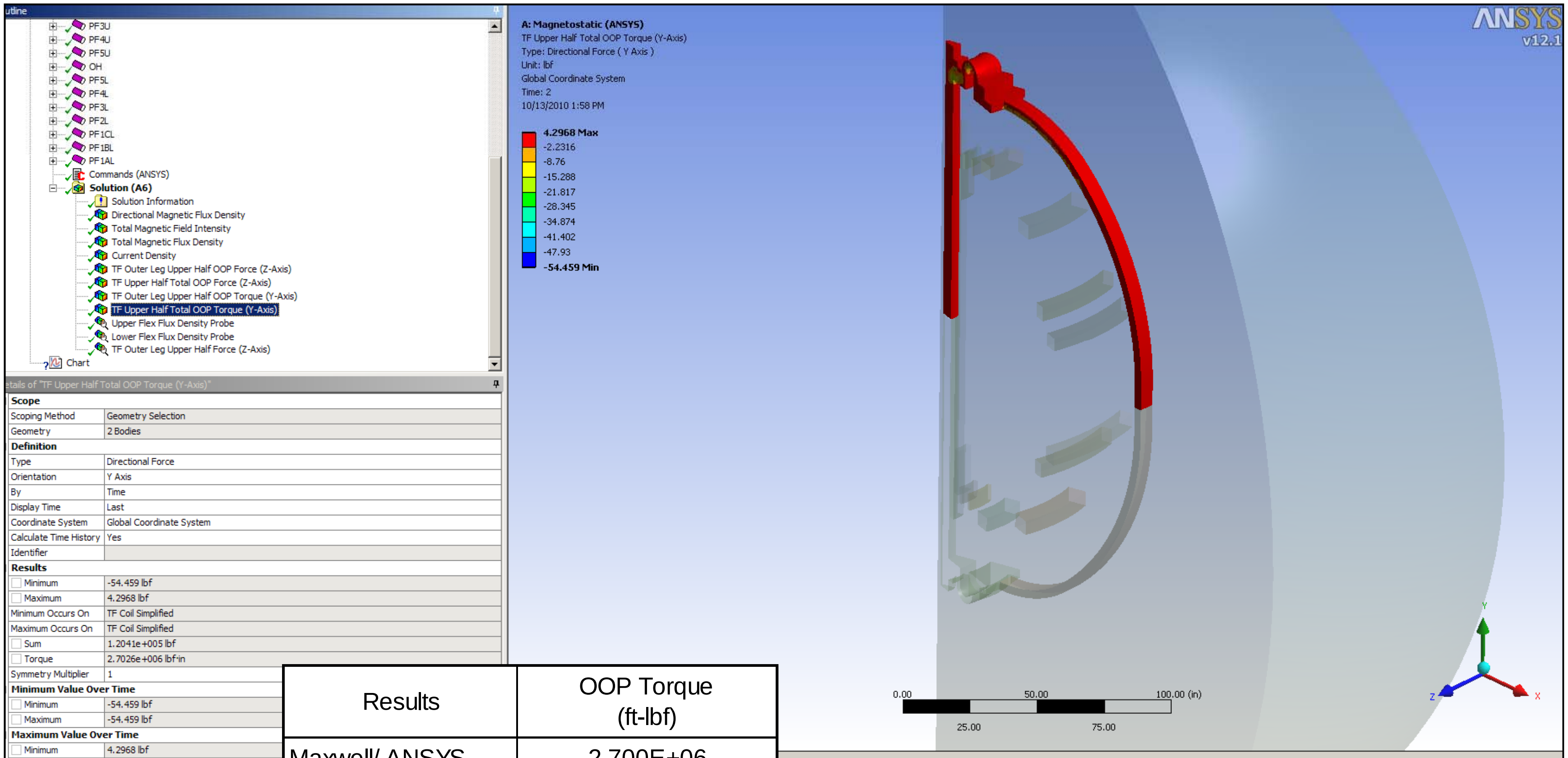
Current Scenario #79 w/ Headroom



Results	PF5U Vertical Force (lbf)
Maxwell/ ANSYS	-2.496E+05
Design Spreadsheet	-2.403E+05

Maxwell/ANSYS WB EM Generated Loads: PF5U Vertical Force

Current Scenario #79 w/ Headroom



Results	OOP Torque (ft-lbf)
Maxwell/ ANSYS	2.700E+06
Design Spreadsheet	2.850E+06

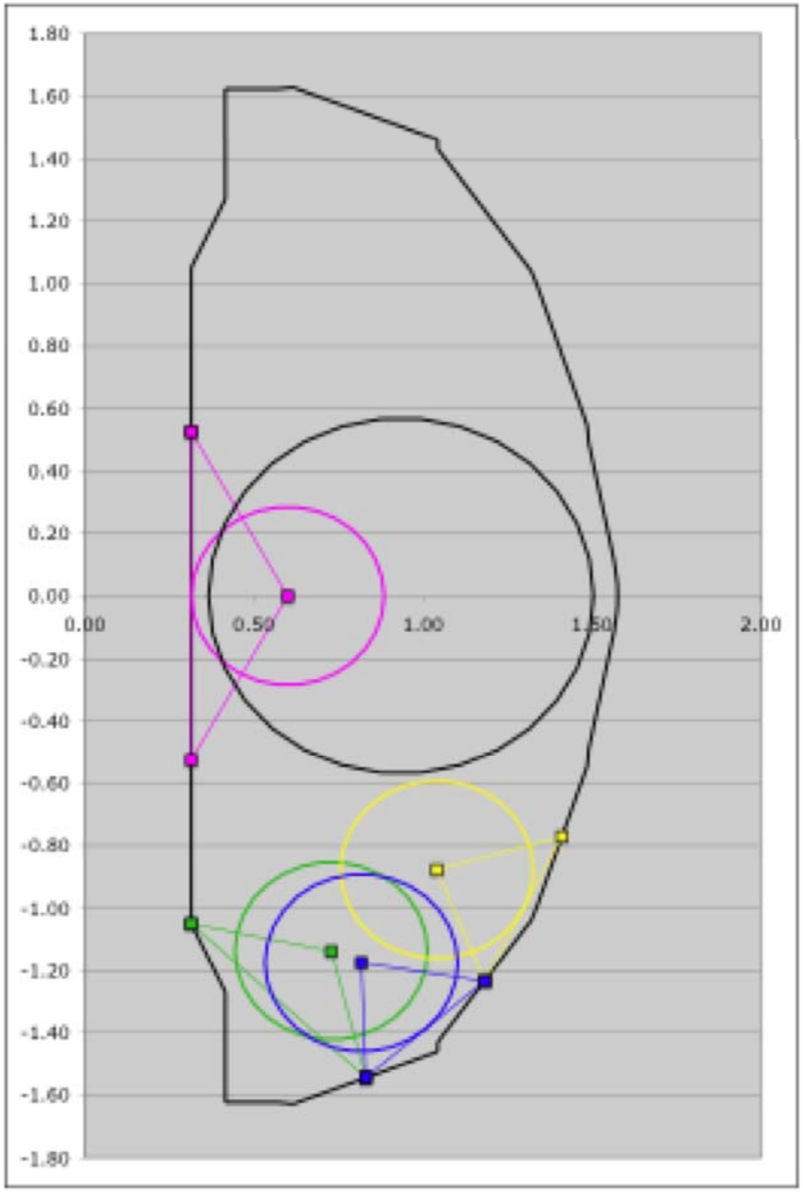
Maxwell/ANSYS WB EM Generated Loads: TF Half Plane OOP Torque

Current Scenario #79 w/ Headroom

Transient Maxwell EM Analysis:
Vacuum Vessel Disruption Load:

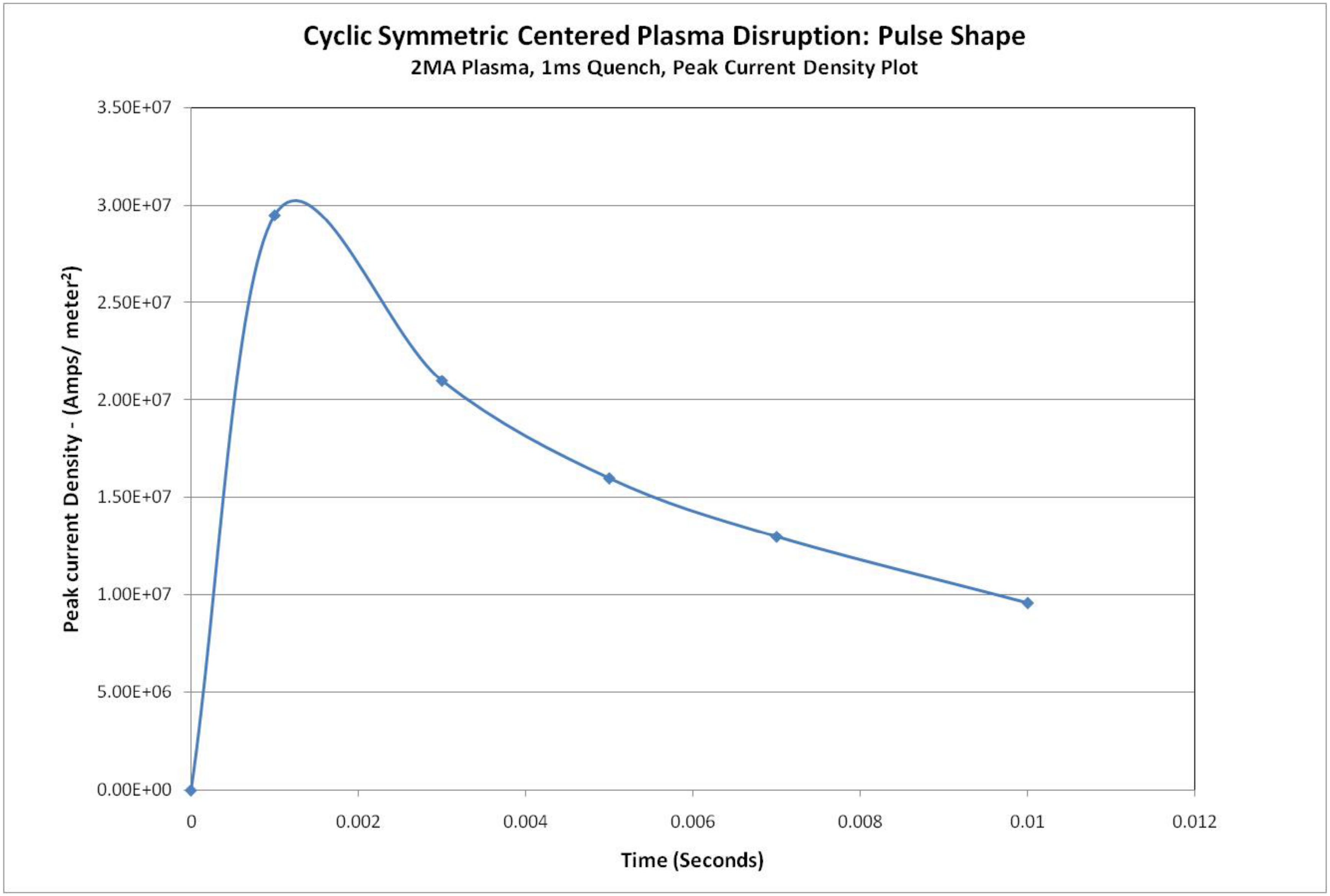
Centered-Plasma Disruption Scenario

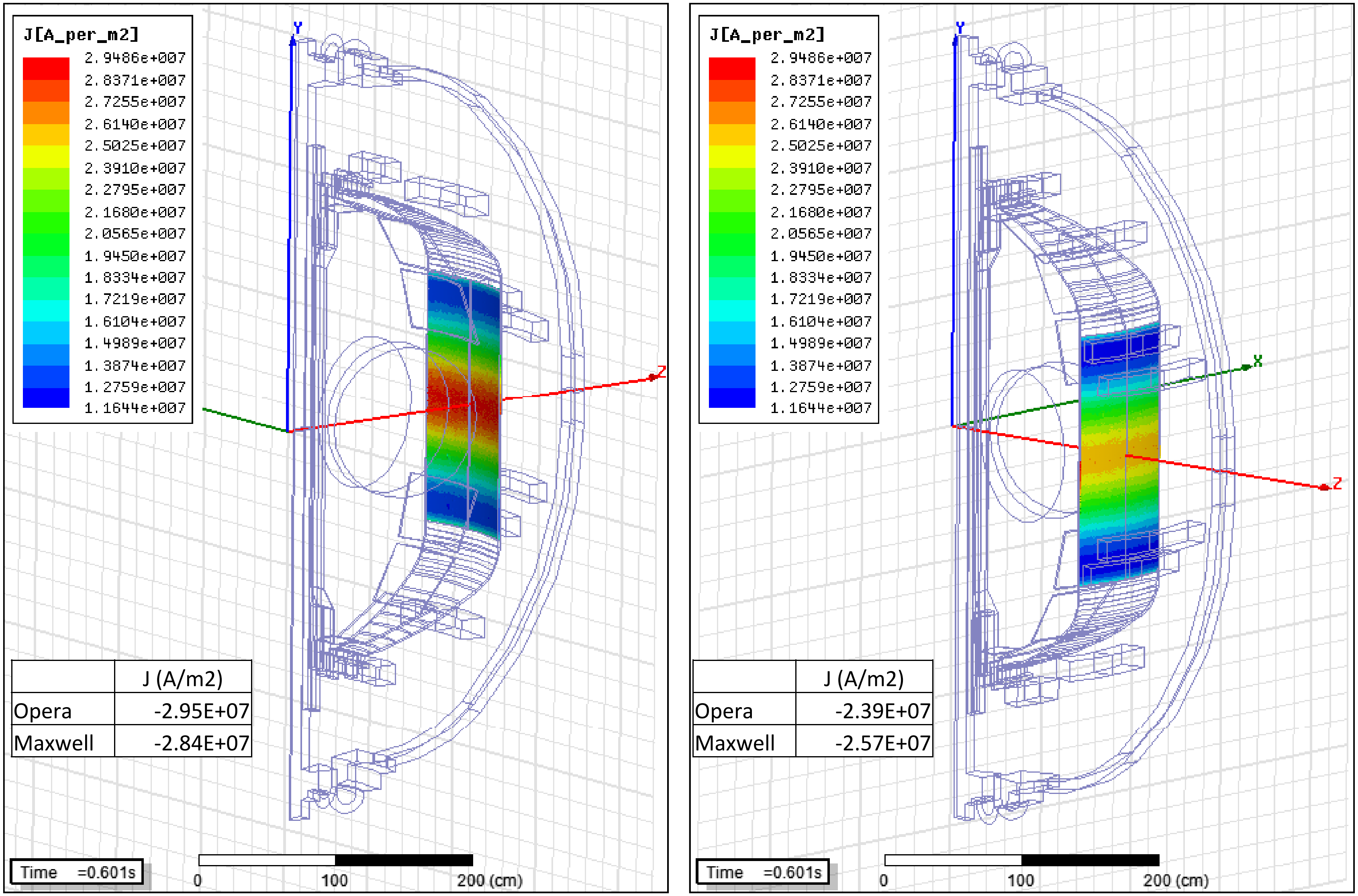
	Centered	Offset, Midplane	Offset, Inboard	Offset, Central	Offset, Outboard
Center of plasma (r,z) [m]	0.9344	0.5996	0.7280	0.8174	1.0406
	0.0000	0.0000	-1.1376	-1.1758	-0.8768
Minor radius of plasma [m]	0.5696	0.2848	0.2848	0.2848	0.2848
Current Quench					
Initial plasma current [MA]	2	2	2	2	2
Linear current derivative [MA/s]	-1000	-1000	-1000	-1000	-1000
VDE/Halo					
Initial plasma current	2	0	0	0	0
Final plasma current [MA]	0	2	2	2	2
Linear current derivative [MA/s]	-200	200	200	200	200
Halo current [MA]	n.a	20%=	35%=	35%=	35%=
		400kA	700kA	700kA	700kA
Halo current entry point (r,z) [m]	n.a	0.3148	0.3148	0.8302	1.1813
		0.6041	-1.2081	-1.5441	-1.2348
Halo current exit point (r,z) [m]	n.a	0.3148	0.8302	1.1813	1.4105
		-0.6041	-1.5441	-1.2348	-0.7713



For the current quench mode, five cases shall be assessed by simulating the linear decay of current at the rate specified for the five locations.

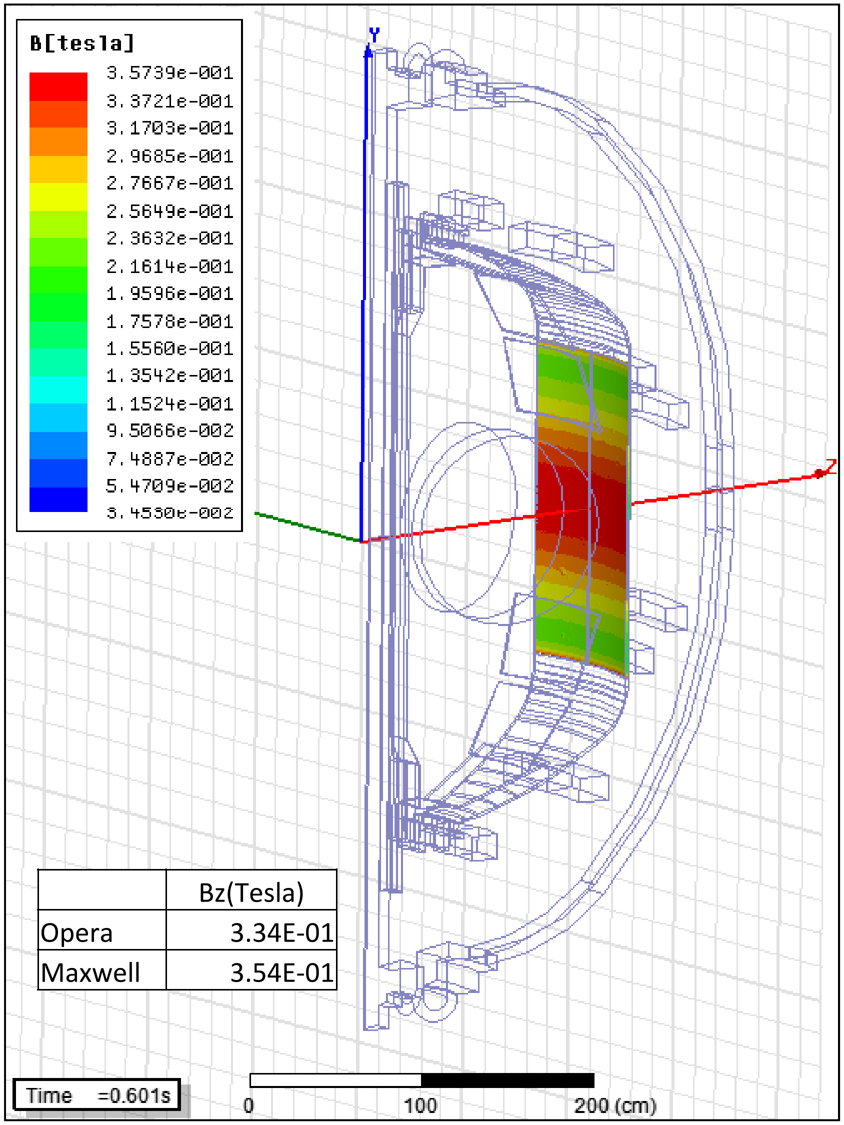
For the VDE/Halo mode, four cases shall be assessed. In each case the current in the centered plasma shall be decreased as indicated while the current in the offset plasma shall be increased as indicated to simulate plasma motion. Forces due to induced currents shall be added to forces due to halo currents.

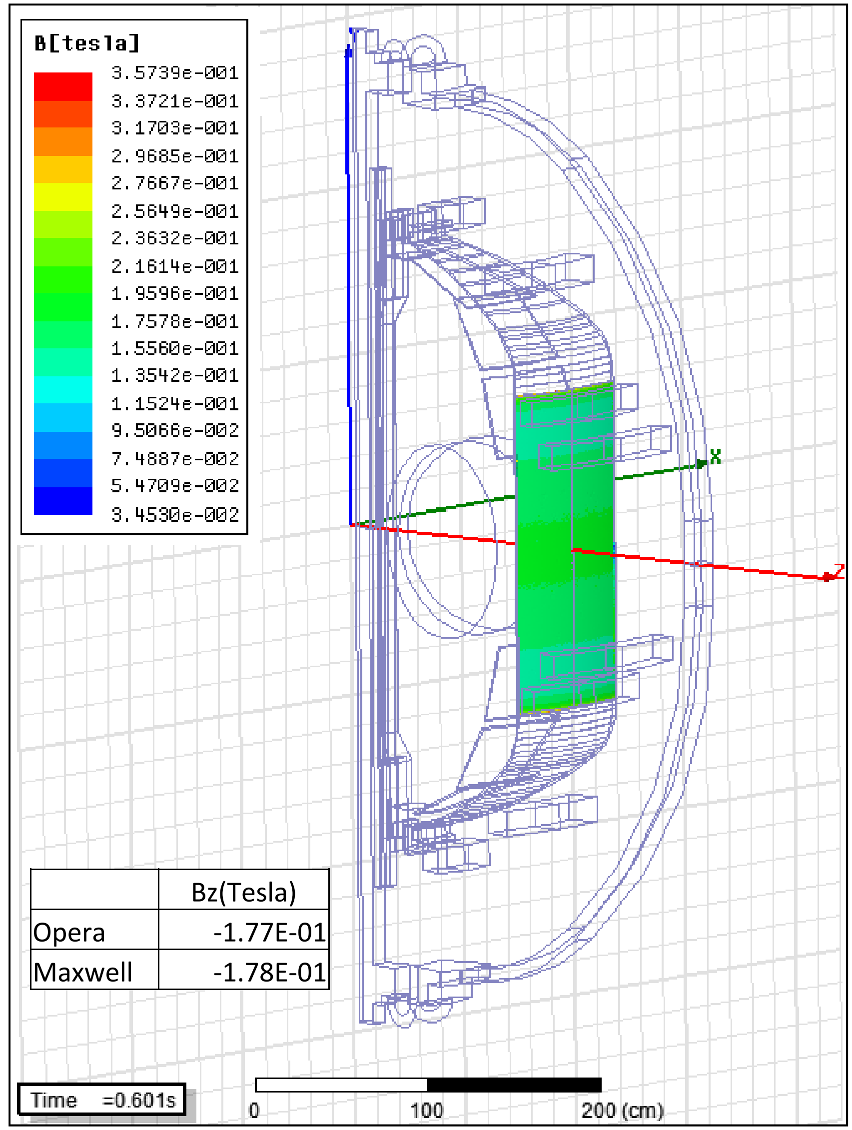

Cyclic Symmetric Centered Plasma Disruption: Pulse Shape
2MA Plasma, 1ms Quench, Peak Current Density Plot
Peak current Density - (Amps/ meter²)
3.50E+07
3.00E+07
2.50E+07
2.00E+07
1.50E+07
1.00E+07
5.00E+06
0.00E+00
0
0.002
0.004
0.006
0.008
0.01
0.012
Time (Seconds)



Maxwell Cyclic Symmetric, Plasma Disruption-Only (No Coils) Results: Current Density

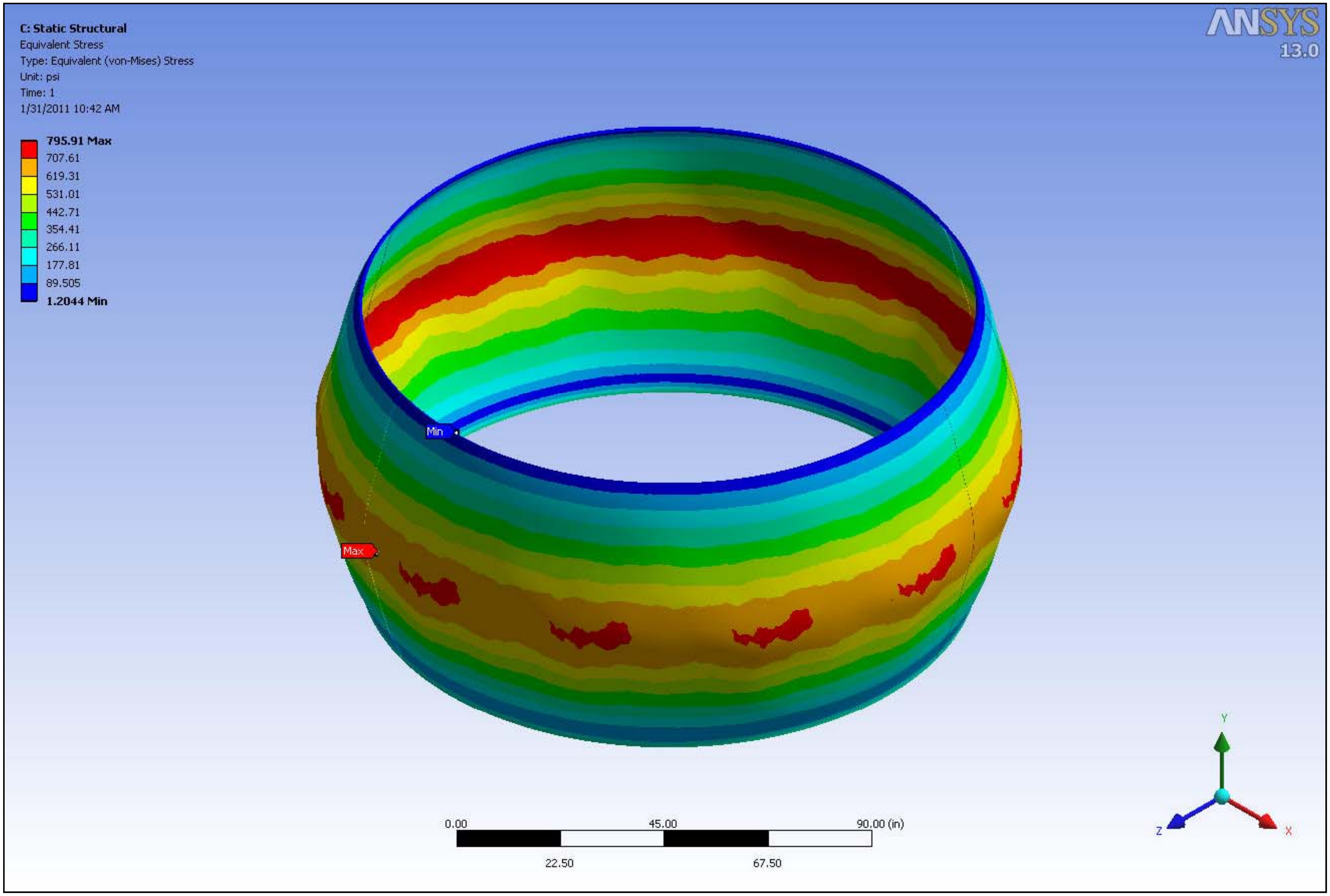
1ms Quench, Centered Plasma





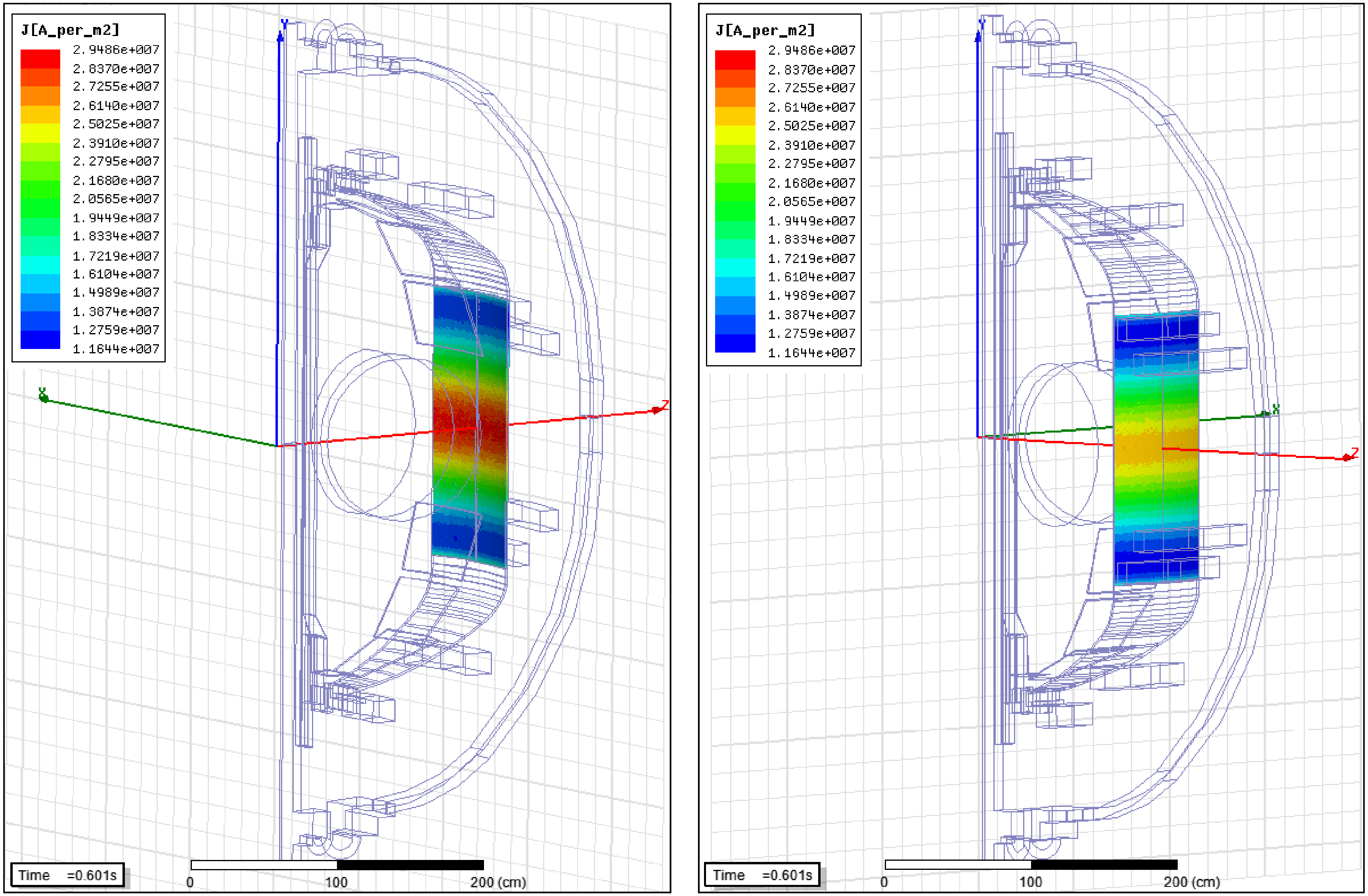
Maxwell Cyclic Symmetric, Plasma Disruption-Only (No Coils) Results: Magnetic Flux Density

1ms Quench, Centered Plasma



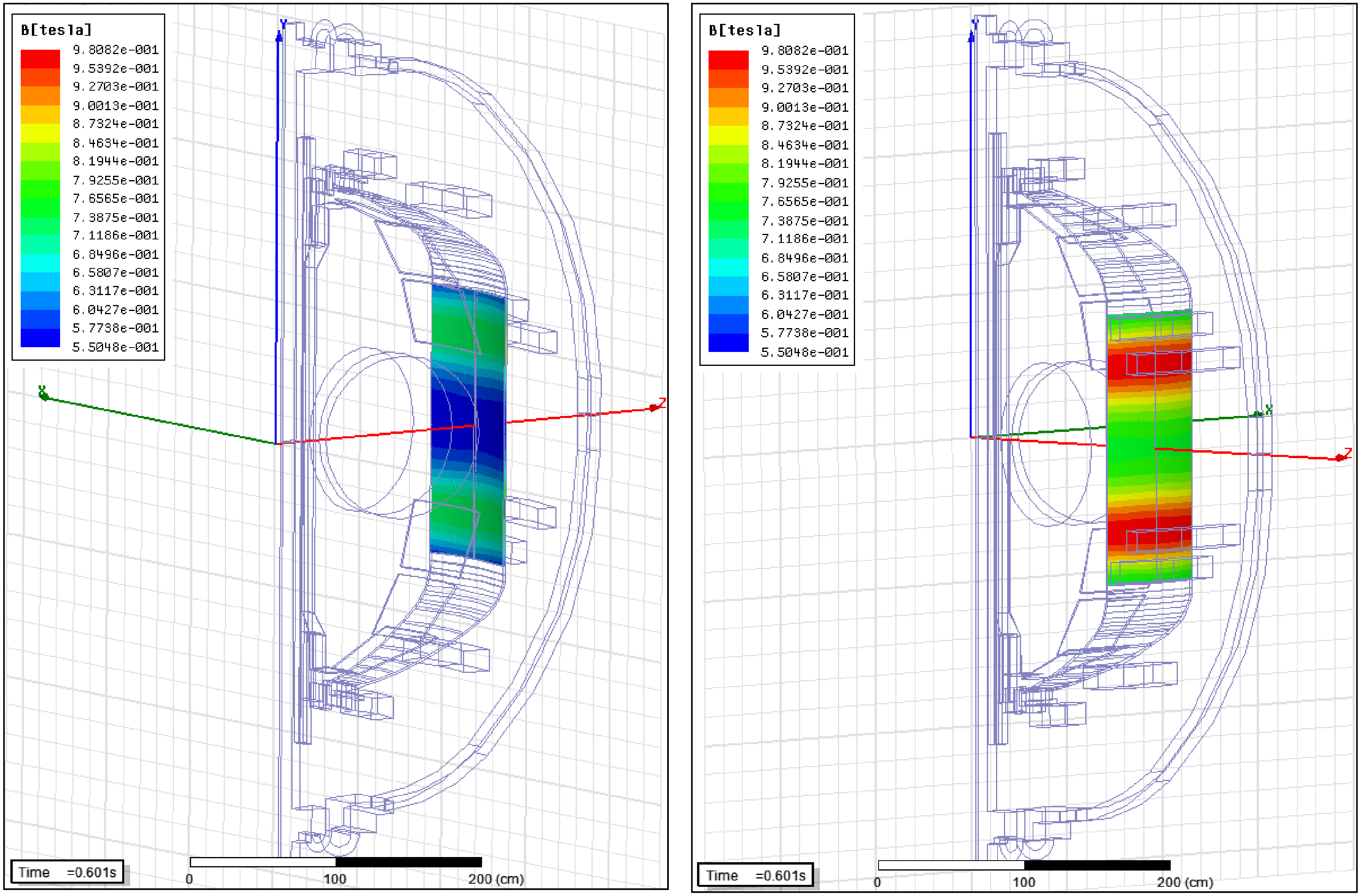
ANSYS Cyclic Symmetric, Plasma Disruption-Only (No Coils) Results: Stress

1ms Quench, Centered Plasma, 360°Visual Expansion



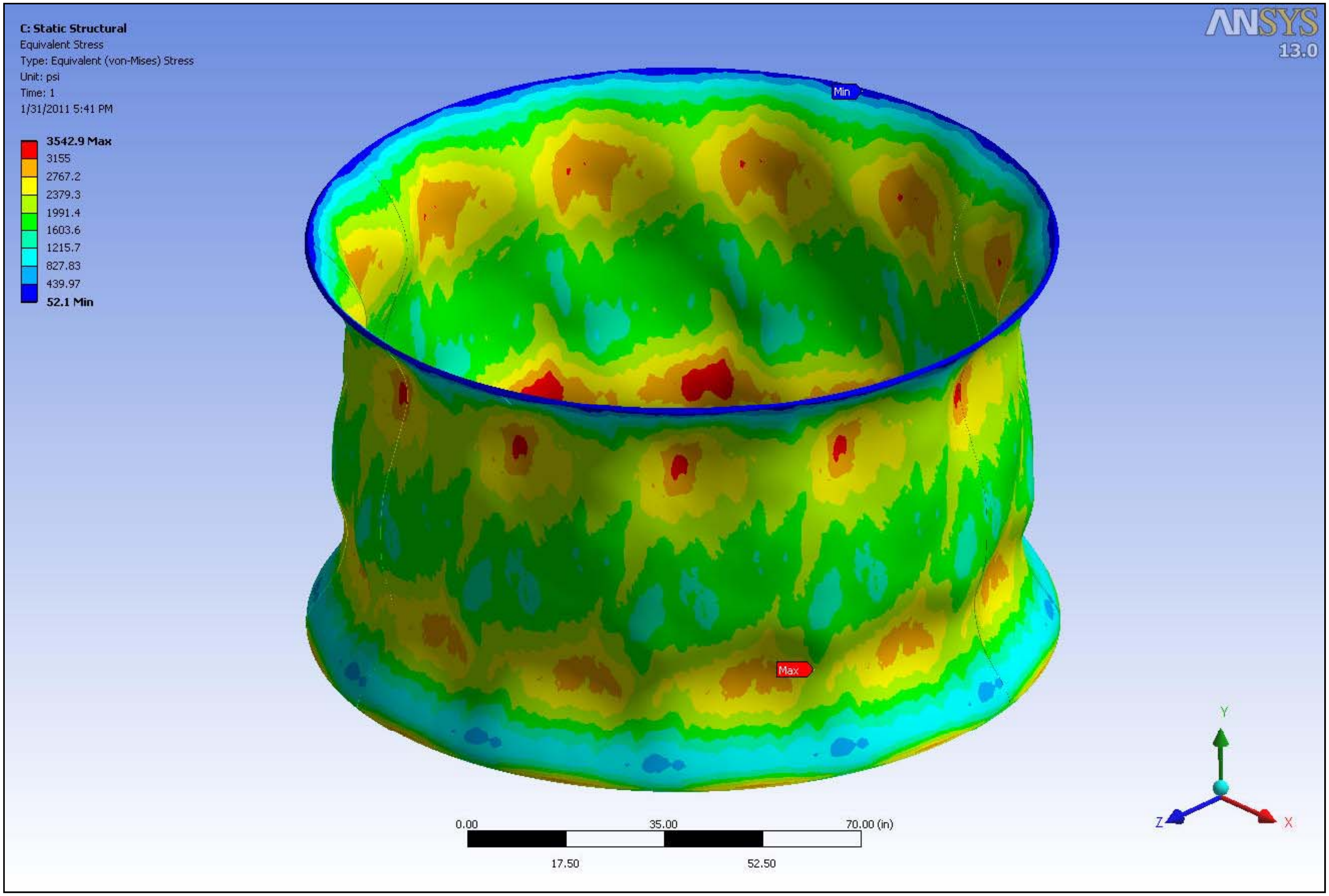
Maxwell Cyclic Symmetric, Plasma Disruption w/ Coils Results: Current Density

1ms Quench, Centered Plasma, Scenario #79 Currents w/ Overhead



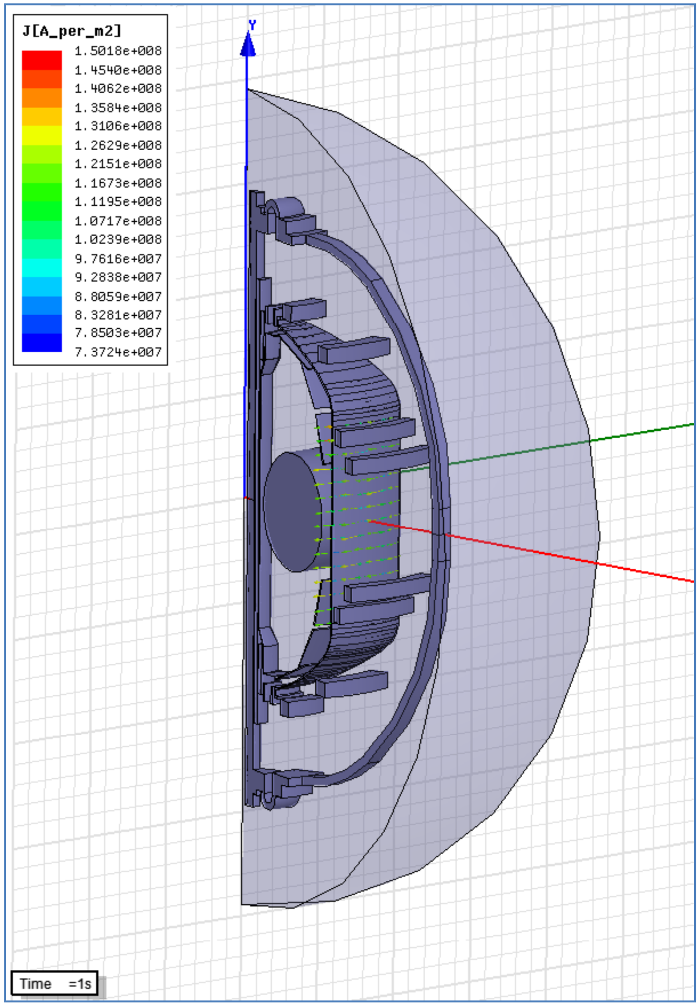
Maxwell Cyclic Symmetric, Plasma Disruption w/ Coils Results: Magnetic Flux Density

1ms Quench, Centered Plasma, Scenario #79 Currents w/ Overhead

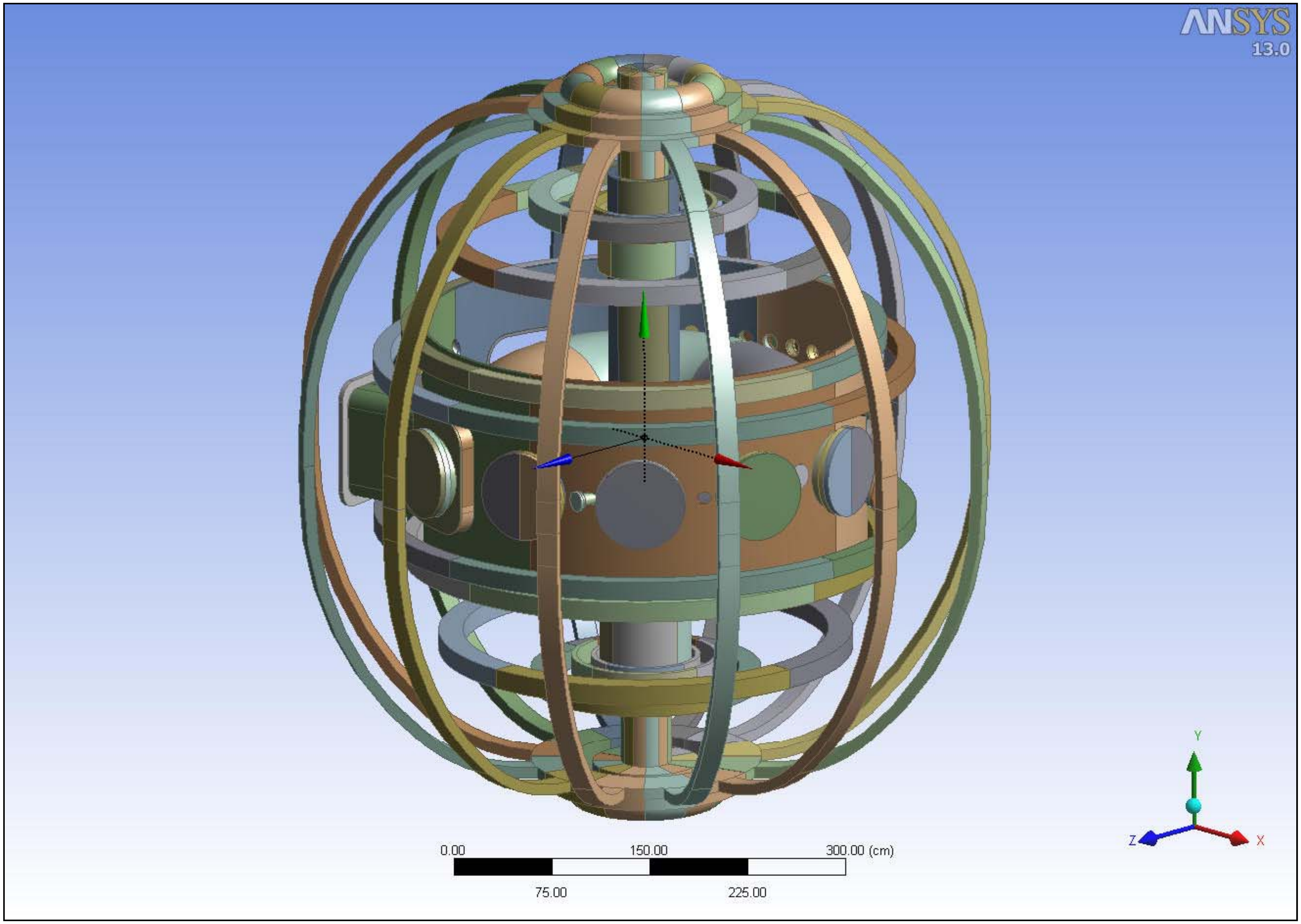


ANSYS Cyclic Symmetric, Plasma Disruption w/ Coils) Results: Stress
1ms Quench, Centered Plasma, Scenario #79 Currents w/ Overhead, 360 °Visual Expansion

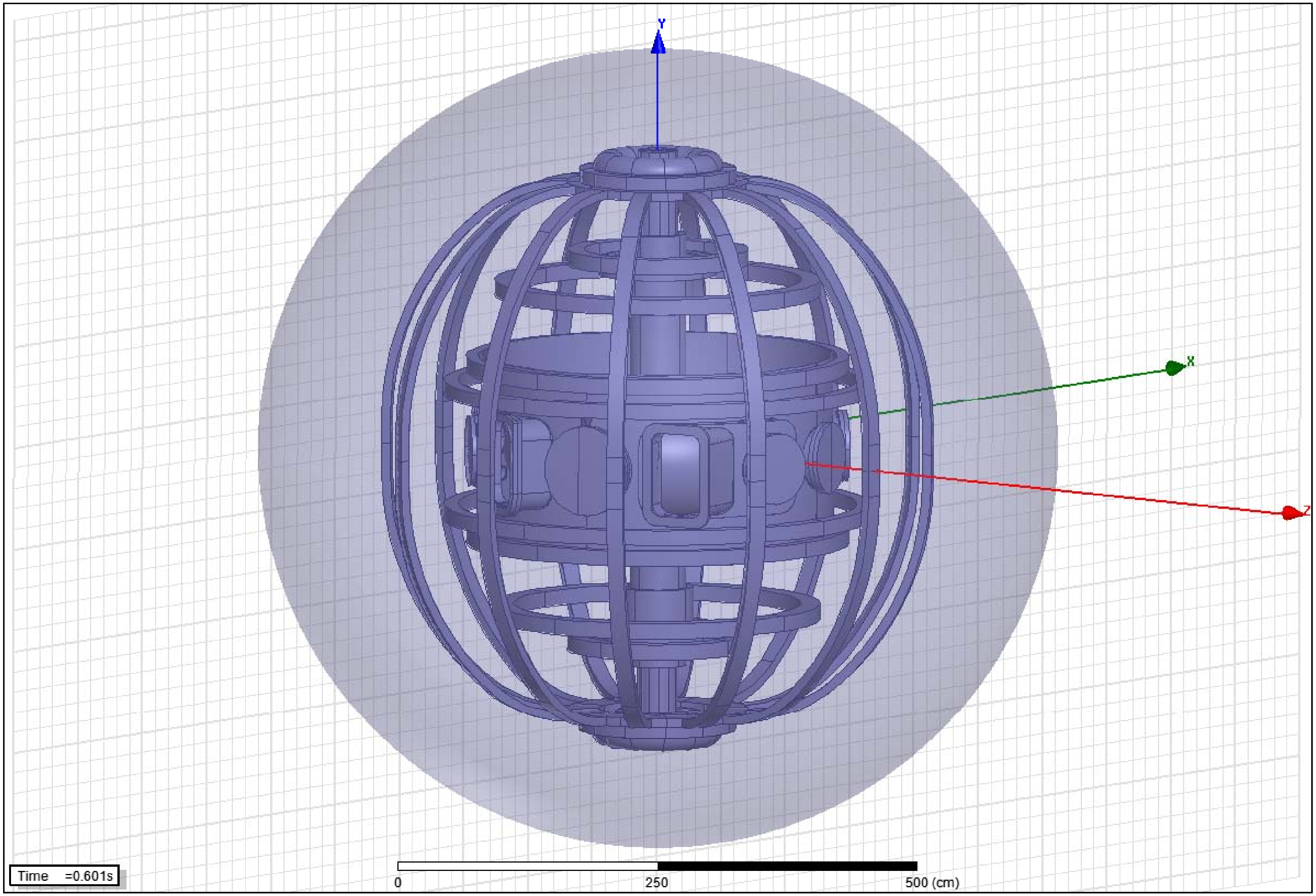
Conclusions from Maxwell Transient Cyclic Symmetric Model Study



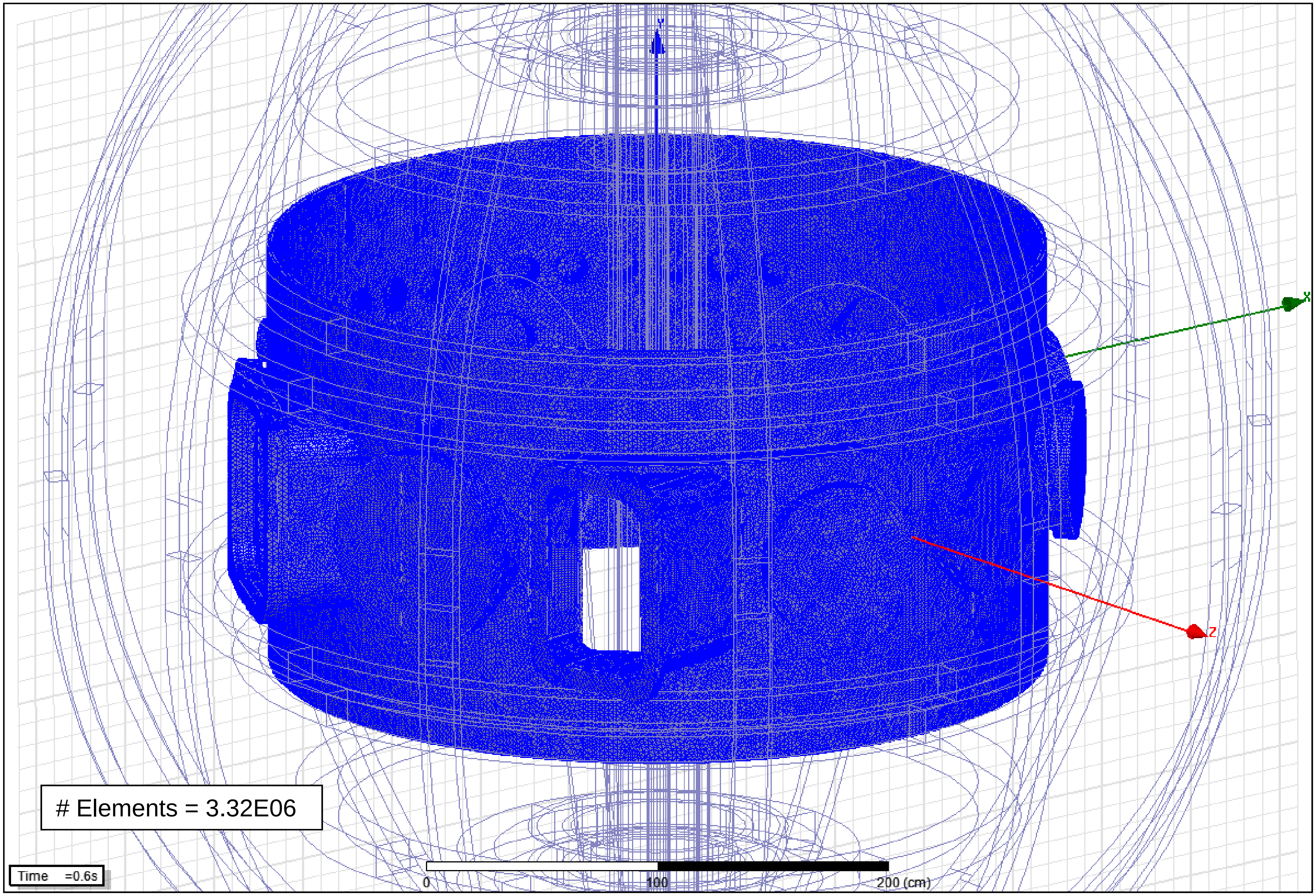
- Ramping required for plasma and coil currents. Optimum times: ramp = .1s; dwell = .5s; variable timestep size: .05s during ramp and dwell; and .0005s during disruption
- Meshing: max. element size in vessel wall = 2 cm, max. faceting angle = 5 deg
  - >5E06 elements required for full 360 deg model with port extensions
- Domes, passive plates, and cs casing, are not required in eddy current solution for vv midsection CPD analysis
- Effective Lorentz force pulse period = .006s



ANSYS WB Solid Model of Simplified Coil and VV w/ Ports
Exported to Maxwell

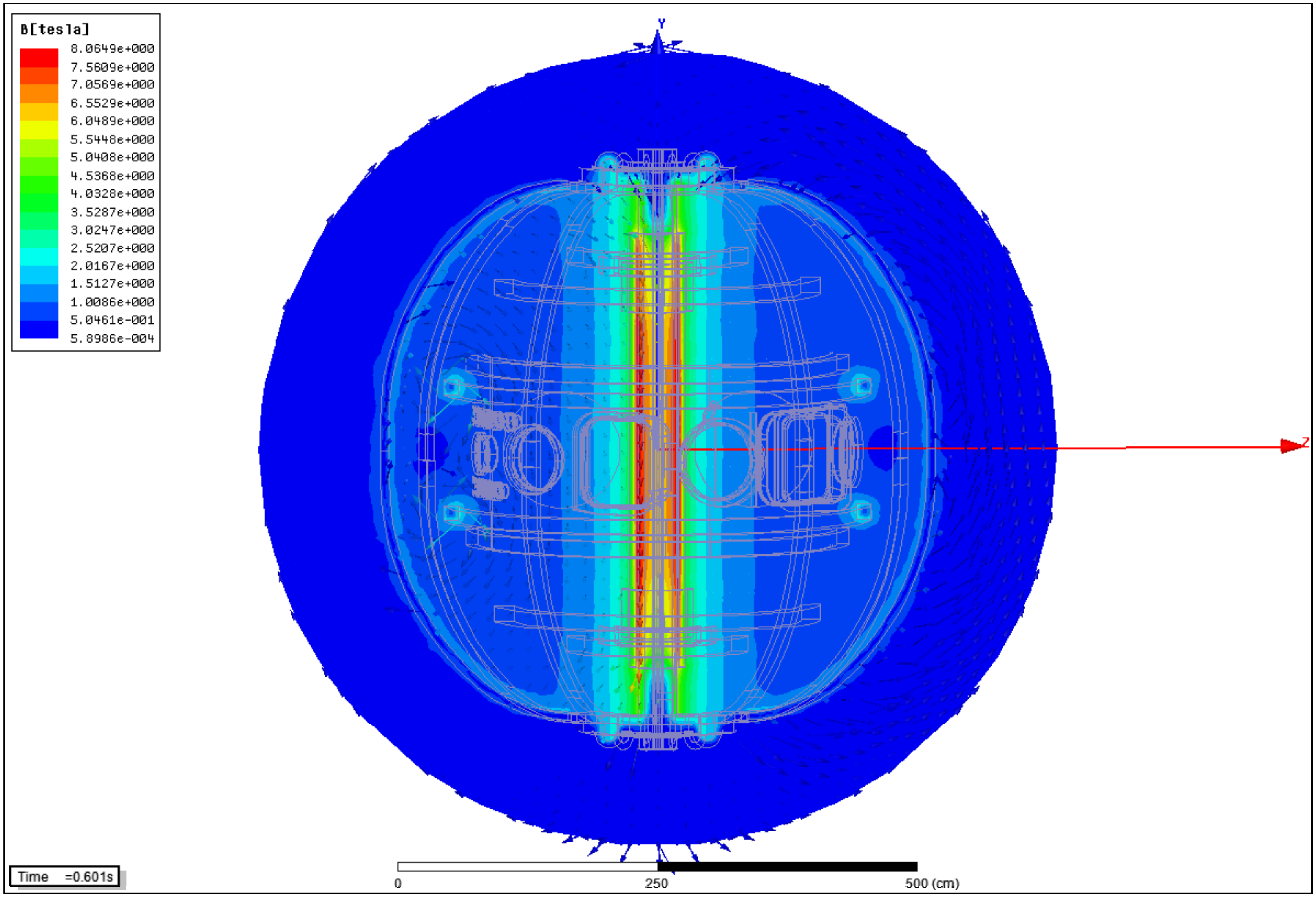


Maxwell Solid Model with Vacuum Enclosure: w/ Ports



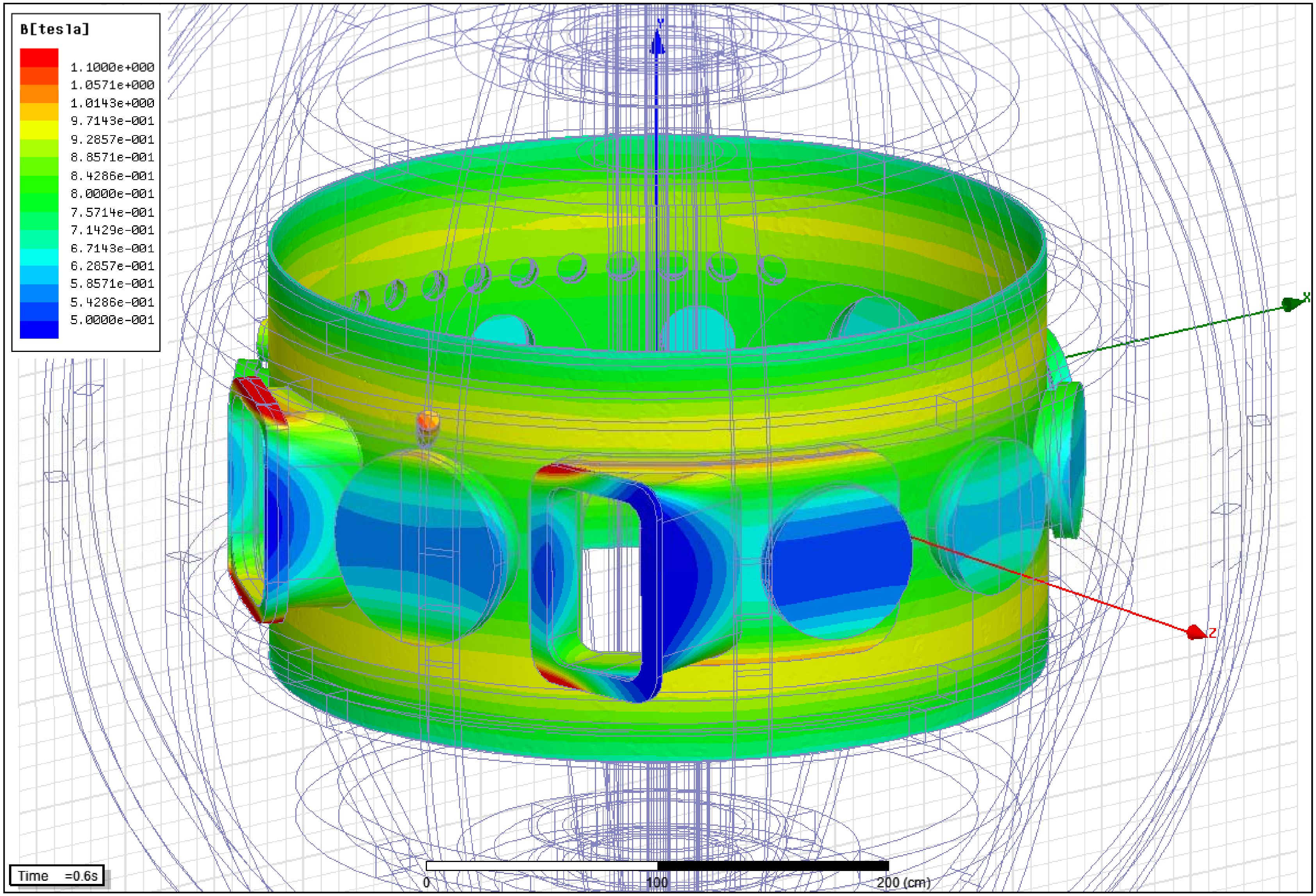
Maxwell Vacuum Vessel w/ Ports Mesh:

VV Mesh Settings: Element Length = 3 cm, Faceting Angle = 5 degrees



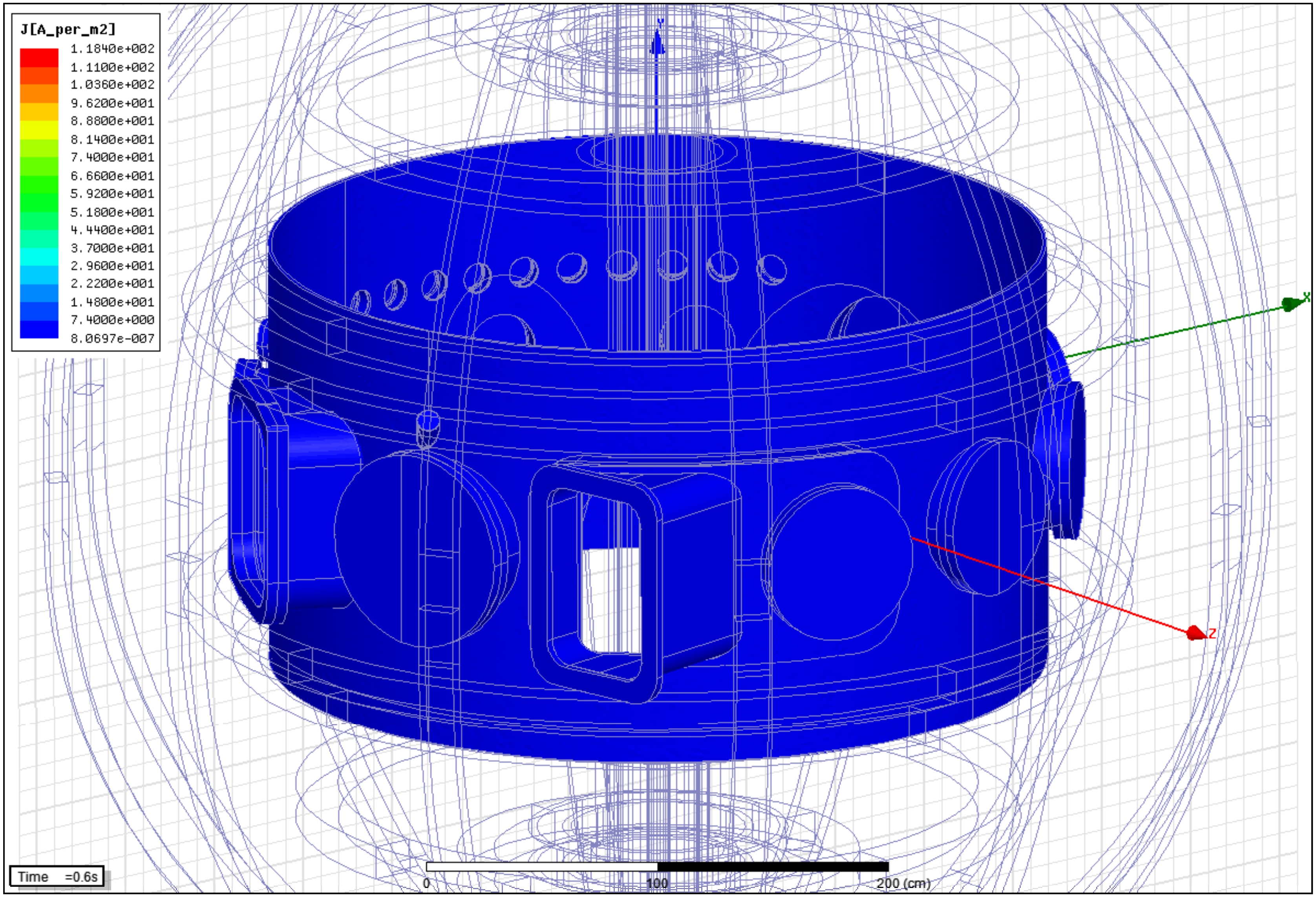
Magnetic Flux Density on Y-Z Plane: VV w/ Ports: End of Quench

Current Scenario #79 w/ Headroom



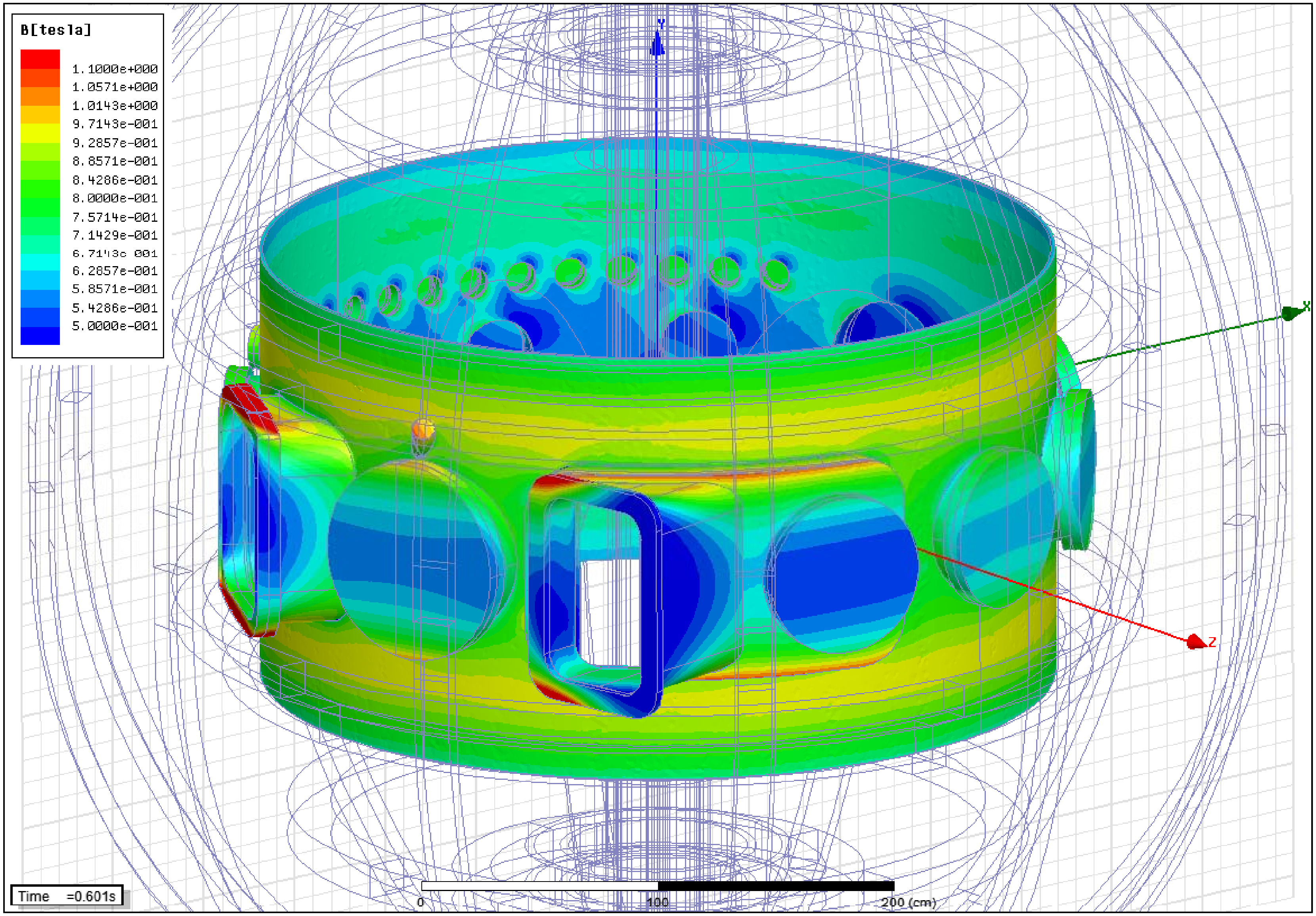
Magnetic Flux Density on Vacuum Vessel w/ Ports: Start of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



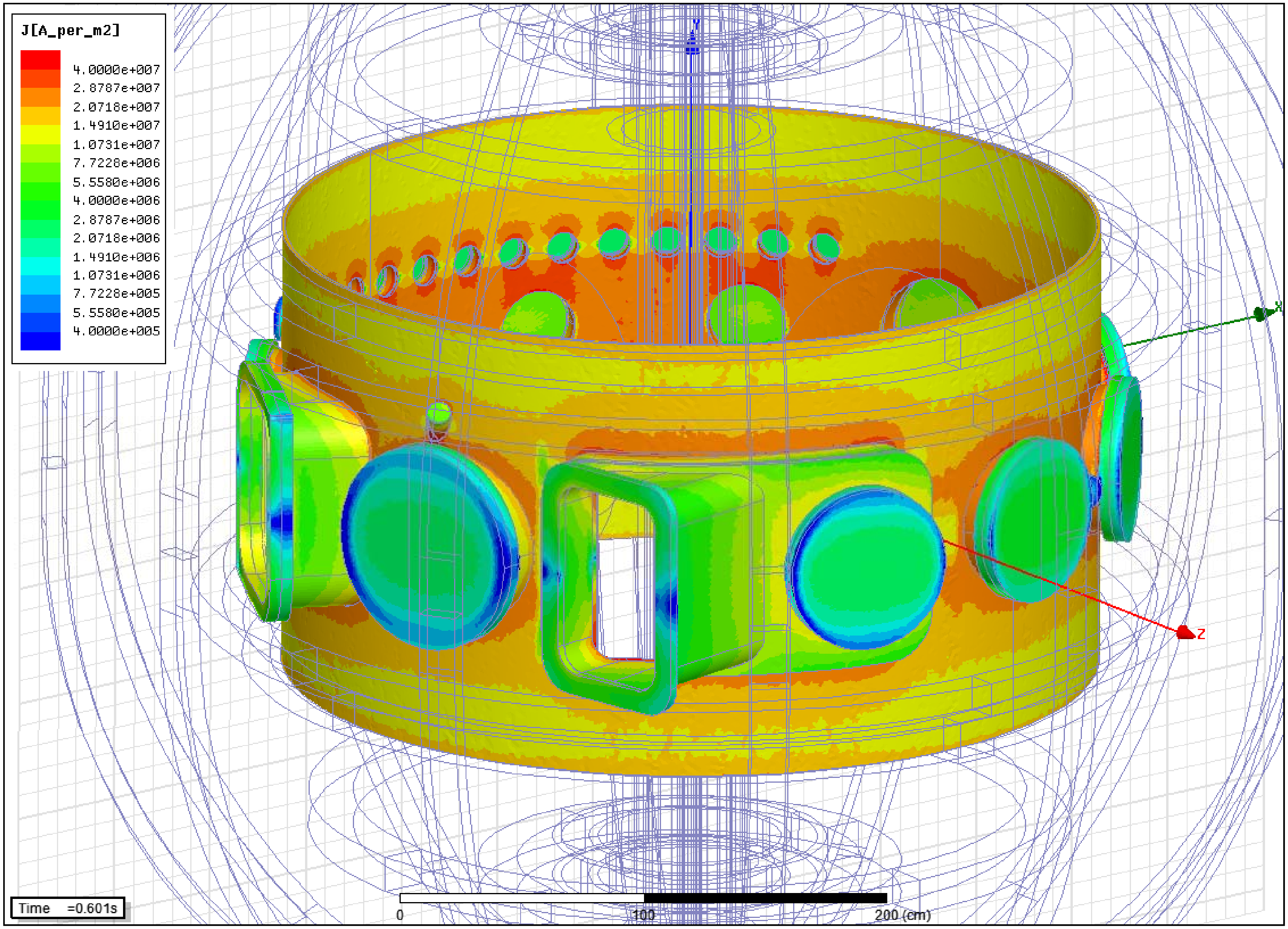
Eddy Current Density on Vacuum Vessel w/ Ports: Start of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



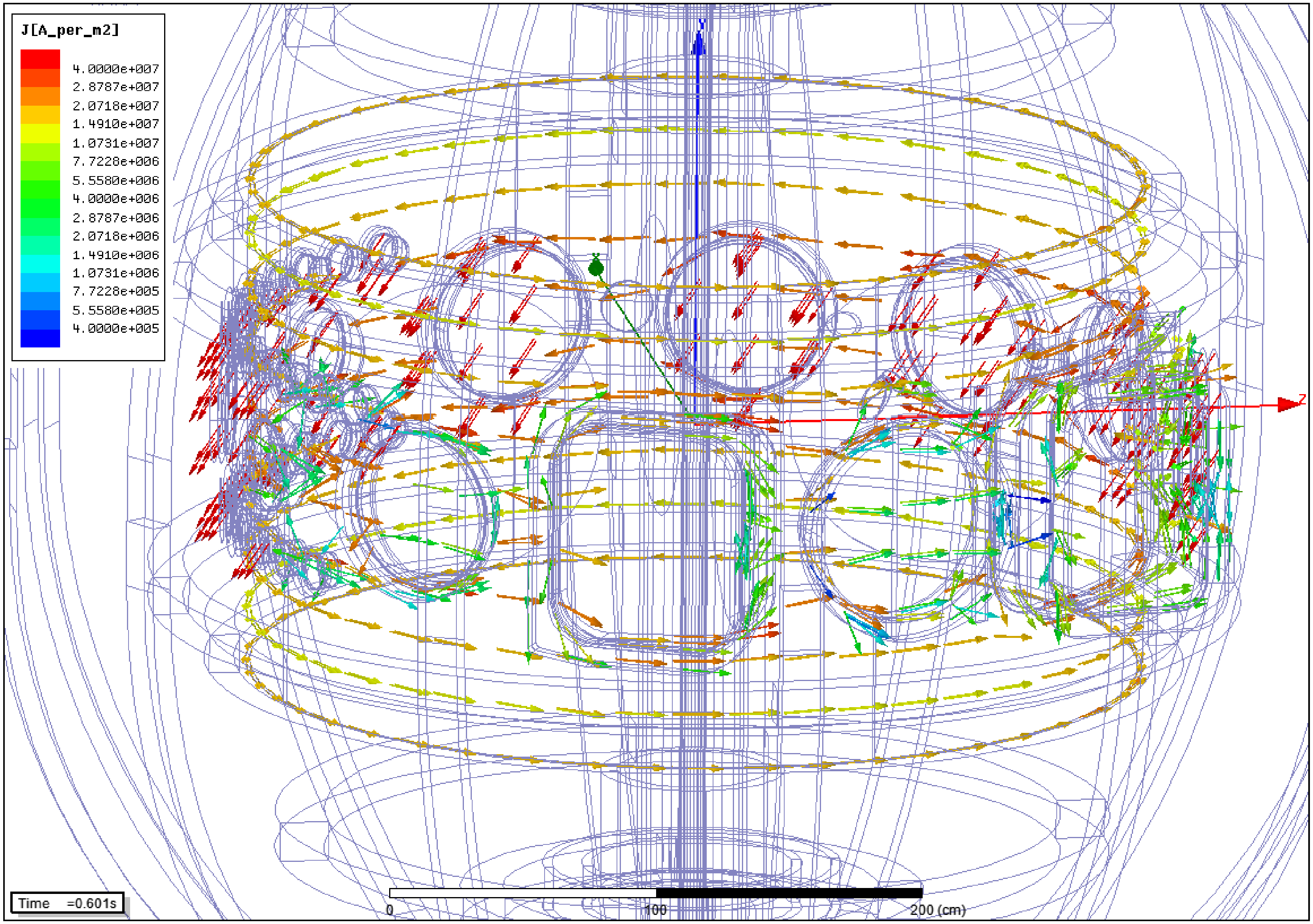
Magnetic Flux Density on Vacuum Vessel w/ Ports: End of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



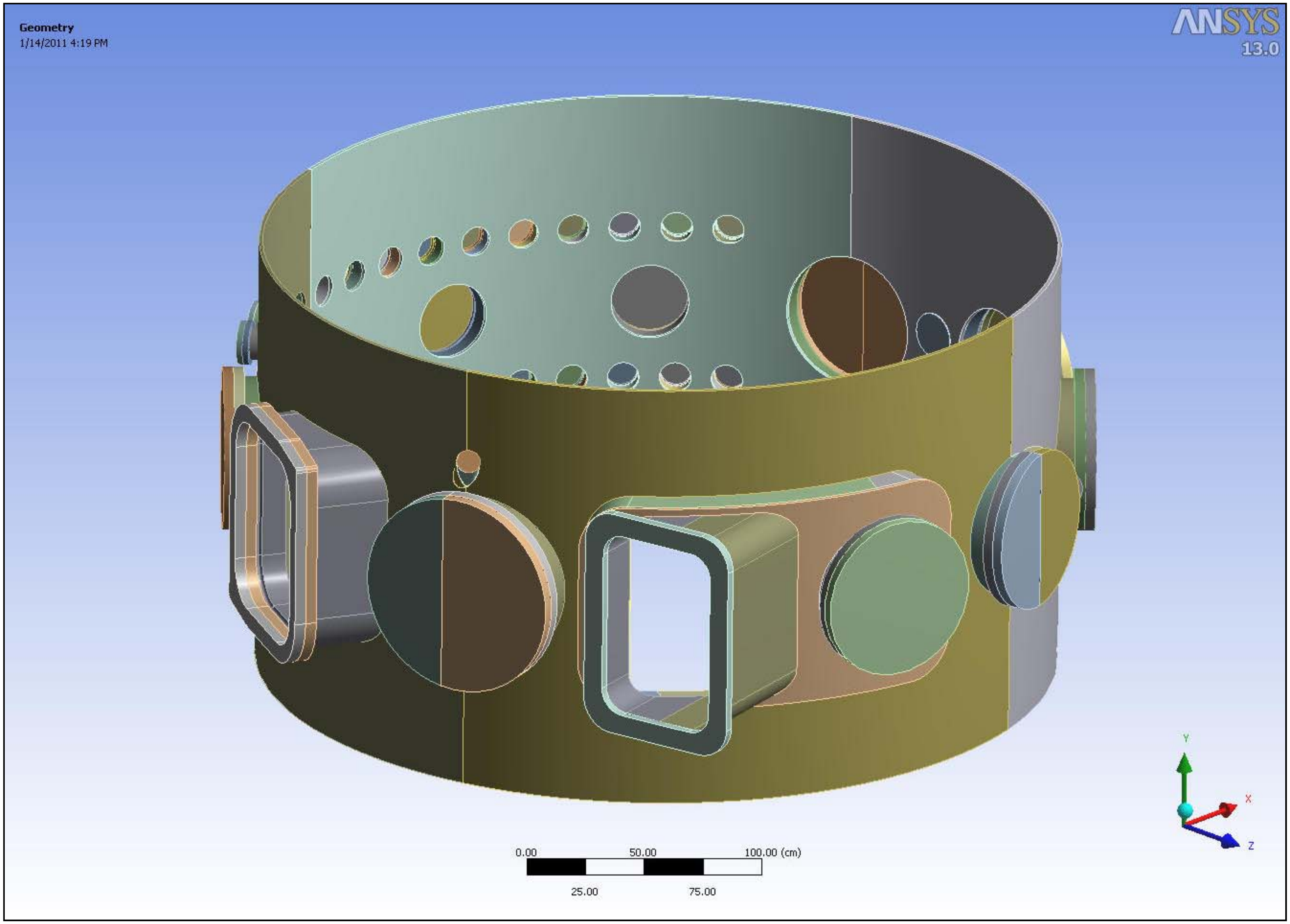
Eddy Current Density on Vacuum Vessel w/ Ports: End of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field

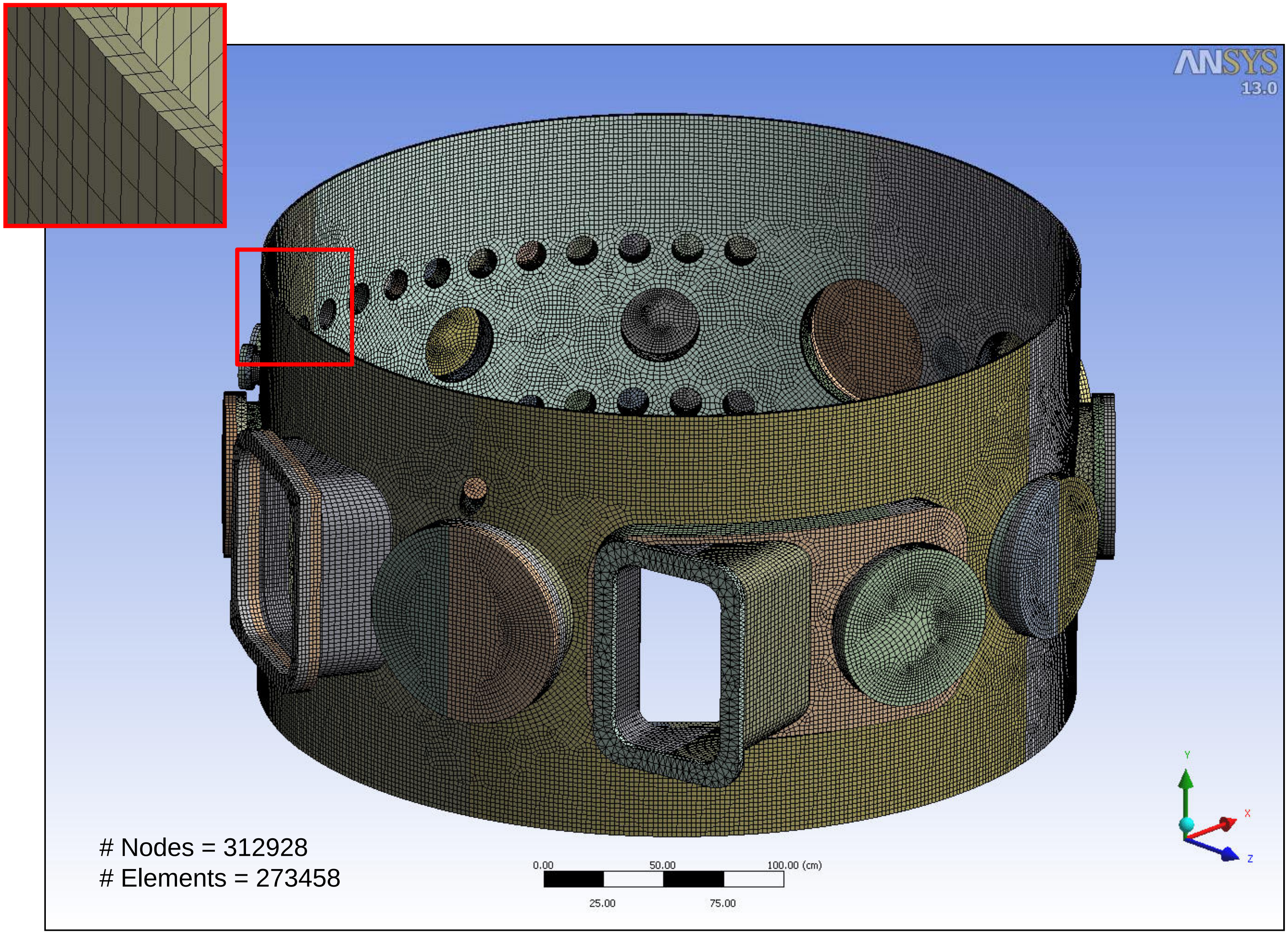


Eddy Current Density on Vacuum Vessel w/ Ports: End of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field

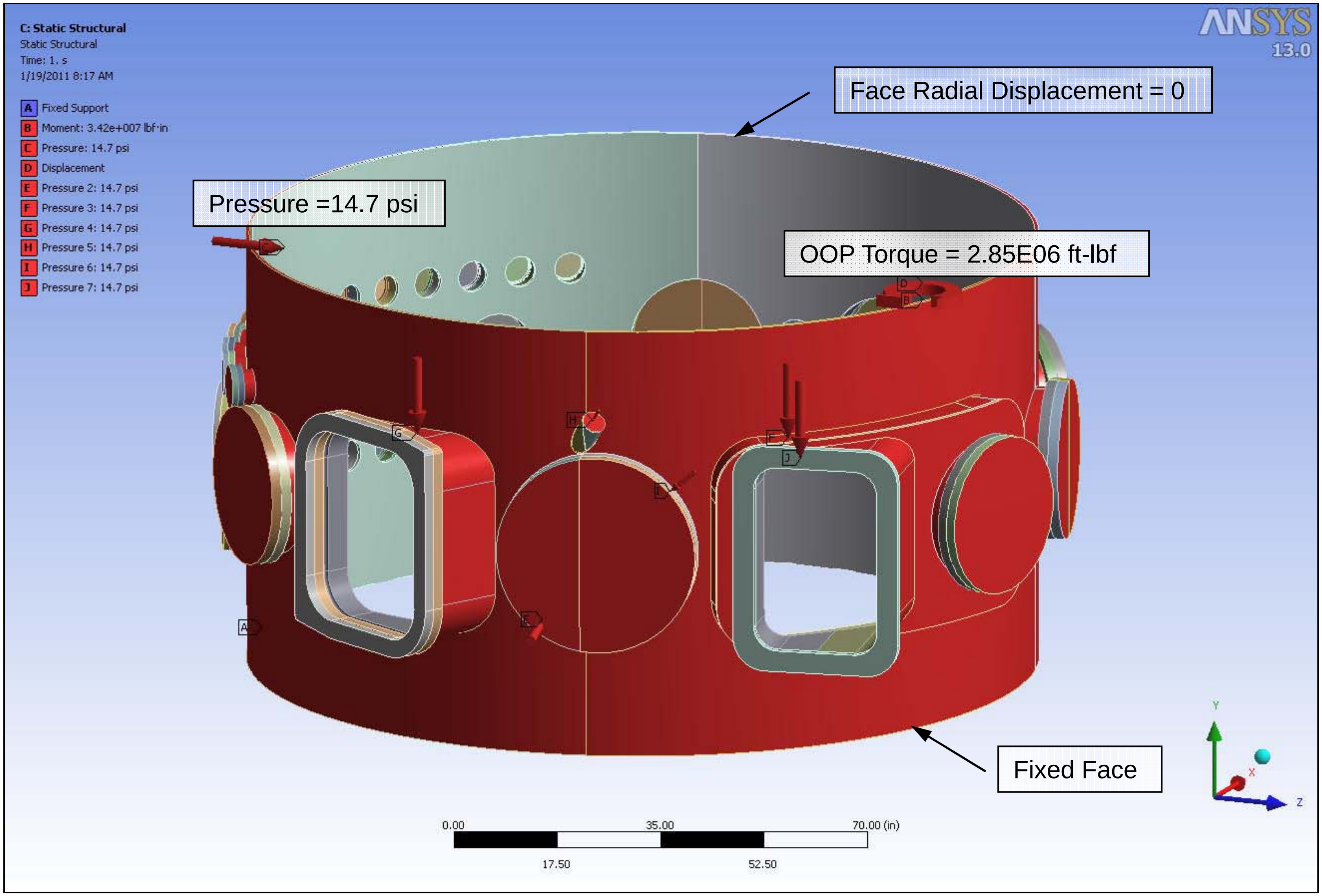


ANSYS DM Solid Model: Vacuum Vessel w/ Port Extensions

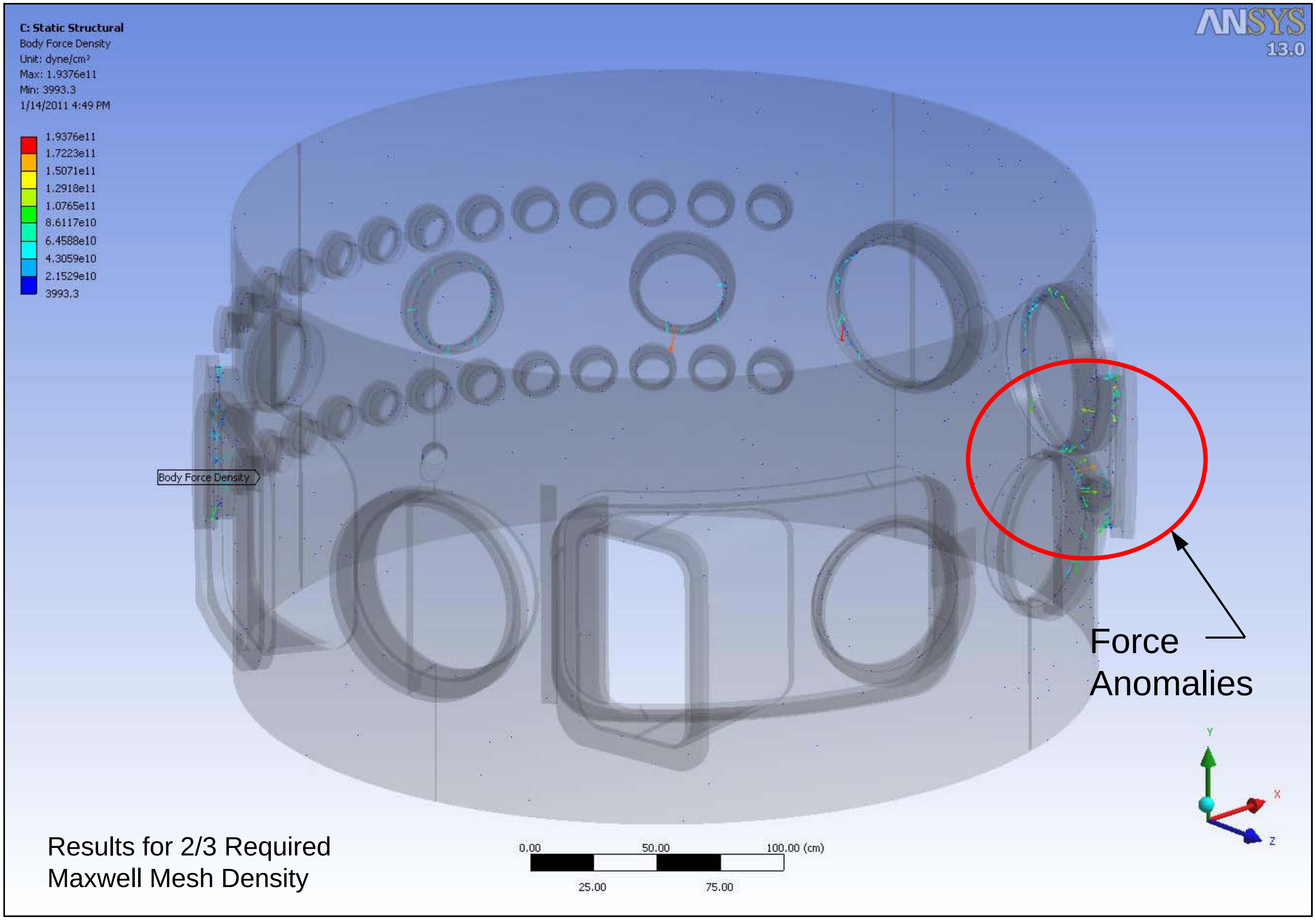


ANSYS WB Static Structural Model w/ Ports: Mesh

VV Mesh Settings: Automatic Sweep, # Div. = 3; Element Size = 2 cm; No Mid-side Nodes

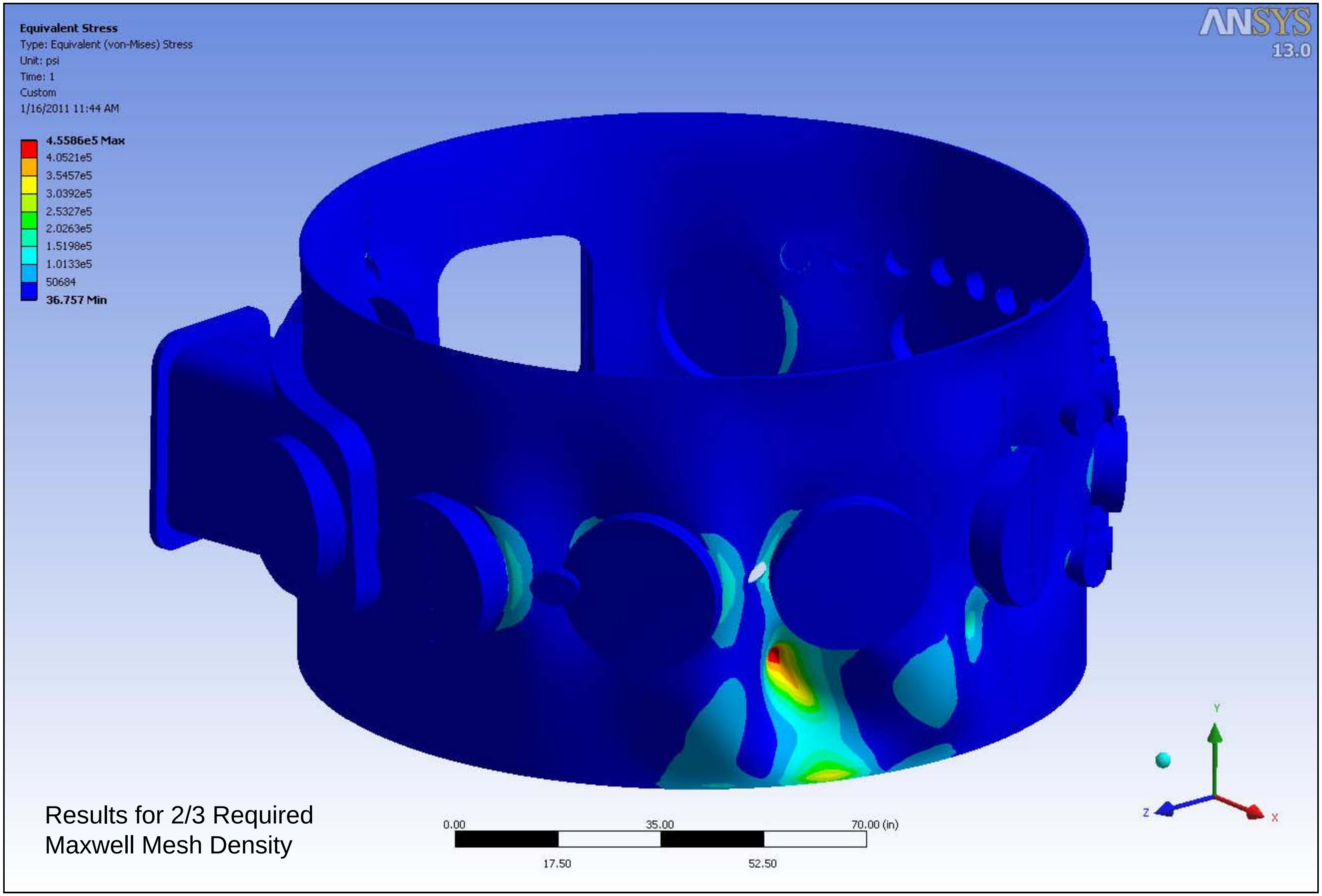


ANSYS Static Structural Model: Loads and Boundary Conditions



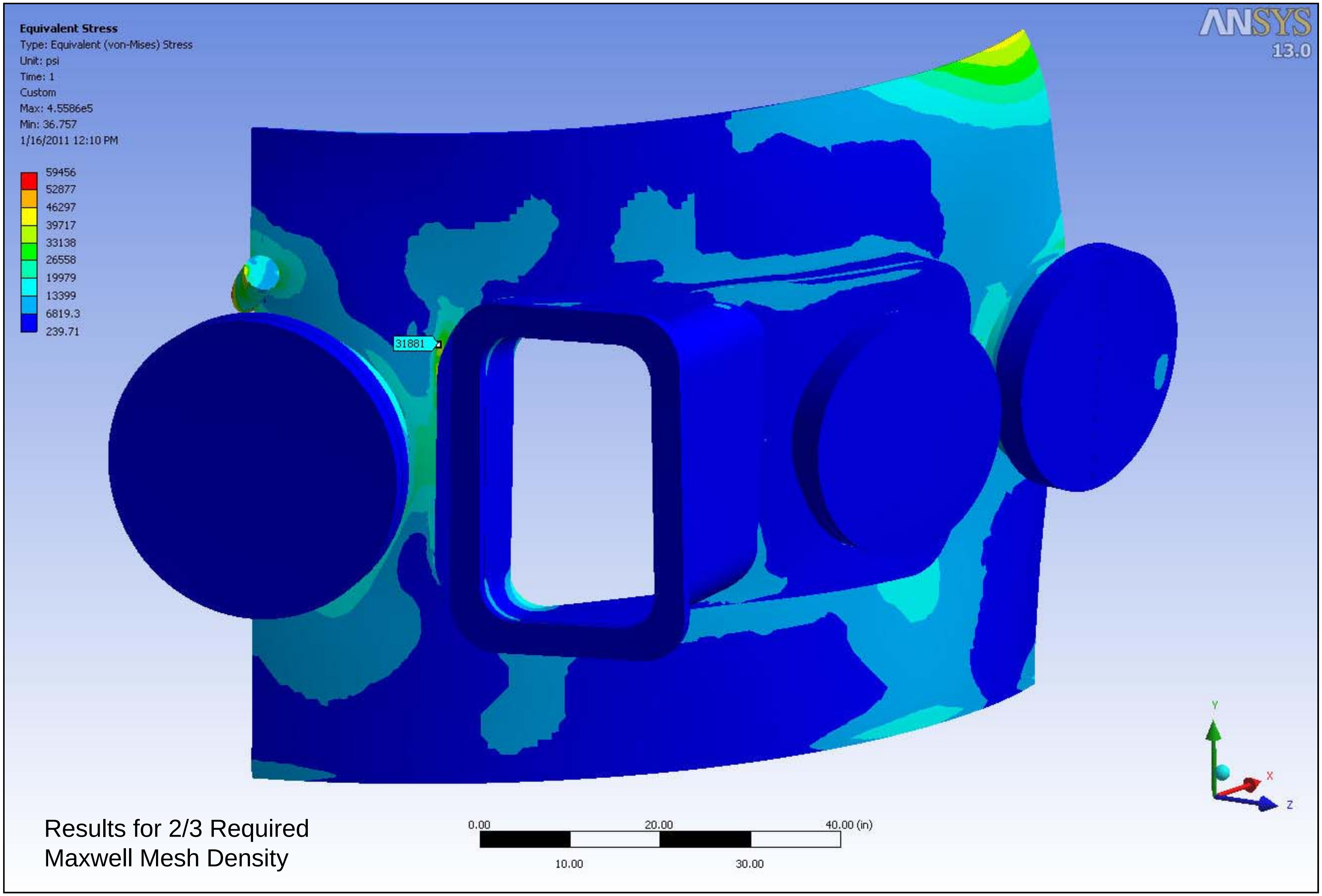
ANSYS Static Structural Results w/ Port Extensions: Force Density

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



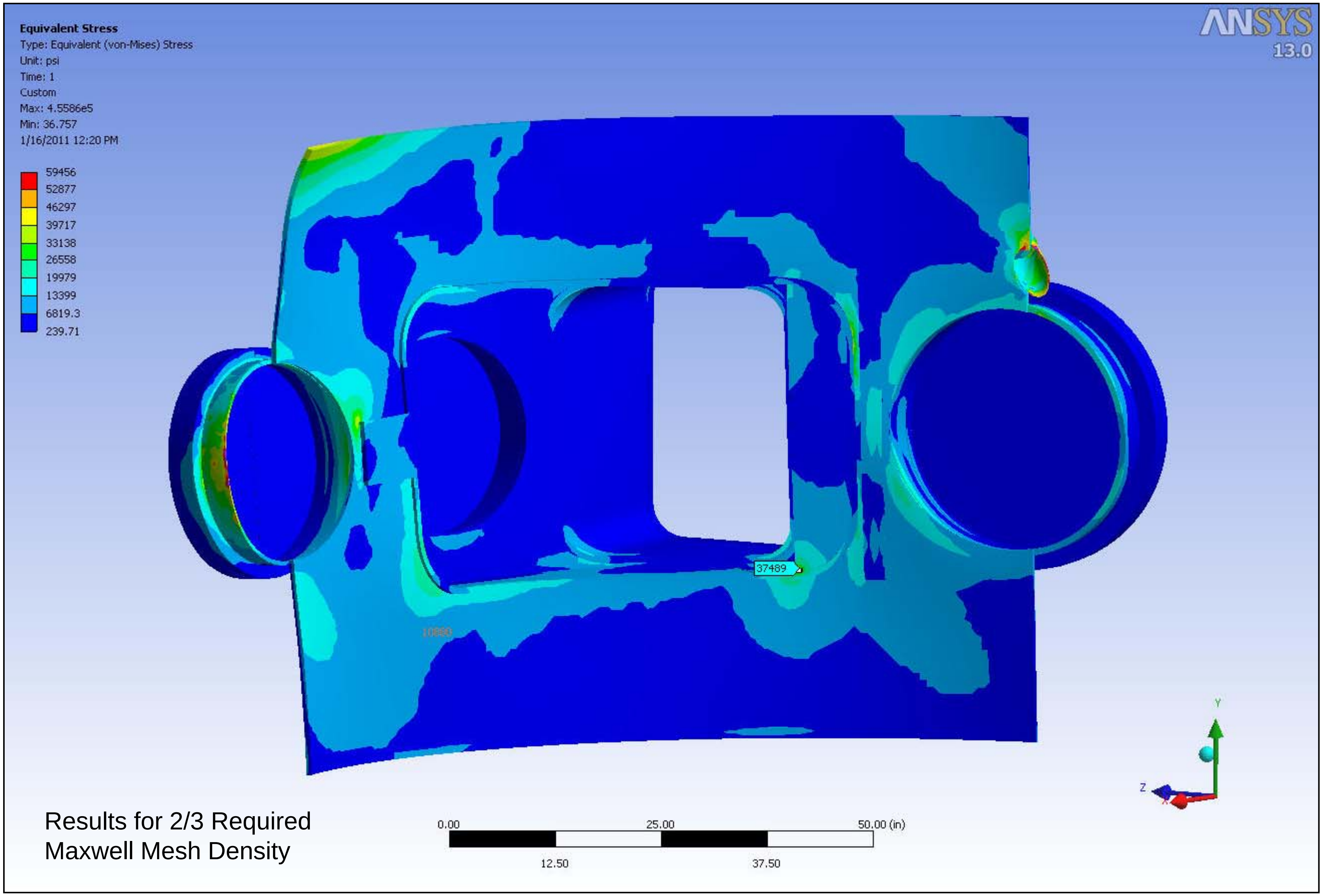
ANSYS Static Structural Results w/ Port Extensions: von Mises Stress

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field

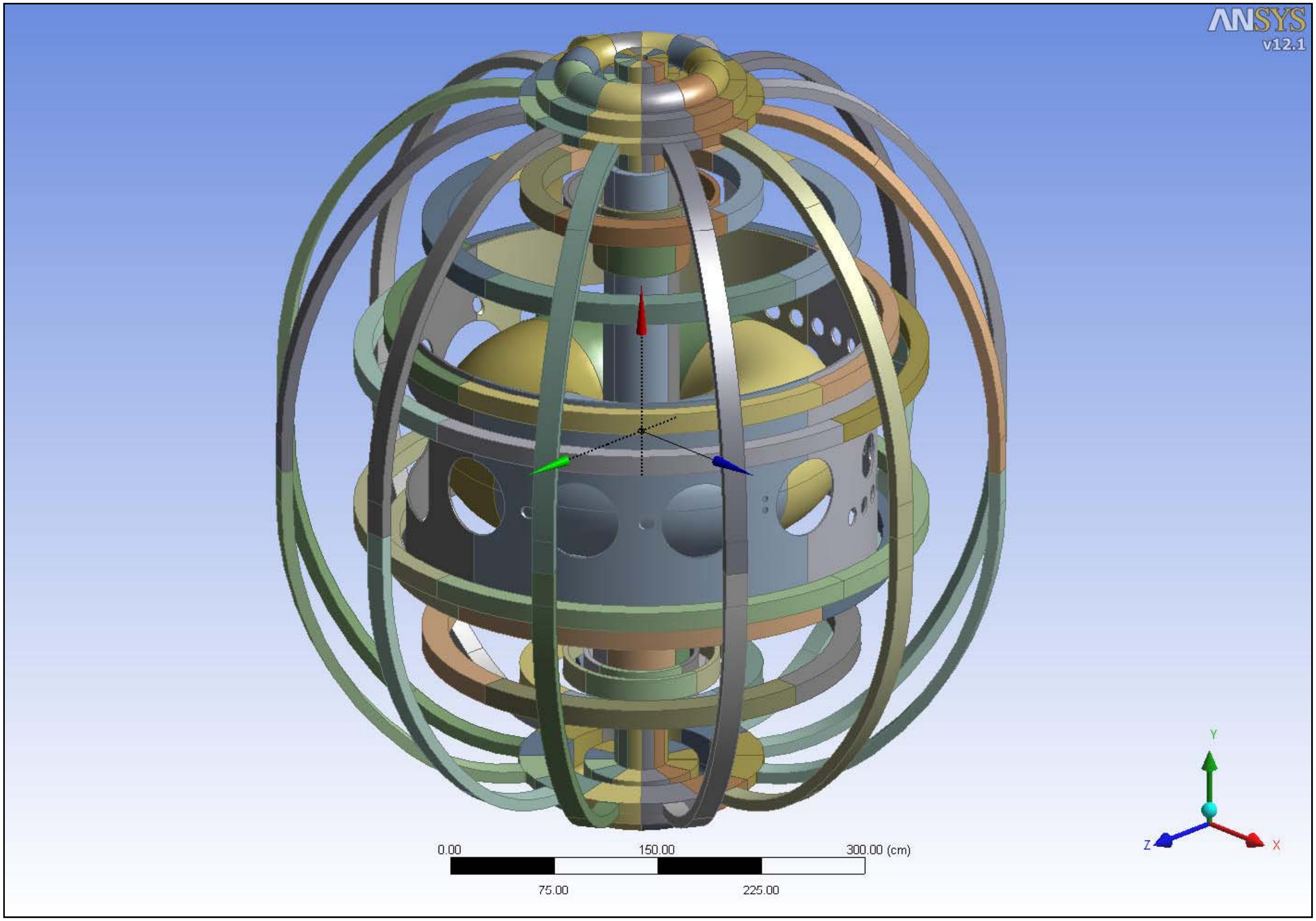


ANSYS Static Structural Results w/ Port Extensions: von Mises Stress (2)

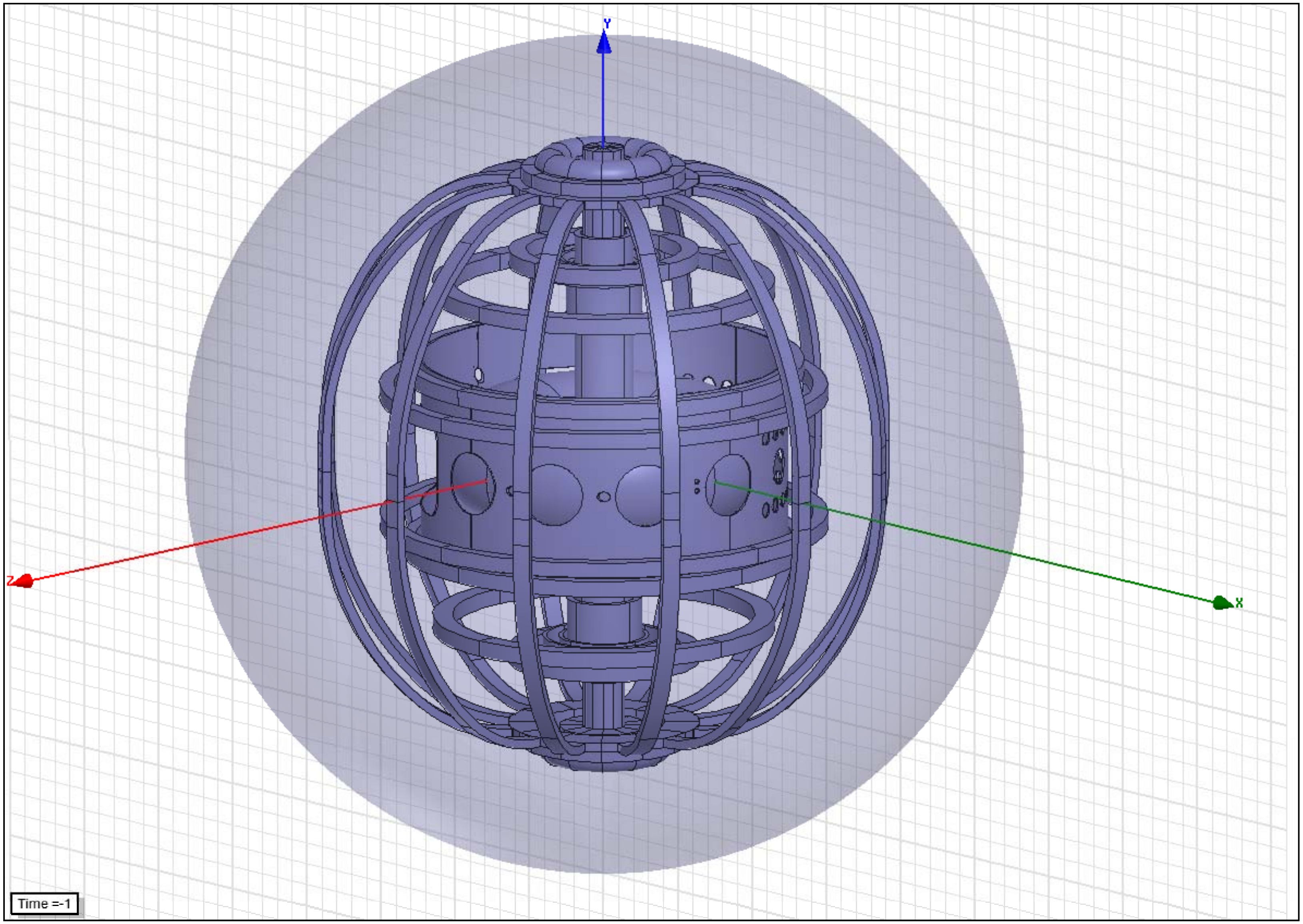
1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



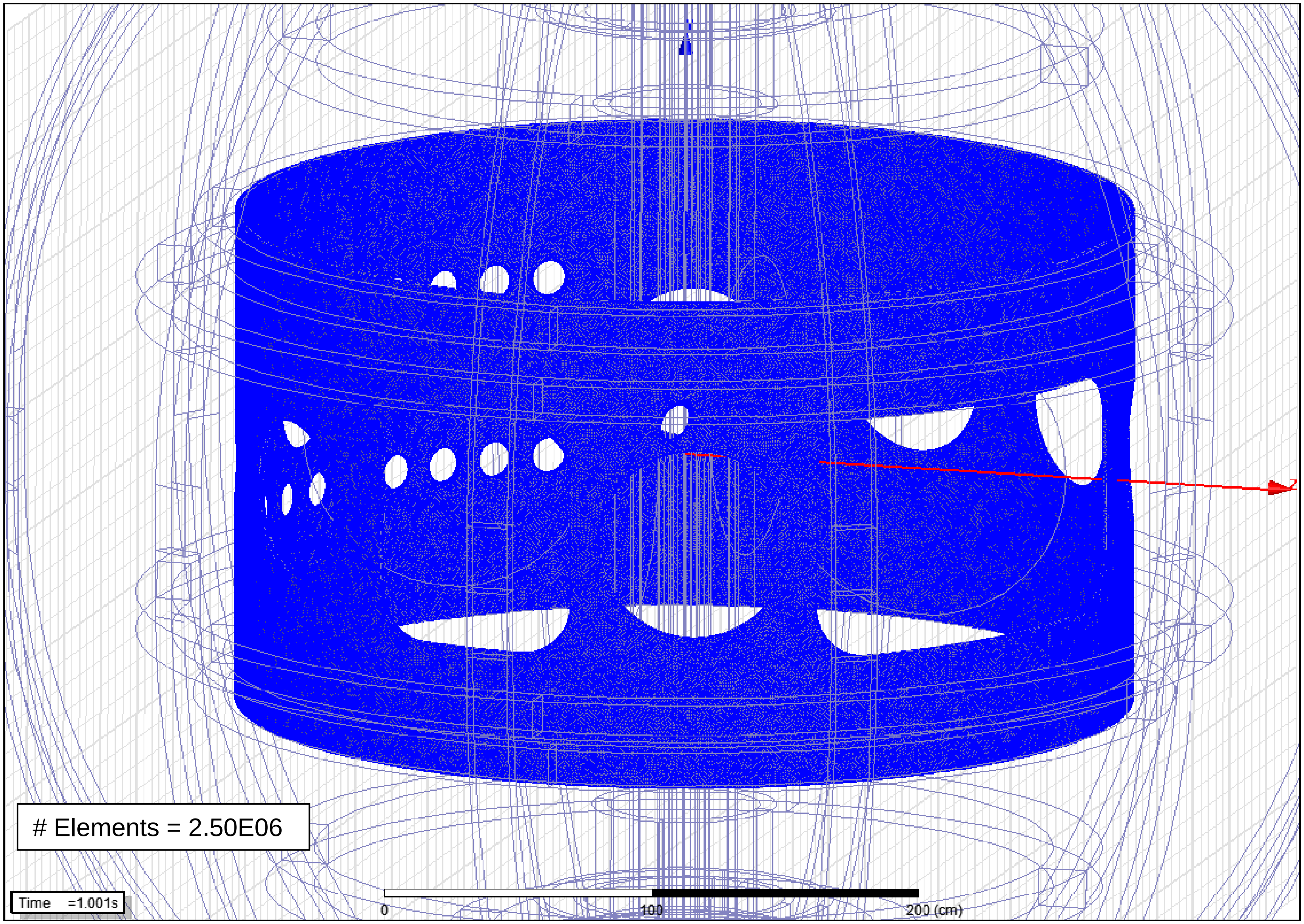
ANSYS Static Structural Results w/ Port Extensions: von Mises Stress (3)
1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



ANSYS WB Solid Model of Simplified Coil and VV Exported to Maxwell

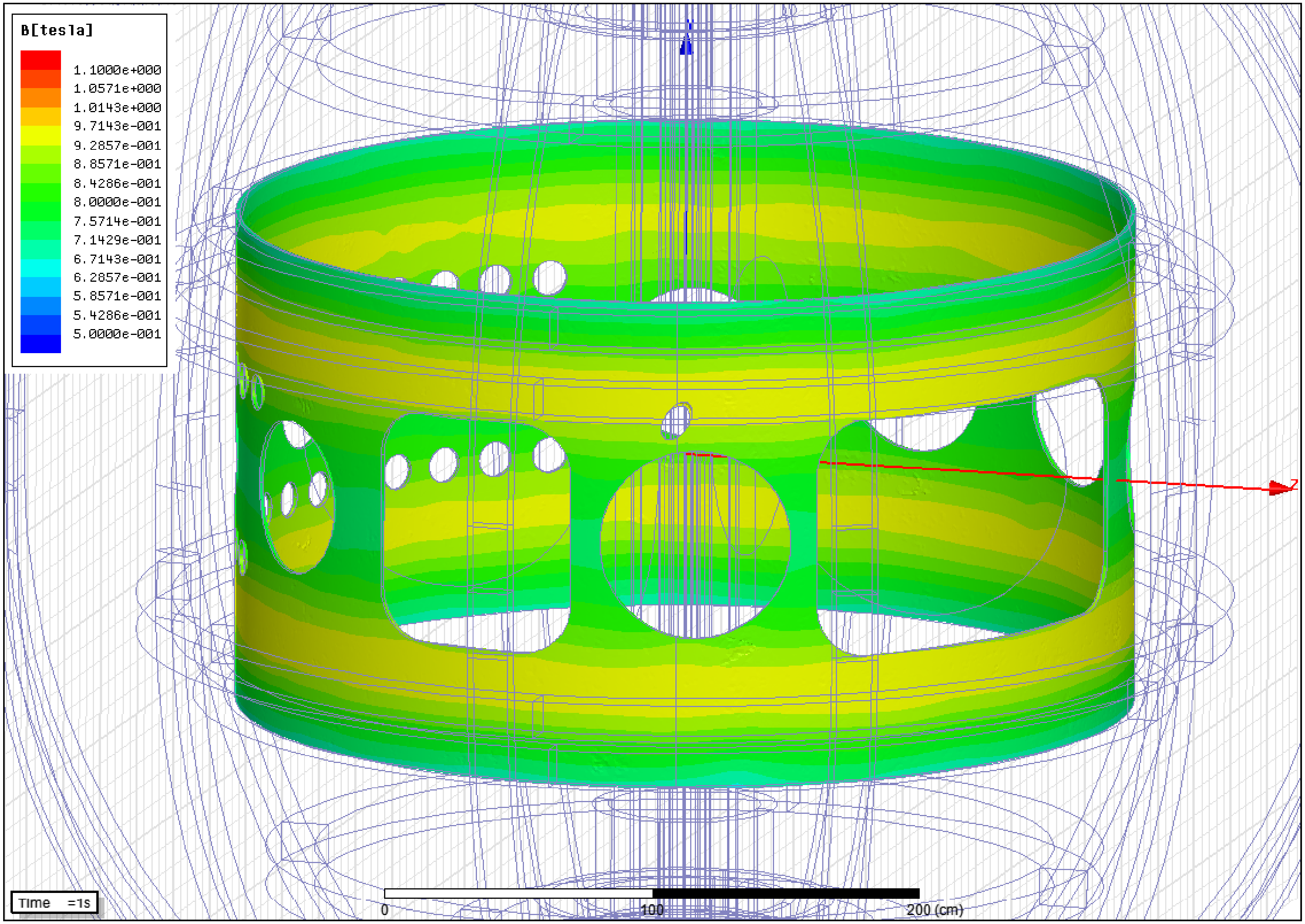


Maxwell Solid Model with Vacuum Enclosure: w/o Ports



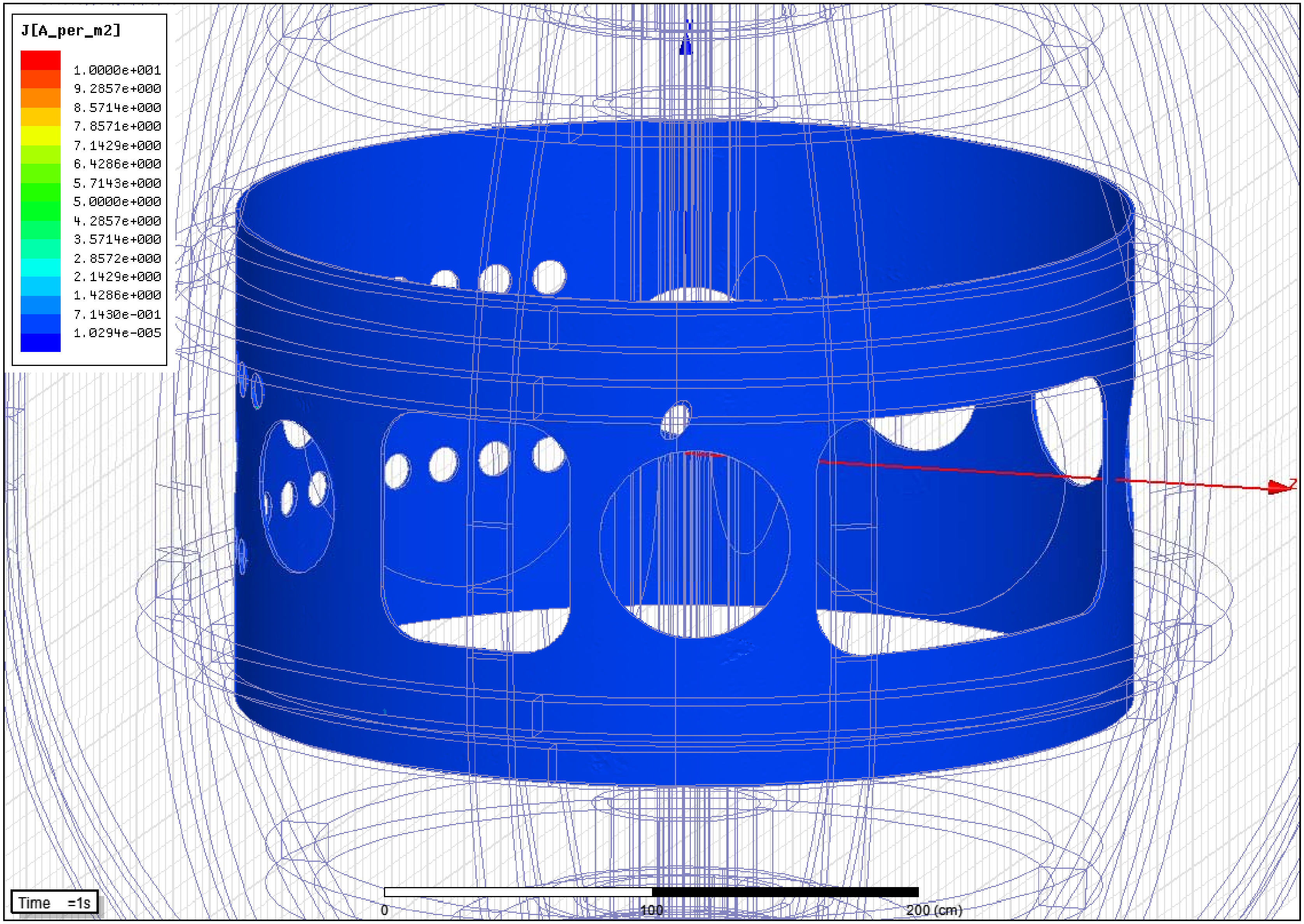
Maxwell Vacuum Vessel w/o Ports Mesh:

VV Mesh Settings: Element Length = 2 cm, Faceting Angle = 1 degree



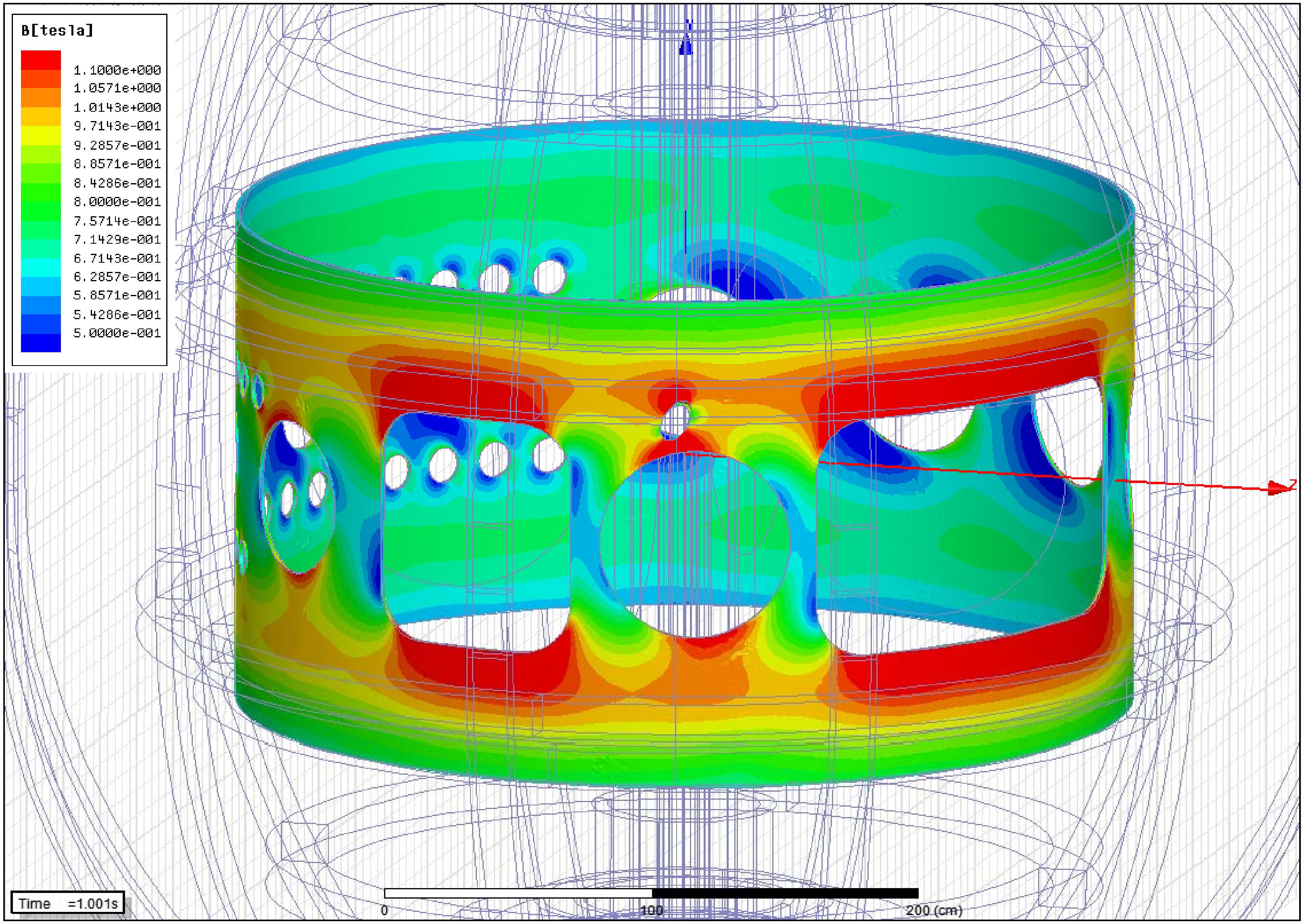
Magnetic Flux Density on Vacuum Vessel w/o Ports: Start of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



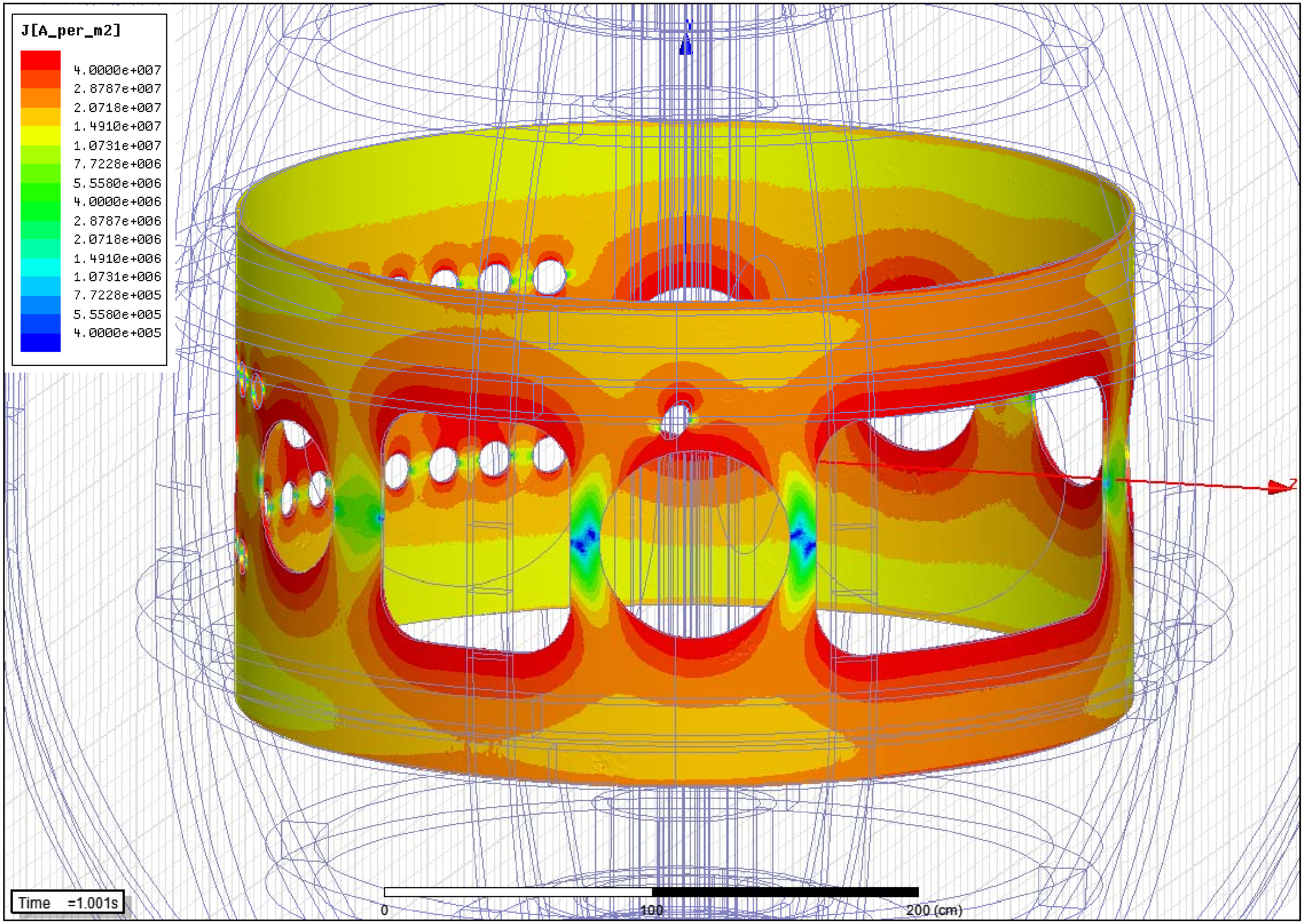
Eddy Current Density on Vacuum Vessel w/o Ports: Start of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



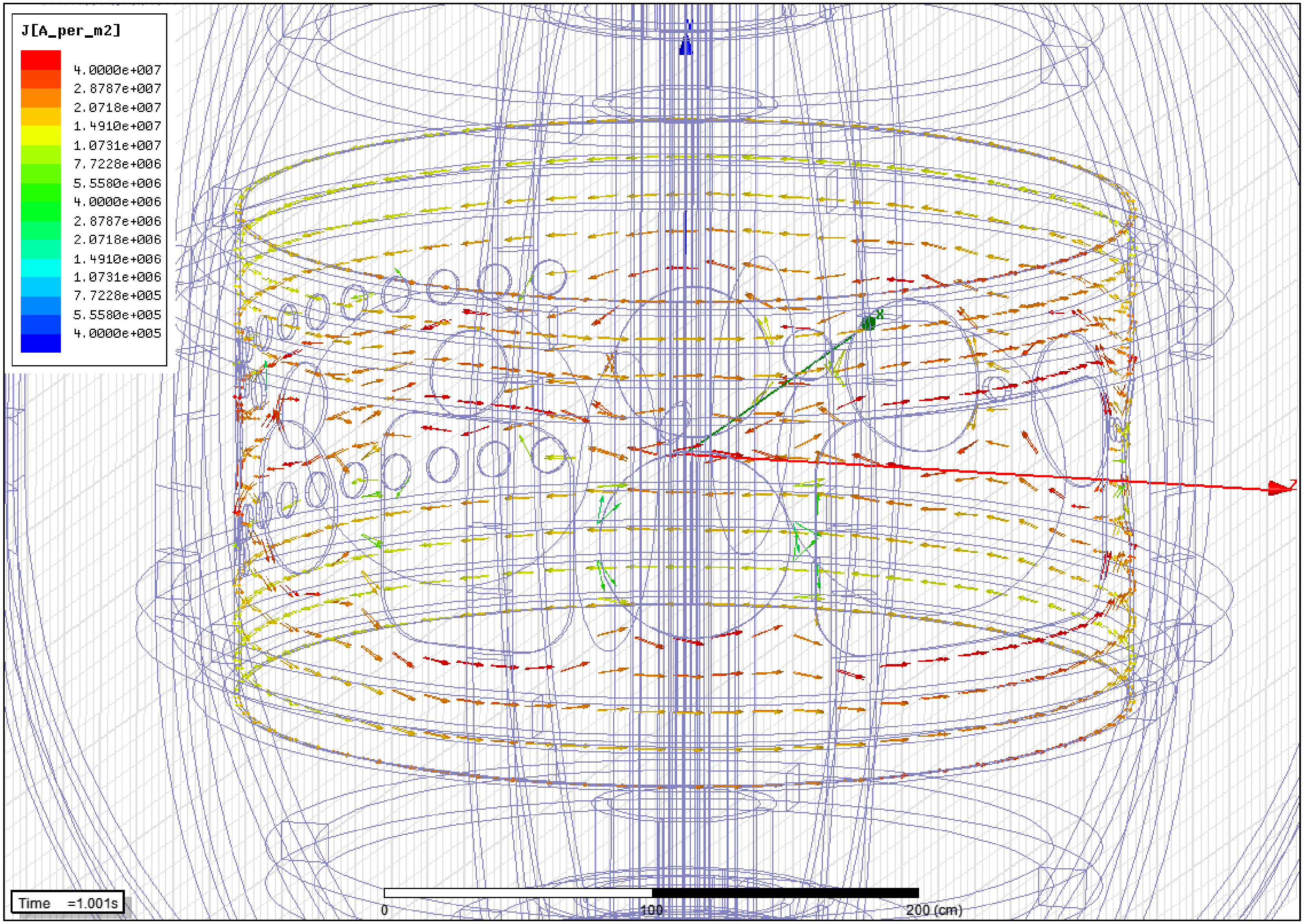
Magnetic Flux Density on Vacuum Vessel w/o Ports: End of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



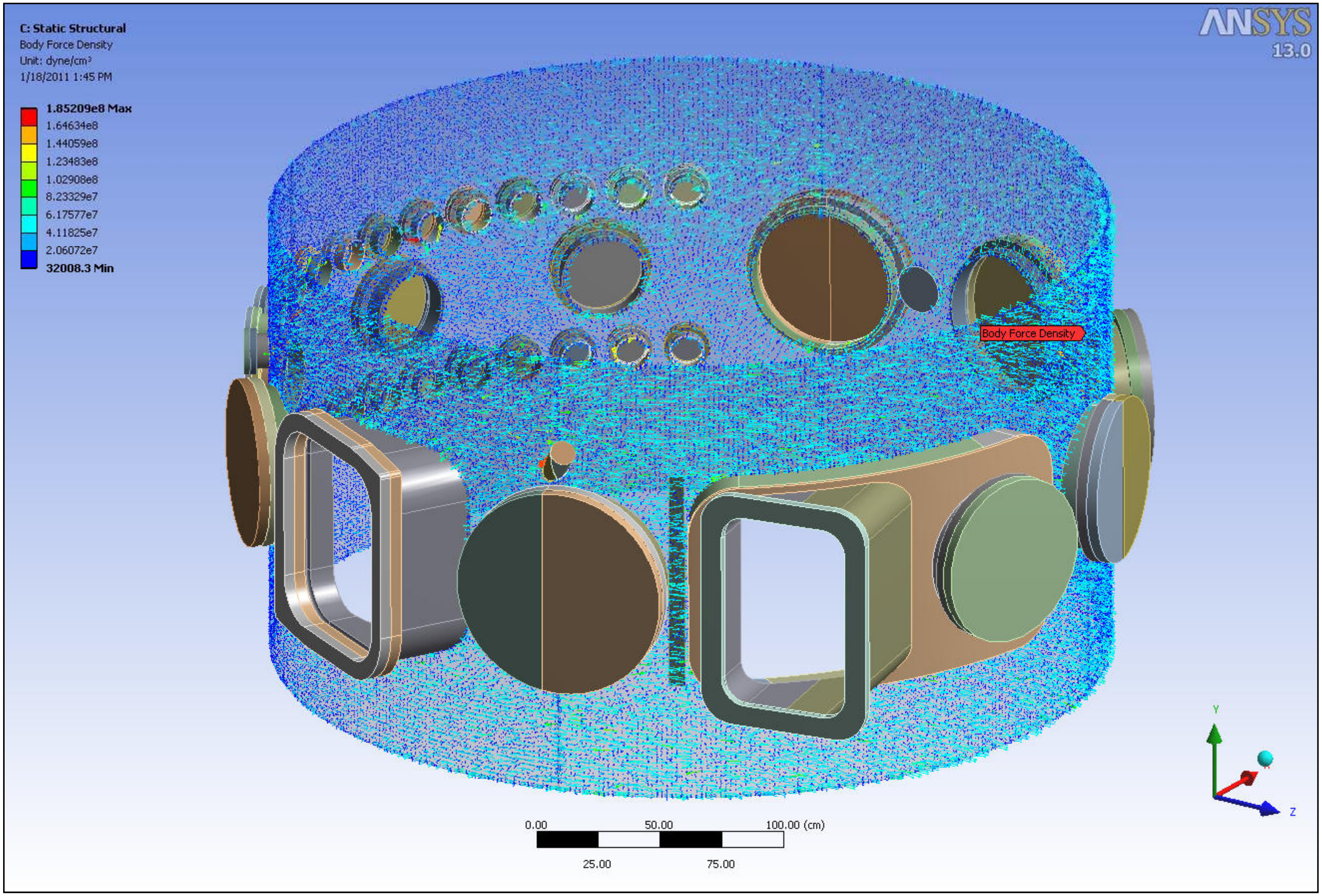
Eddy Current Density on Vacuum Vessel w/o Ports: End of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



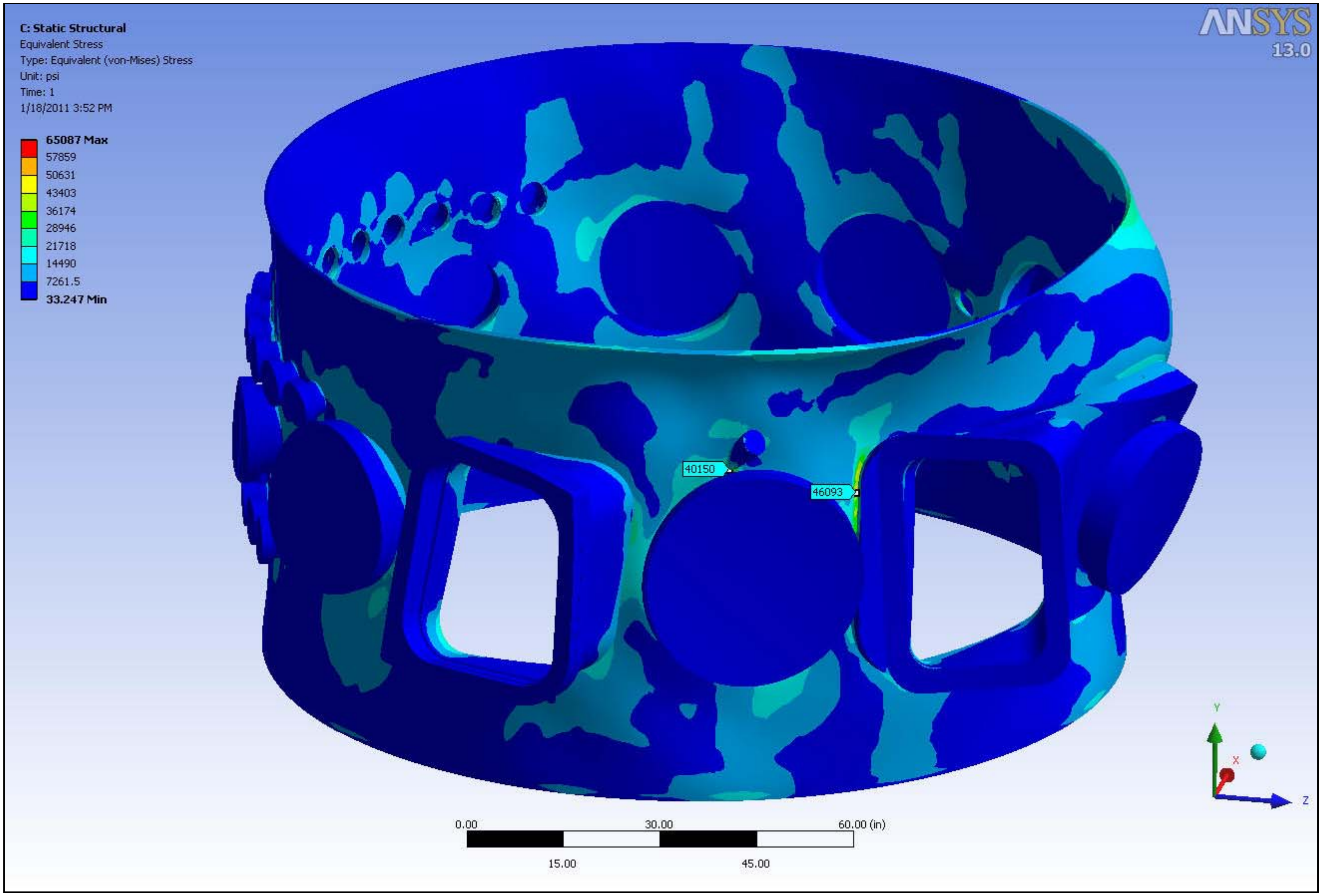
Eddy Current Density on Vacuum Vessel w/o Ports: End of Quench

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field

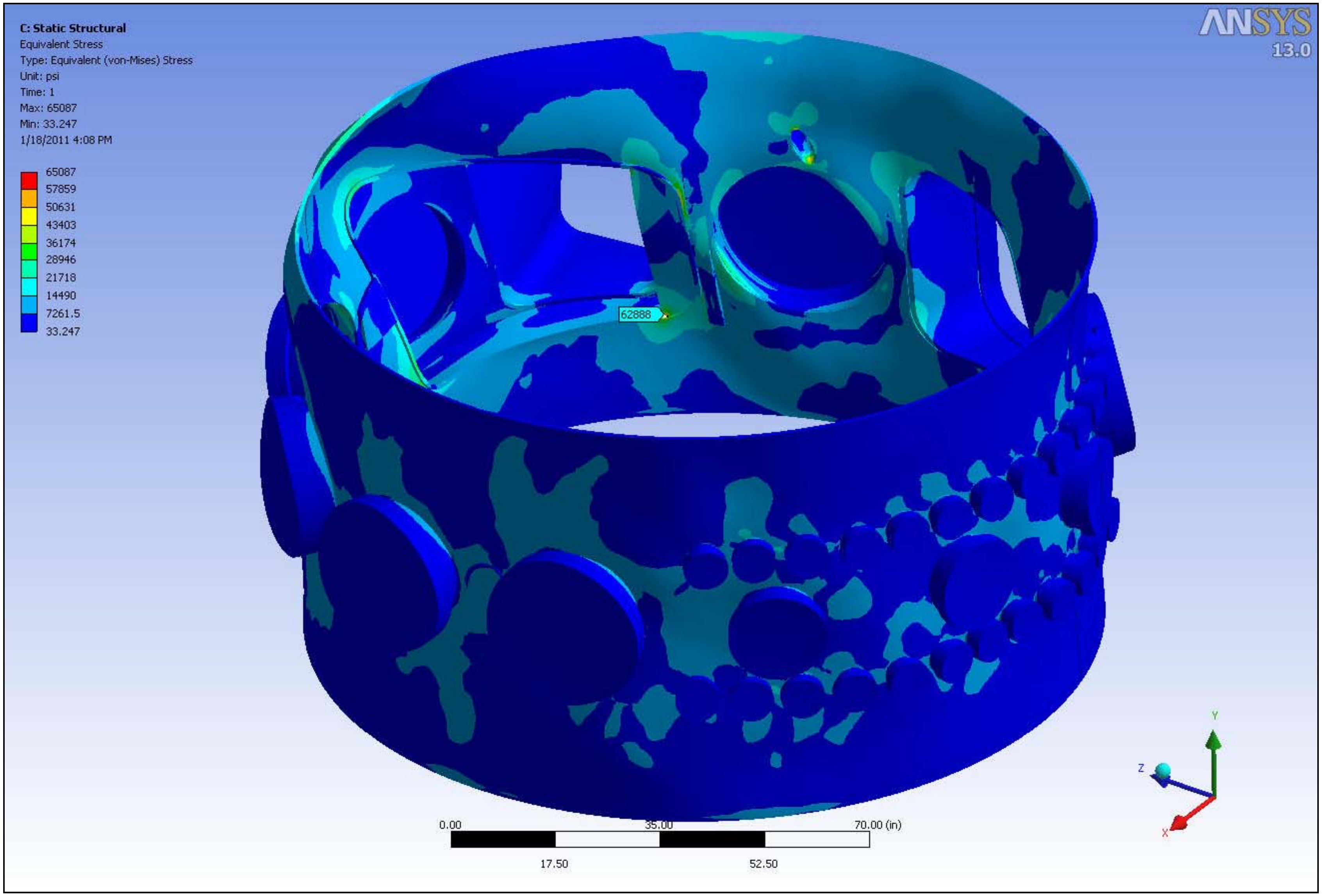


ANSYS Static Structural Results, Ports excluded from EM Solution: Force Density

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



Static Structural Results, Ports Excluded from EM Solution: von Mises Stress
1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



Static Structural Results, Ports Excluded from EM Solution: von Mises Stress (2)

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field

Room Temperature Allowable for 316 and 304 SST

Material	Sm	1.5Sm
316 LN SST	183 MPa (26.6 ksi)	275 MPa (40 ksi)
316 LN SST Weld	160 MPa (23.2 ksi)	241 MPa (35ksi)

05/19/1998 13:53 6174720409 NEWENGLANDSTEELTANK PAGE 03

Avesta Sheffield

Avesta Sheffield Plate Inc.

Certificate of Analysis and Tests

OUR ORDER 106101 - 01 HEAT & PIECE 87893-3B 5/13/98

PSI MIC NO. C992

SOLD TO: PROCESS SYSTEMS INTERNATIONAL
20 WALKUP DRIVE
WESTBOROUGH MA 01581

SHIP TO: NEW ENGLAND STEEL TANK
111 BROOK ROAD
SOUTH QUINCY MA 02169
737001-06

---------------------------- YOUR ORDER & DATE ----------------------------

558635 3/18/98 TAG# PART #V077P001

---------------------------- ITEM DESCRIPTION ----------------------------

HEAT & PIECE 87893 - 3B 3A
WEIGHT 3002
FINISH 1
GRADE 304 UNS-S30400
DIMENSIONS .625 X 76.000 X 212.000 EXACT

---------------------------- SPECIFICATIONS ----------------------------

THE PRODUCTS LISTED ON THIS MILL TEST REPORT SATISFY PREFERENCE CRITERION B AS DEFINED IN ARTICLE 401 OF THE NORTH AMERICAN FREE TRADE AGREEMENT. COUNTRY OF ORIGIN IS USA

ASTM A240-96A ASMESA240-96AD
NO WELD REPAIR ON MATERIAL
ASTM A262-93A PRAC A

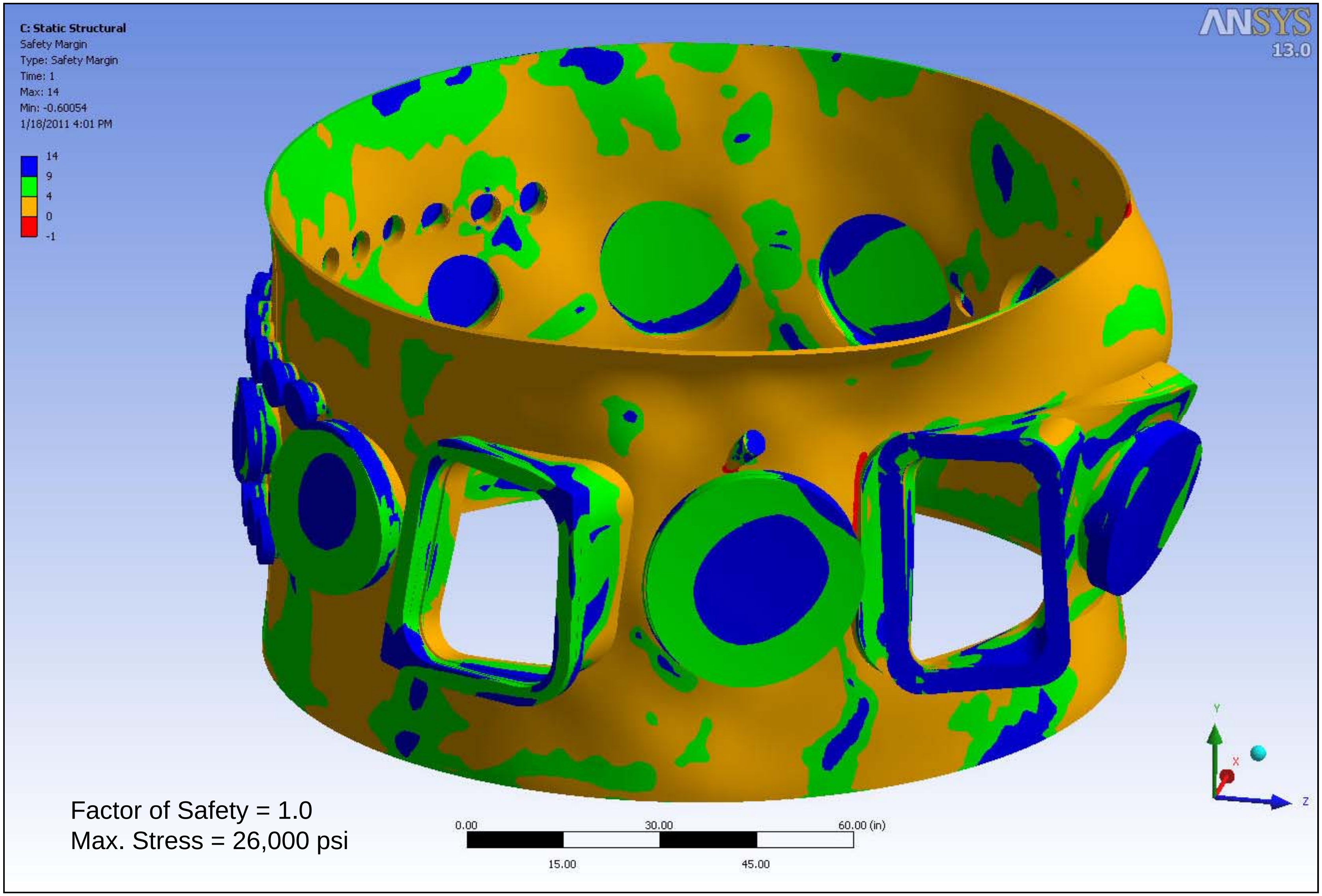
ASTM A480-96,ASMESA480-96AD
MAG PERM <1.05 ASTM A342 (6)
ASTM A262-93A PRAC E

PLATES & TEST PCS SOLUTION ANNEALED @ 1950 DEGREES FARENHEIT MINIMUM.
THEN WATER COOLED OR RAPIDLY COOLED BY AIR
FREE OF MERCURY CONTAMINATION
HOT ROLLED, ANNEALED & PICKLED (HRAP)

---------------------------- MECHANICAL & OTHER TESTS ----------------------------

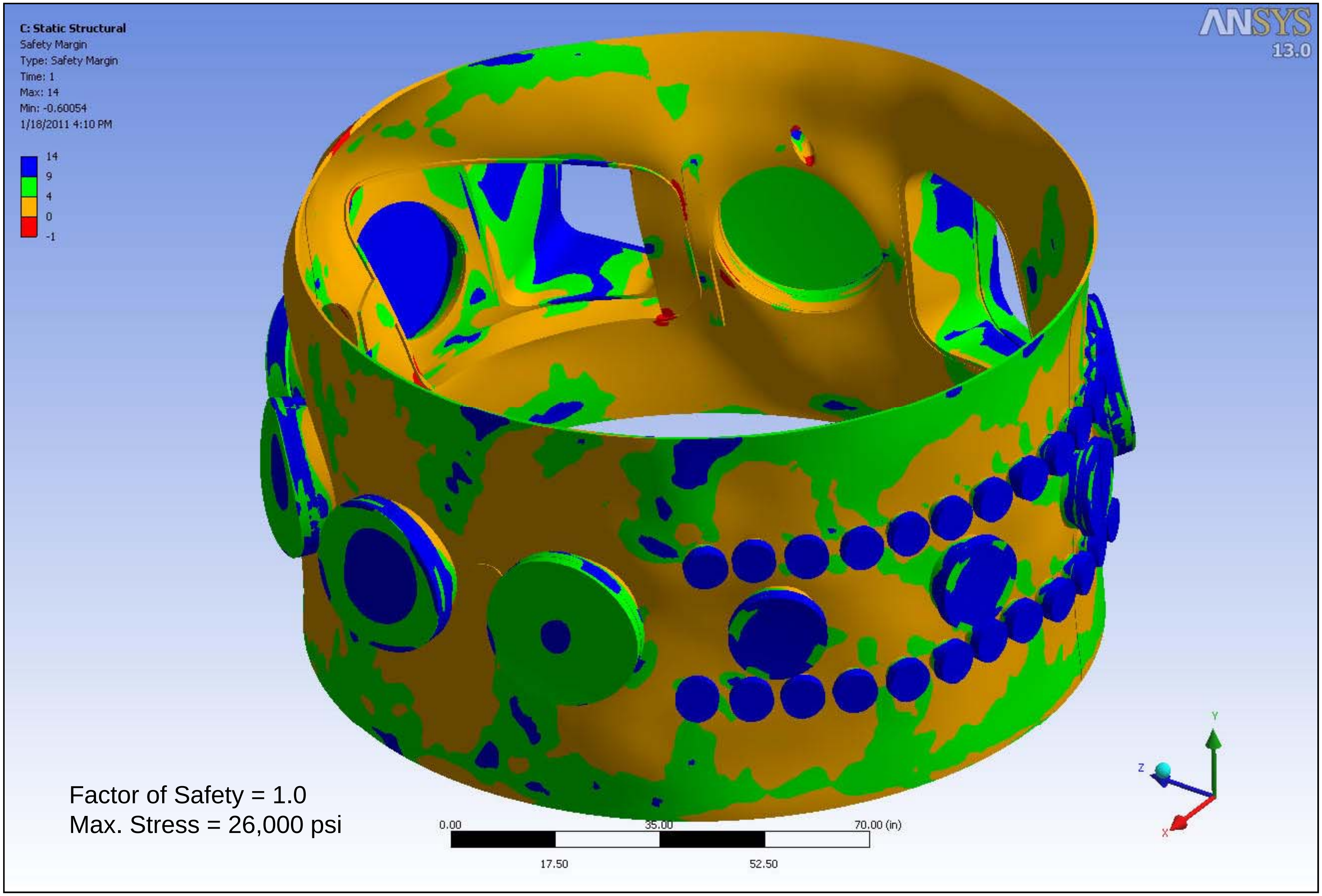
HARDNESS RB	81
GRAIN SIZE	5
YIELD STRENGTH (PSI)	45256
TENSILE STRENGTH (PSI)	91368
BEND	OK
INTERGRANULAR CORROSION	OK
ELONGATION % IN 2"	63.6
REDUCTION OF AREA %	72.5

Mill Certs for the 304 Vessel Show a 45 ksi Yield



Static Structural Results, Ports Excluded from EM Solution: Margin of Safety

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field



Static Structural Results, Ports Excluded from EM Solution: Margin of Safety (2)

1ms Centered-Plasma Disruption: Current Scenario #79 w/ Headroom Background Field

HALF-SINE PULSE

Consider the "half-sine" acceleration pulse (Fig. 31.20*A*) of amplitude $\ddot{u}_m$ and duration τ:

$$\ddot{u} = \ddot{u}_m \sin \frac{\pi t}{\tau} \qquad [0 \le t \le \tau]$$
$$\ddot{u} = 0 \qquad [t > \tau] \tag{31.34}$$

From Eq. (31.28), the effective duration is

$$\tau_r = \frac{2}{\pi}\,\tau \tag{31.35}$$

VERSED SINE PULSE

The versed sine pulse (Fig. 31.20*B*) is described by

$$\ddot{u} = \frac{\ddot{u}_m}{2}\left(1 - \cos \frac{2\pi t}{\tau}\right) = \ddot{u}_m \sin^2 \frac{\pi t}{\tau} \qquad [0 \le t \le \tau]$$
$$\ddot{u} = 0 \qquad [t > \tau] \tag{31.36}$$

The effective duration τ_r given by Eq. (31.28) is

$$\tau_r = (½)\tau \tag{31.37}$$

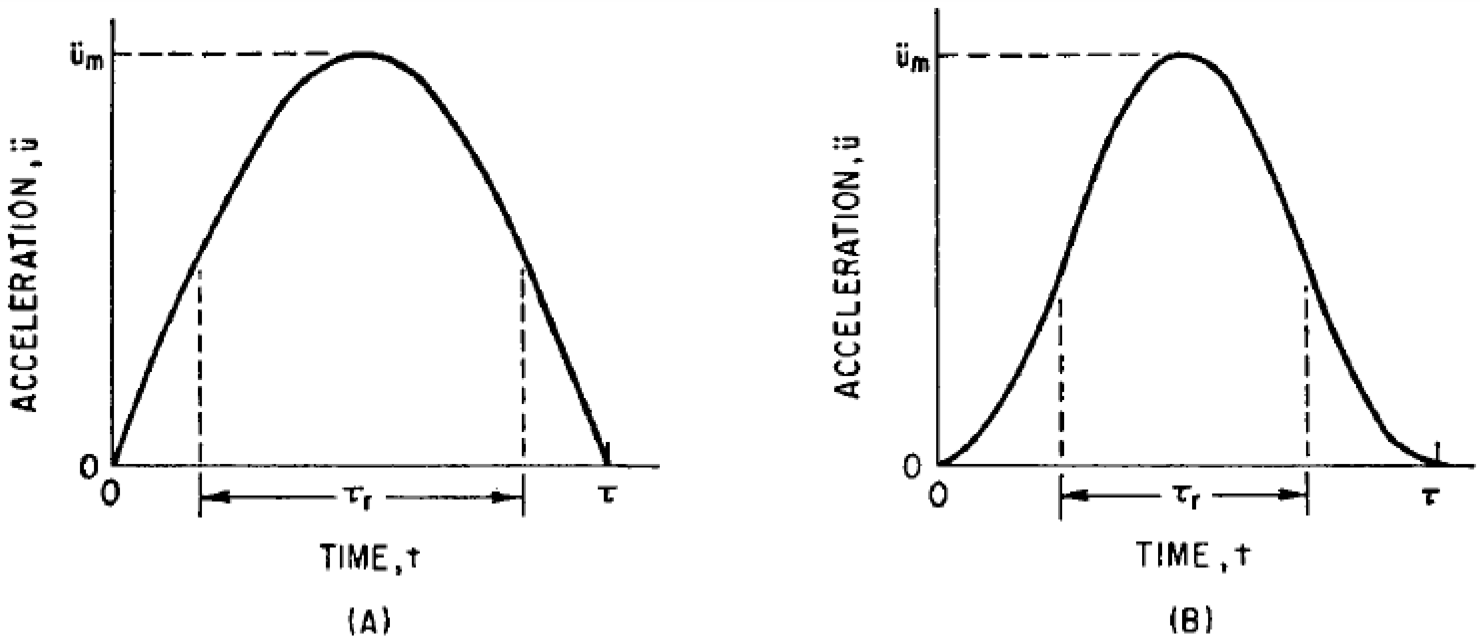


FIGURE 31.20 Half-sine acceleration pulse (*A*) and versed sine acceleration pulse (*B*).

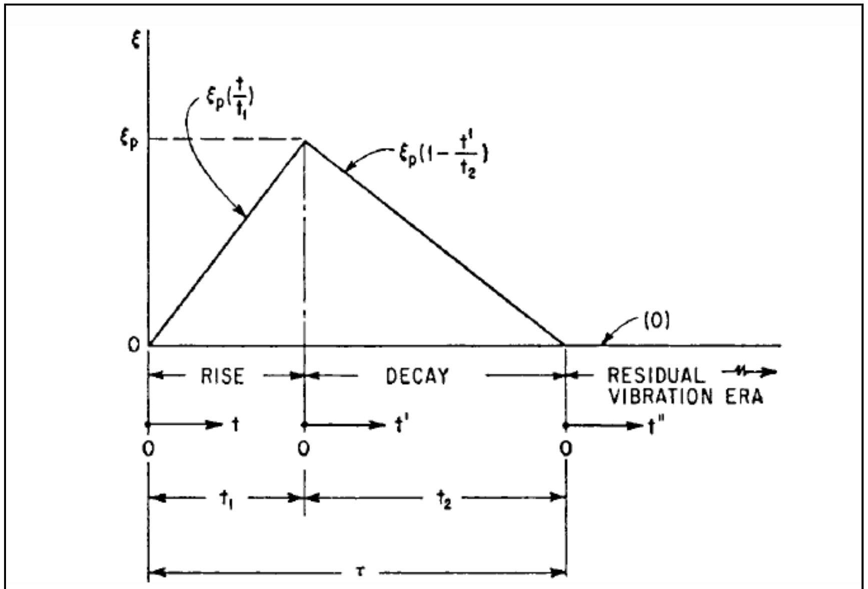


FIGURE 8.21 General triangular pulse.

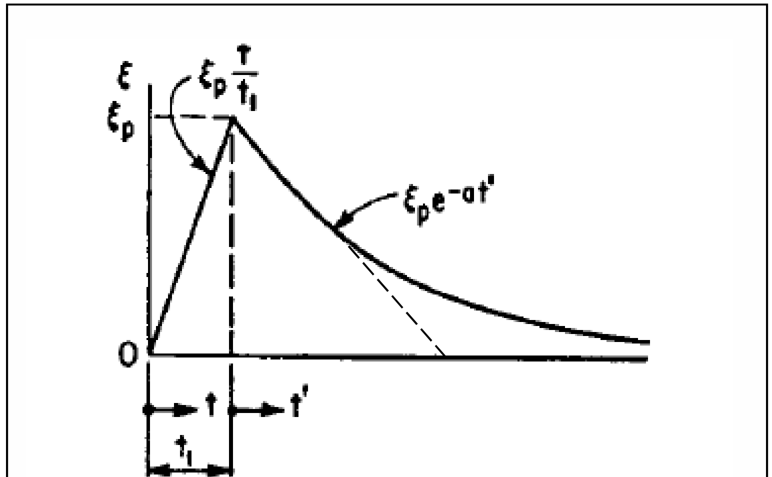
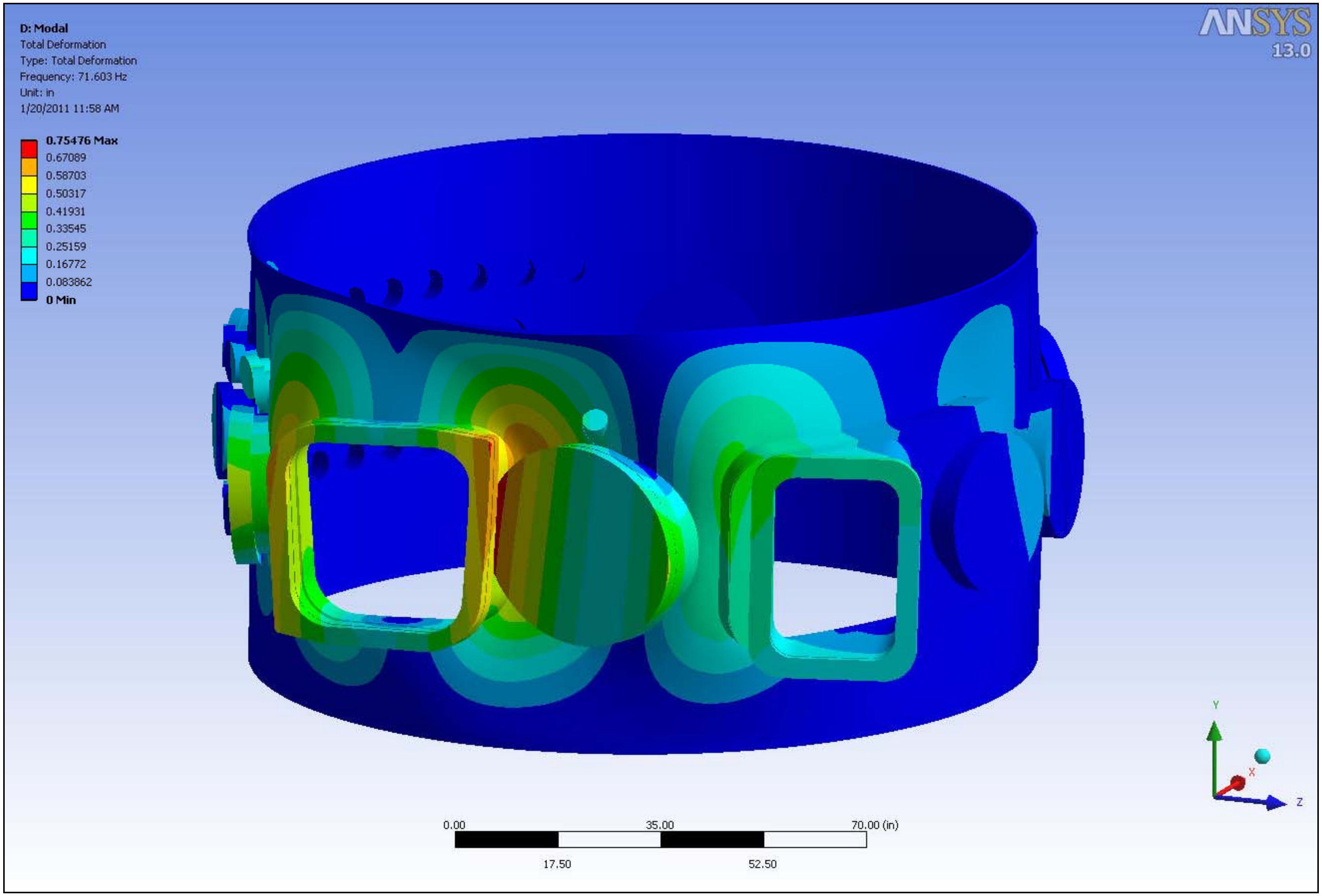


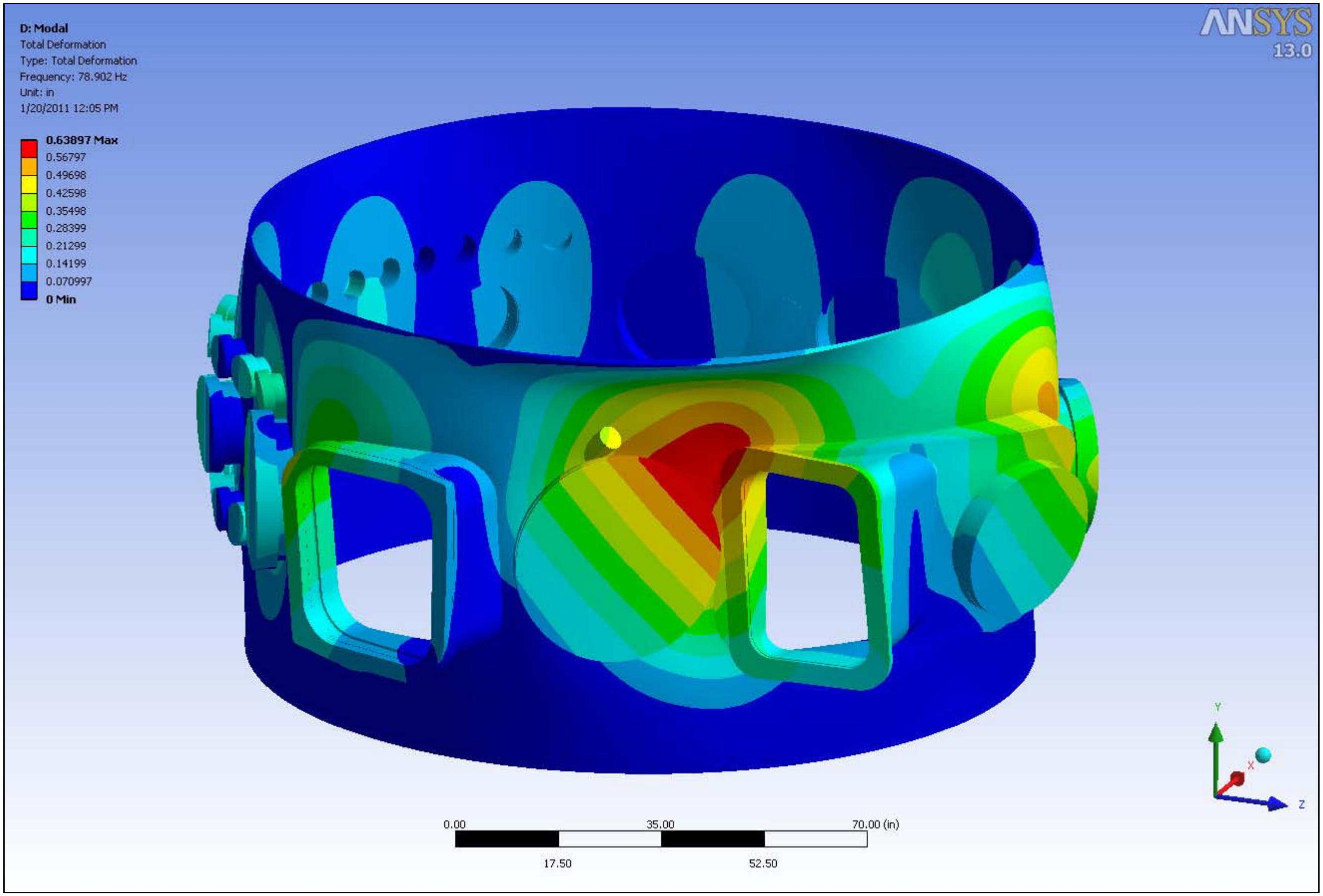
FIGURE 8.35 Pulse formed by a straight-line rise followed by an exponential decay asymptotic to the time axis.

t_r ~ 6 ms

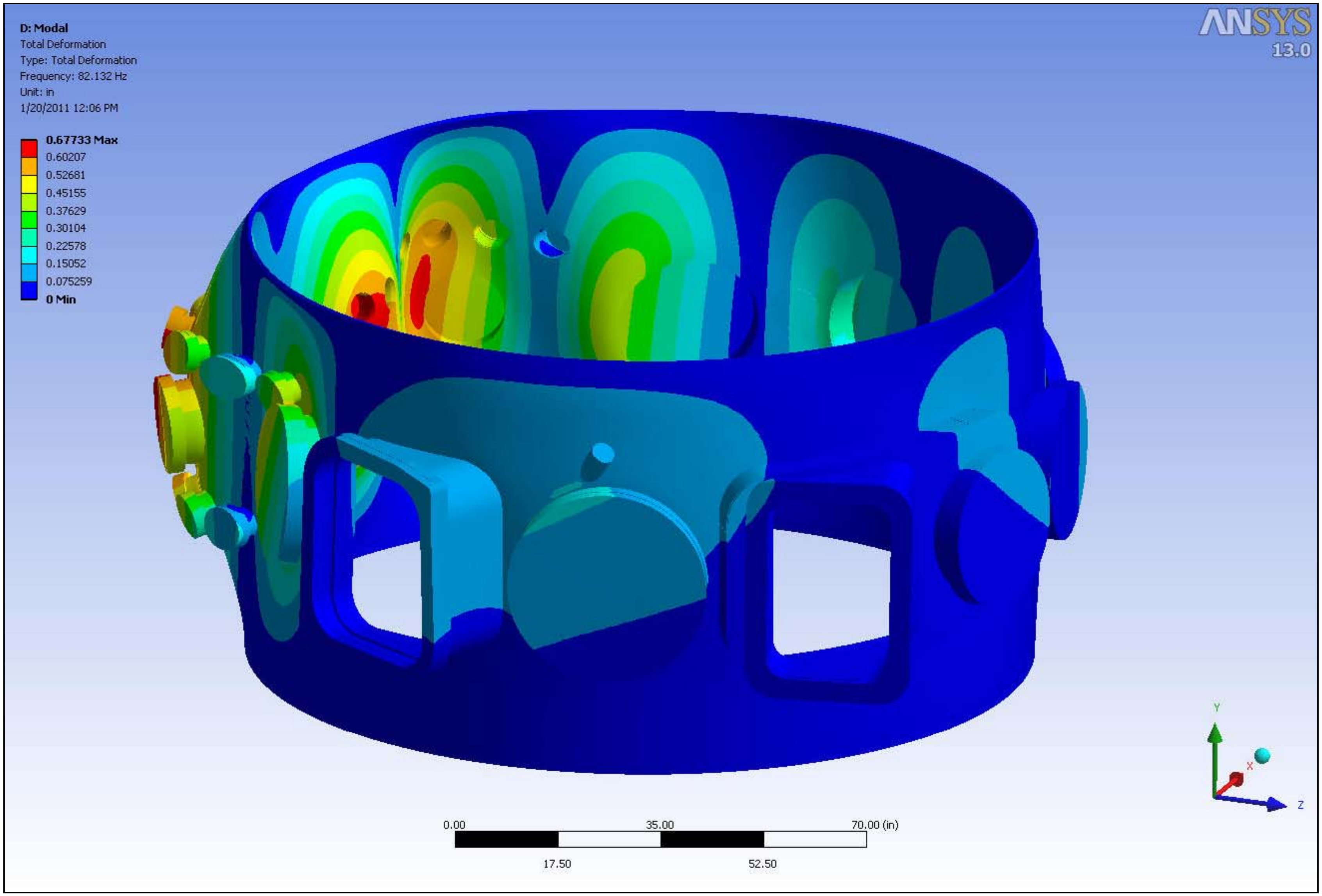
Centered Plasma Disruption: Effective Pulse Duration



Modal Analysis Results: VV w/ Ports and Static Model B.C.'s: Mode 1 = 72 Hz



Modal Analysis Results: VV w/ Ports and Static Model B.C.’s: Mode 2 = 79 Hz



Modal Analysis Results: VV w/ Ports and Static Model B.C.'s: Mode 3 = 82 Hz

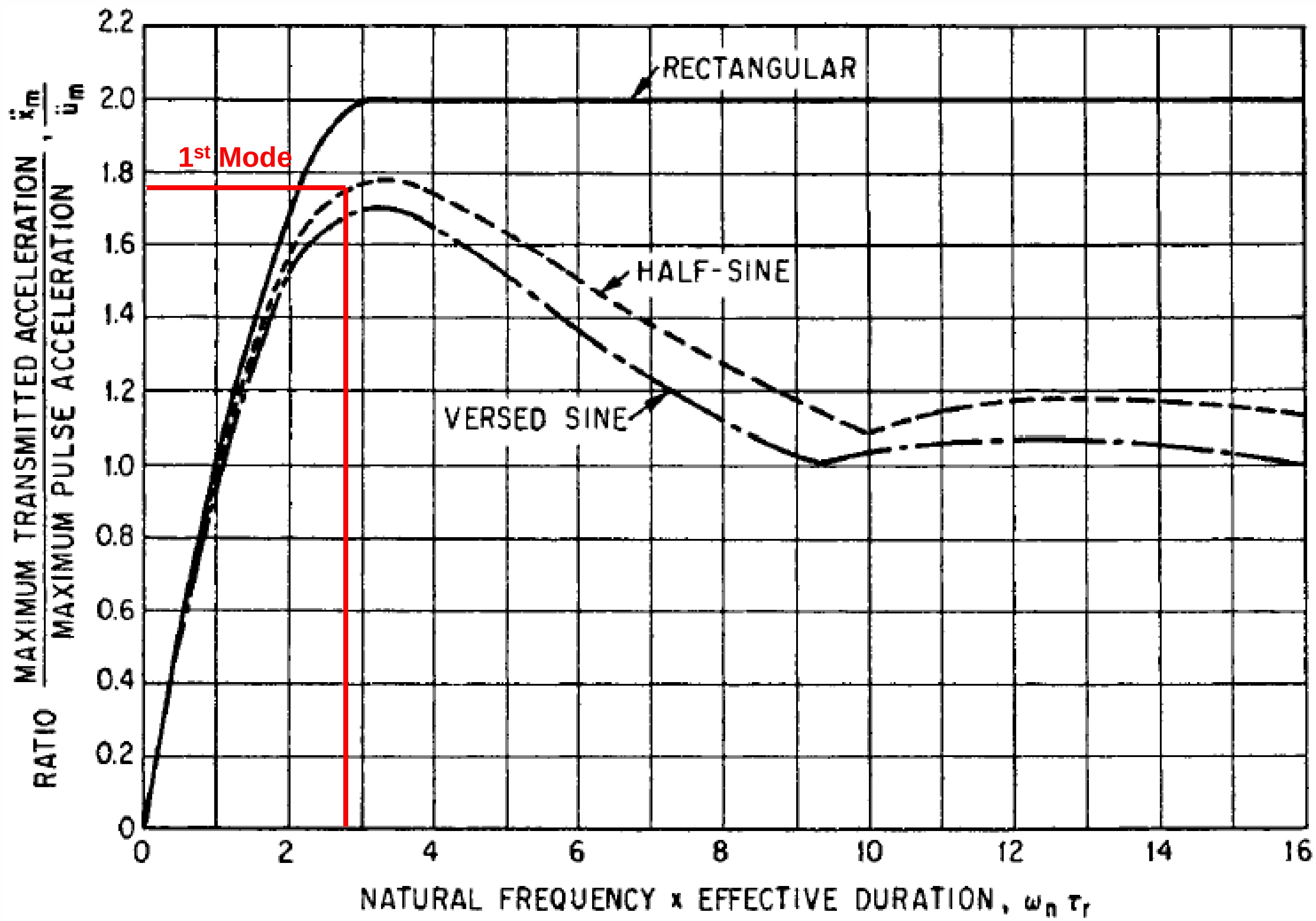
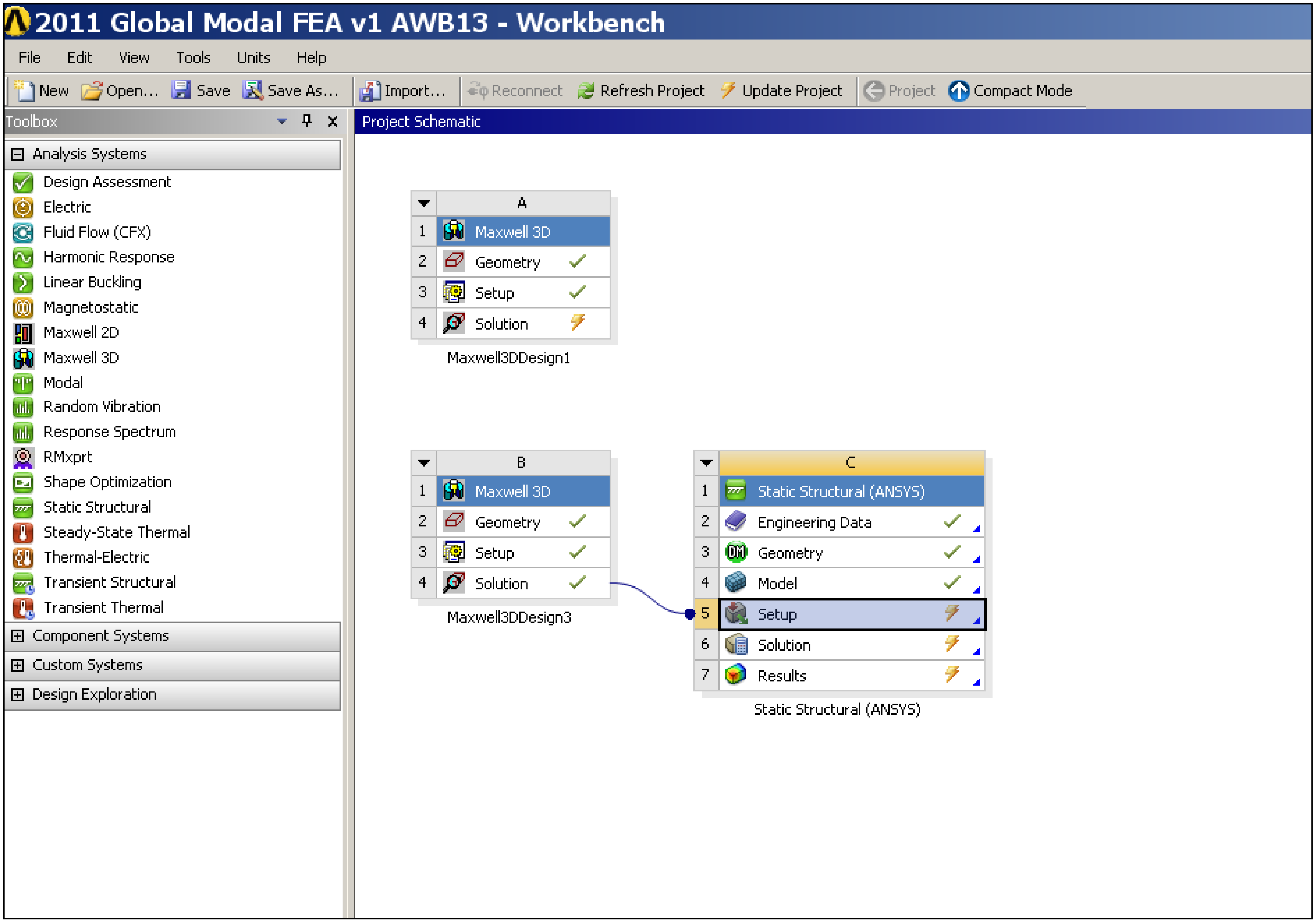
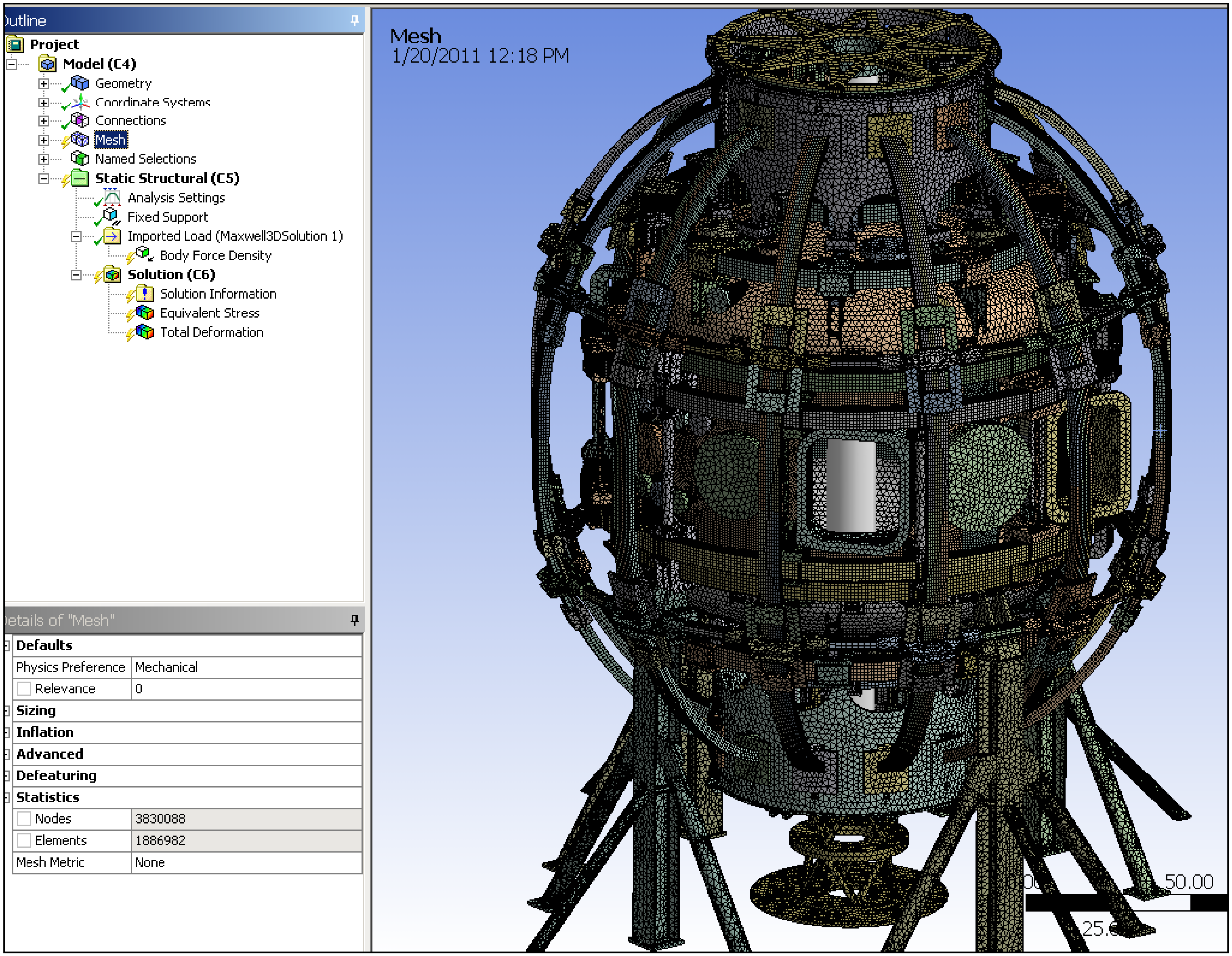
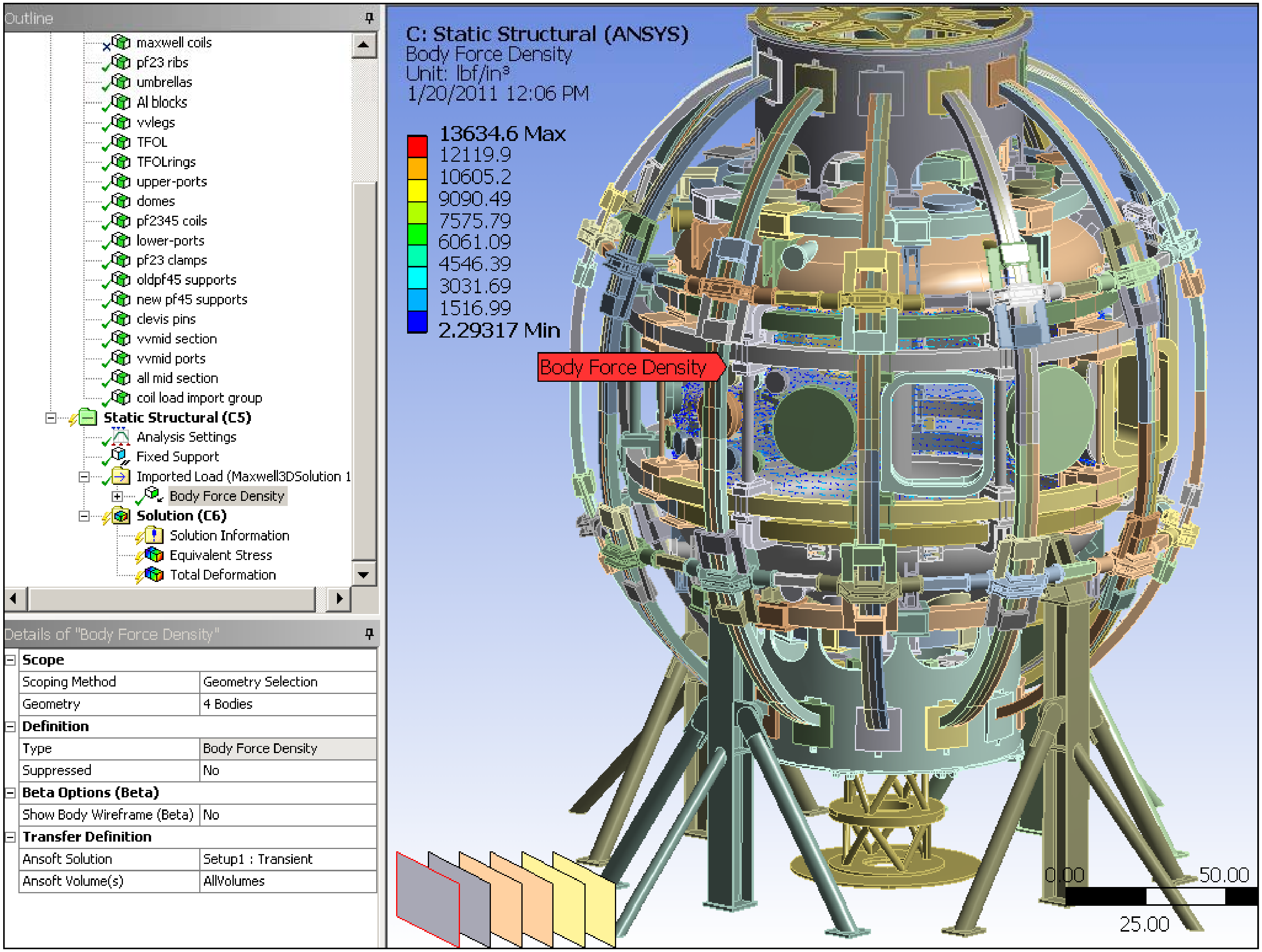


FIGURE 31.22 Shock transmissibility for the undamped linear system of Fig. 31.6 as a function of angular natural frequency ω_n and effective pulse duration τ_r.


2011 Global Modal FEA v1 AWB13 - Workbench
File
Edit
View
Tools
Units
Help
New
Open...
Save
Save As...
Import...
Reconnect
Refresh Project
Update Project
Project
Compact Mode
Toolbox
Project Schematic
Analysis Systems
Design Assessment
Electric
Fluid Flow (CFX)
Harmonic Response
Linear Buckling
Magnetostatic
Maxwell 2D
Maxwell 3D
Modal
Random Vibration
Response Spectrum
RMxprt
Shape Optimization
Static Structural
Steady-State Thermal
Thermal-Electric
Transient Structural
Transient Thermal
Component Systems
Custom Systems
Design Exploration
A
1 Maxwell 3D
2 Geometry
3 Setup
4 Solution
Maxwell3DDesign1
B
1 Maxwell 3D
2 Geometry
3 Setup
4 Solution
Maxwell3DDesign3
C
1 Static Structural (ANSYS)
2 Engineering Data
3 Geometry
4 Model
5 Setup
6 Solution
7 Results
Static Structural (ANSYS)



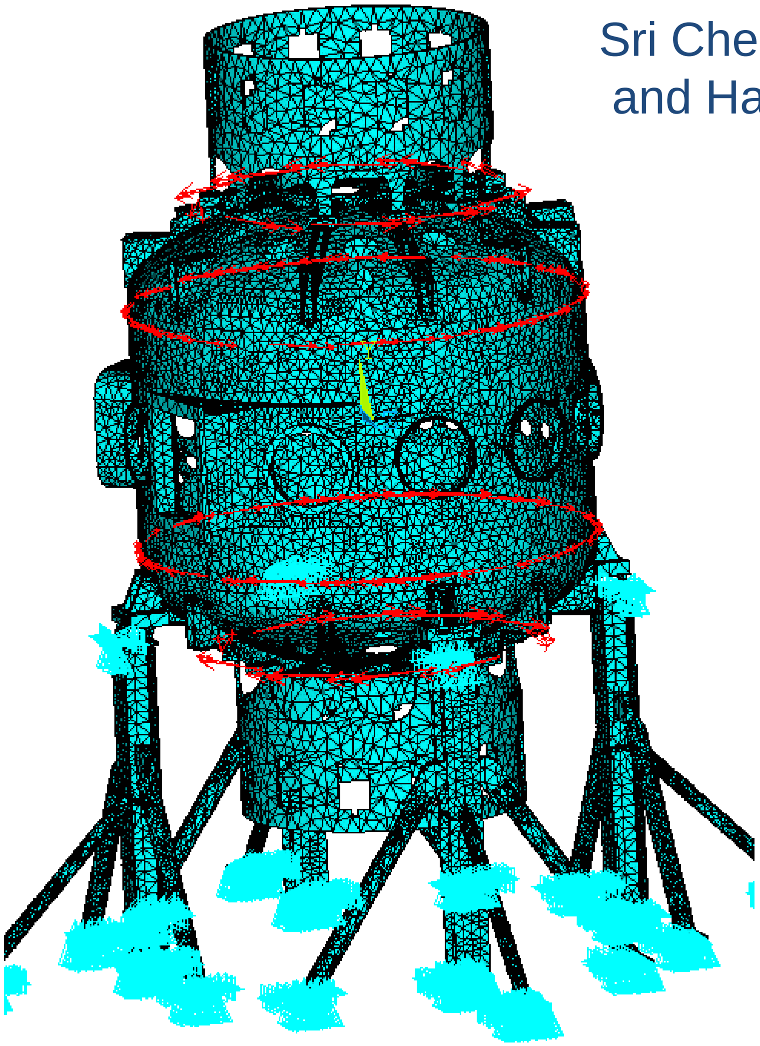
Outline
Project
Model (C4)
Geometry
Coordinate Systems
Connections
Mesh
Named Selections
Static Structural (C5)
Analysis Settings
Fixed Support
Imported Load (Maxwell3DSolution 1)
Body Force Density
Solution (C6)
Solution Information
Equivalent Stress
Total Deformation
Details of "Mesh"
Defaults
Physics Preference Mechanical
Relevance 0
Sizing
Inflation
Advanced
Defeaturing
Statistics
Nodes 3830088
Elements 1886982
Mesh Metric None
Mesh
1/20/2011 12:18 PM
50.00


Outline
maxwell coils
pf23 ribs
umbrellas
Al blocks
vvlegs
TFOL
TFOLrings
upper-ports
domes
pf2345 coils
lower-ports
pf23 clamps
oldpf45 supports
new pf45 supports
clevis pins
vvmid section
vvmid ports
all mid section
coil load import group
Static Structural (C5)
Analysis Settings
Fixed Support
Imported Load (Maxwell3DSolution 1
Body Force Density
Solution (C6)
Solution Information
Equivalent Stress
Total Deformation
Details of "Body Force Density"
Scope
Scoping Method
Geometry Selection
Geometry
4 Bodies
Definition
Type
Body Force Density
Suppressed
No
Beta Options (Beta)
Show Body Wireframe (Beta)
No
Transfer Definition
Ansoft Solution
Setup1 : Transient
Ansoft Volume(s)
AllVolumes
C: Static Structural (ANSYS)
Body Force Density
Unit: lbf/in³
1/20/2011 12:06 PM
13634.6 Max
12119.9
10605.2
9090.49
7575.79
6061.09
4546.39
3031.69
1516.99
2.29317 Min
Body Force Density
0.00
50.00
25.00

Appendix 1:
Previous NSTX Thomson Scattering and NB Ports L, J, and K Stress Analysis

Sri's Port Qualification Stress Analysis: OOP Loads Only, Worst-Case Power

Radius Rod Design



Sri Checked Vessel Stresses with Correct NB Port, and Han's Worst OOP Loads – Vessel Stress is OK.

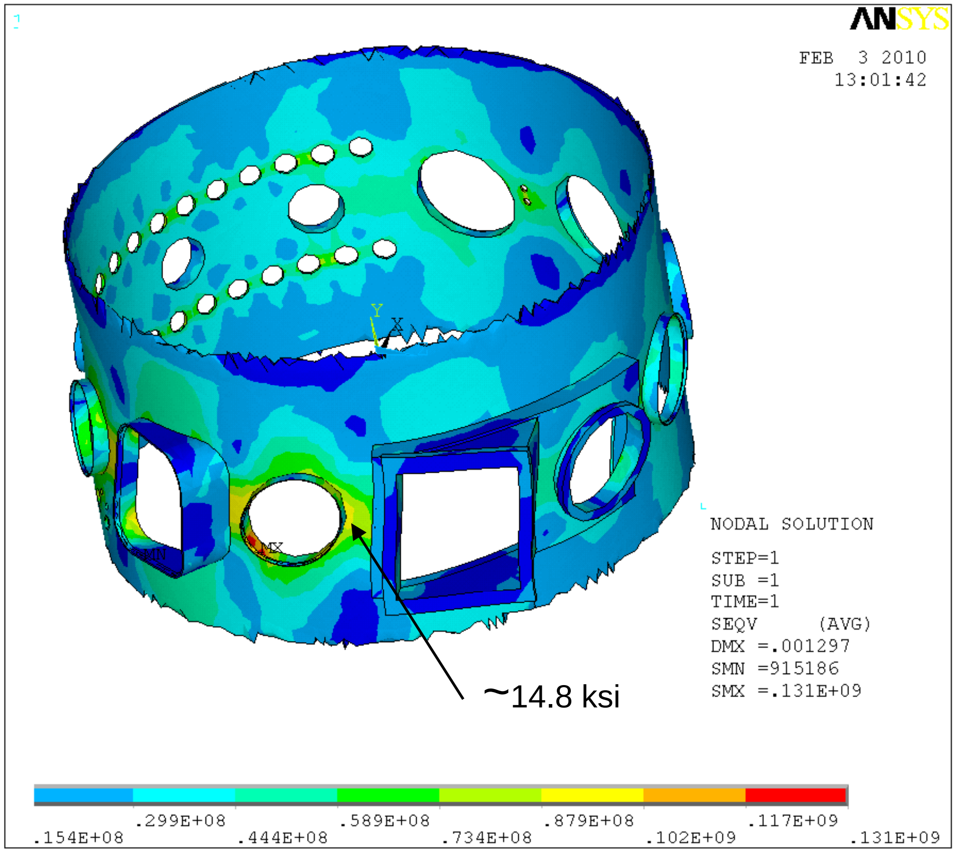
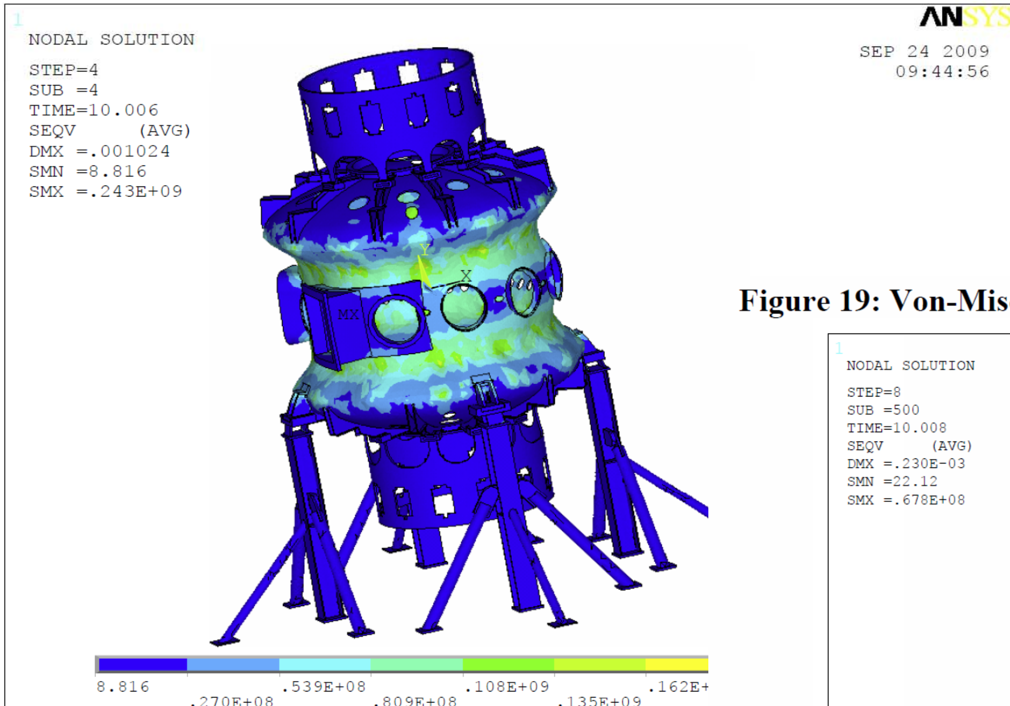
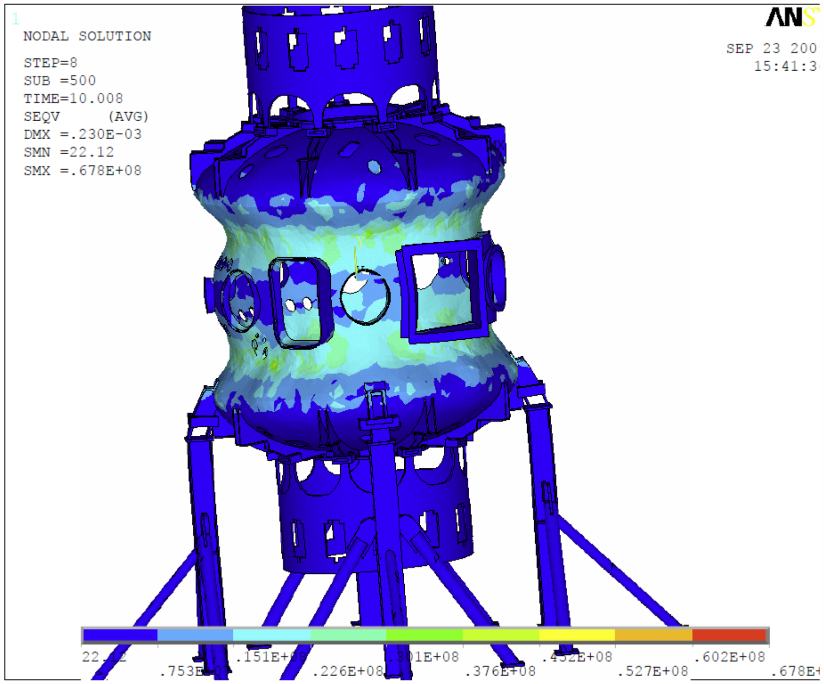


Figure 17: Von-Mises Stress on Vacuum Vessel from Static Analysis



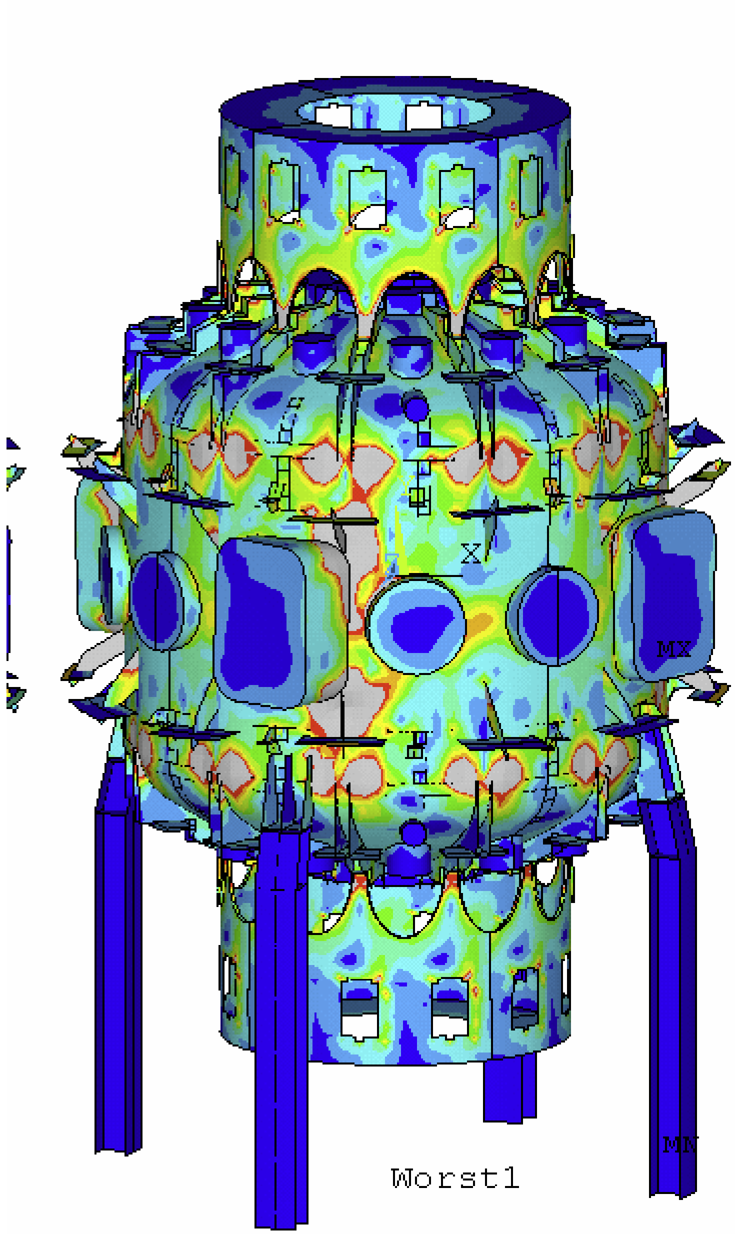
Maximum Stress= 165 Mpa
(24 ksi)

Figure 19: Von-Mises Stress on Vacuum Vessel from Dynamic Analysis



Maximum Stress= 45 Mpa
(6.5 ksi)

Sri's Disruption Analysis Results

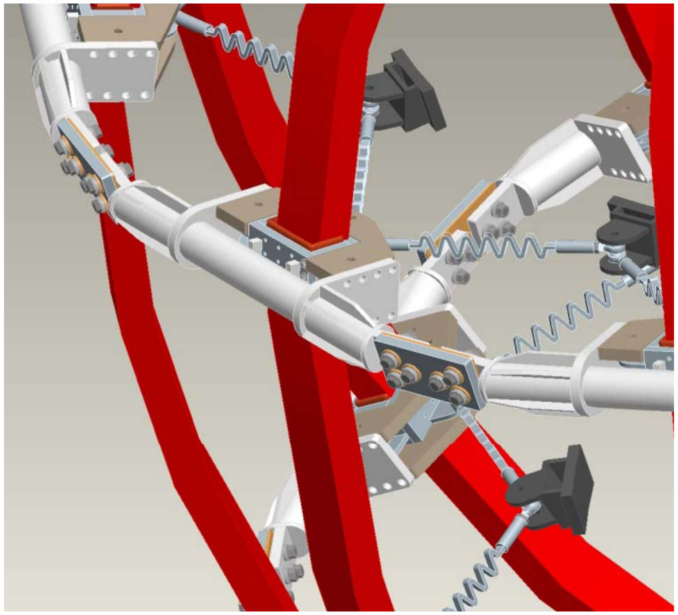


Max. Pressure
Stress ~ 6 ksi

Peter’s Pressure (Global Model) Analysis Results

Han’s Latest TF Outer Leg OOP Lorentz Force Analysis: Scenario 79

TF out leg truss
Option 1: tube ring of 4” diameter and 0.25” thickness with springs (i.e. tie bars).



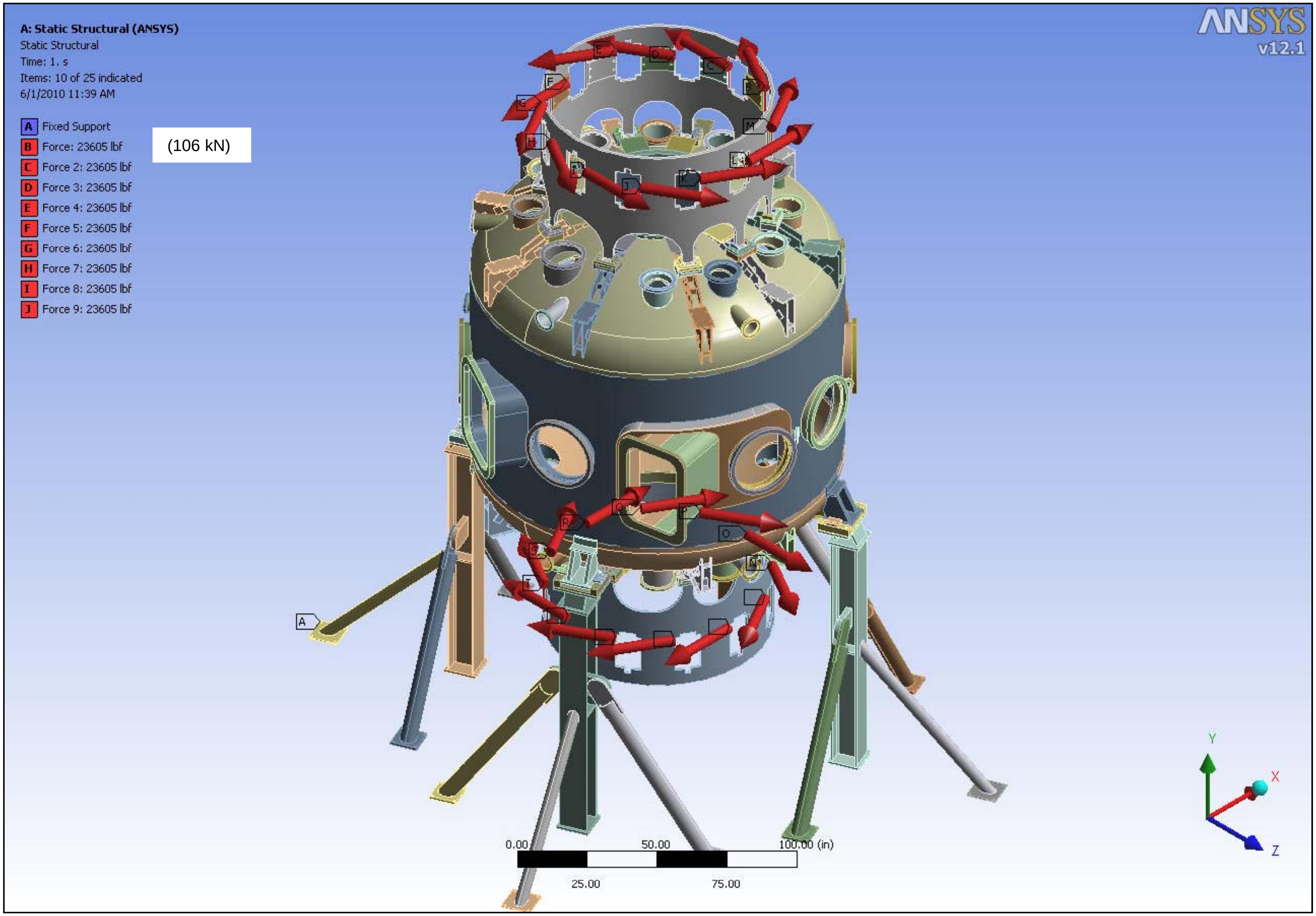
TF outer leg OOP Lorenz force (about 1/3 of power limit condition)

Scenario 79: 106KN *(23,607 lbf) x 3.4 ft radius x 12 coils = 968k ft-lbf (Note: Total OOP torque per CN, ANSYS EMAG, Maxwell = 2.8 M ft-lbf)*

Ring (ss): 4” tube with 1/4” thickness

Cylindrical coordinate: model Z is machine vertical axis, model X is radial and Y is theta direction.

spring stiffness (klbs/in)	modulus (Pa)	tie bar load (KN)	clevis shear load (KN)	Utheta (mm)	coil stress (Mpa)	Cu bond shear stress Sxy (Mpa)	Cu bond shear stress Syz (Mpa)	Max Cu bond shear stress (Mpa)
22.33	9.E+08	23	28	6.52	153	7.63	12.3	12.6
17.37	7.E+08	20	24	7.26	161	7.67	13.1	13.3
12.41	5.E+08	15	19	7.84	170	7.86	14.1	14.1



Port ‘L’ Baseline Design, 24” Dia. x 1/2” Wall Tube: Solid Model

Current Scenario 79

Appendix 2:
Transient Response of Multiple-Degree of Freedom, Linear, Undamped Systems

(Shock and Vibration Handbook, 4th Edition, C. M. Harris, 1995)

MULTIPLE DEGREE-OF-FREEDOM, LINEAR, UNDAMPED SYSTEMS

Some of the transient response analyses, presented for the single degree-of-freedom system, are in complete enough form that they can be employed in determining the responses of linear, undamped, multiple degree-of-freedom systems. This can be done by the use of *normal* (*principal*) *coordinates.* A system of normal coordinates is a system of generalized coordinates chosen in such a way that vibration in each normal mode involves only one coordinate, a normal coordinate. The differential equations of motion, when written in normal coordinates, are all independent of each other. Each differential equation is related to a particular normal mode and involves only one coordinate. The differential equations are of the same general form as the differential equation of motion for the single degree-of-freedom system. The response of the system in terms of the physical coordinates, for example, displacement or stress at various locations in the system, is determined by superposition of the normal coordinate responses.

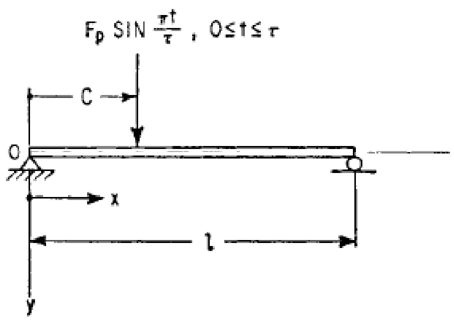


FIGURE 8.46 Simply supported beam loaded by a concentrated force sine pulse of half-cycle duration.

Example 8.12: Sine Force Pulse Acting on a Simple Beam. Consider the flexural vibration of a prismatic bar with simply supported ends, Fig. 8.46. A sine-pulse concentrated force F_p sin $(\pi t/\tau)$ is applied to the beam at a distance c from the left end (origin of coordinates). Assume that the beam is initially at rest. The displacement response of the beam, during the time of action of the pulse, is given by the following series:

$$y = \frac{2F_p l^3}{\pi^4 EI} \sum_{i=1}^{i=\infty} \frac{1}{i^4} \sin \frac{i\pi c}{l} \sin \frac{i\pi x}{l} \left[\frac{1}{1 - T_i^2/4\tau^2} \left(\sin \frac{\pi t}{\tau} - \frac{T_i}{2\tau} \sin \omega_i t \right) \right] \qquad [0 \le t \le \tau] \tag{8.62a}$$

where $$i = 1, 2, 3, \ldots; \; T_i = \frac{2\pi}{\omega_i} = \frac{2l^2}{i^2\pi} \sqrt{\frac{A\gamma}{EIg}} = \frac{T_1}{i^2}, \text{ sec}$$

A comparison of Eqs. (8.62a) and (8.32a) shows that the time function [sin $(\pi t/\tau)$ – $(T_i/2\tau)$ sin $\omega_i t$] for the ith term in the beam-response series is of exactly the same form as the time function [sin $(\pi t/\tau)$ – $(T/2\tau)$ sin $\omega_n t$] in the response of the single degree-of-freedom system. Furthermore, the magnification factors $1/(1 - T_i^2/4\tau^2)$ and $1/(1 - T^2/4\tau^2)$ in the two equations have identical forms.

Following the end of the pulse, beginning at $t = \tau$, the vibration of the beam is expressed by

$$y = \frac{2F_p l^3}{\pi^4 EI} \sum_{i=1}^{i=\infty} \frac{1}{i^4} \sin \frac{i\pi c}{l} \sin \frac{i\pi x}{l} \left[\frac{(T_i/\tau)\cos(\pi\tau/T_i)}{(T_i^2/4\tau^2) - 1} \sin \omega_i \left(t - \frac{\tau}{2} \right) \right] \qquad [\tau \leq t] \tag{8.62b}$$

A comparison of Eqs. (8.62*b*) and (8.32*b*) leads to the same conclusion as found above for the time era $0 \leq t \leq \tau$.

Excitation and Displacement at Mid-span. As a specific case, consider the displacement at mid-span when the excitation is applied at mid-span ($c = x = l/2$). The even-numbered terms of the series now are all zero and the series take the following forms:

$$y_{l/2} = \frac{2F_p l^3}{\pi^4 EI} \sum_{i=1,3,5,\ldots}^{\infty} \frac{1}{i^4} \left[\frac{1}{1 - T_i^2/4\tau^2} \left(\sin \frac{\pi t}{\tau} - \frac{T_i}{2\tau} \sin \omega_i t \right) \right] \qquad [0 \leq t \leq \tau] \tag{8.63a}$$

$$y_{l/2} = \frac{2F_p l^3}{\pi^4 EI} \sum_{i=1,3,5,\ldots}^{\infty} \frac{1}{i^4} \left[\frac{(T_i/\tau)\cos(\pi\tau/T_i)}{(T_i^2/4\tau^2) - 1} \sin \omega_i \left(t - \frac{\tau}{2} \right) \right] \qquad [\tau \leq t] \tag{8.63b}$$

Assume, for example, that the pulse period τ equals two-tenths of the fundamental natural period of the beam ($\tau/T_1 = 0.2$). It is found from Fig. 8.16*B*, by using an abscissa value of 0.2, that the maximax response in the *fundamental* mode ($i = 1$) occurs in the residual vibration era ($\tau \leq t$). The value of the corresponding ordinate is 0.75. Consequently, the maximax response for $i = 1$ is 0.75 ($2F_p l^3/\pi^4 EI$).

In order to determine the maximax for the *third* mode ($i = 3$), an abscissa value of $\tau/T_i = i^2\tau/T_1 = 3^2 \times 0.2 = 1.8$, is used. It is found that the maximax is greater than the residual amplitude and consequently that it occurs during the time era $0 \leq t \leq \tau$. The value of the corresponding ordinate is 1.36; however, this must be multiplied by $1/3^4$, as indicated by the series. The maximax for $i = 3$ is thus 0.017 ($2F_p l^3/\pi^4 EI$).

The maximax for $i = 5$ also occurs in the time era $0 \leq t \leq \tau$ and the ordinate may be estimated to be about 1.1. Multiplying by $1/5^4$, it is found that the maximax for $i = 5$ is approximately 0.002 ($2F_p l^3/\pi^4 EI$), a negligible quantity when compared with the maximax value for $i = 1$.

To find the maximax total response to a reasonable approximation, it is necessary to sum on a time basis several terms of the series. In the particular example above, the maximax total response occurs in the residual vibration era and a reasonably accurate value can be obtained by considering only the first term ($i = 1$) in the series, Eq. (8.63*b*).