

Preliminary Moderator Deflection and Tolerance Analysis

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MRA Lead Engineer

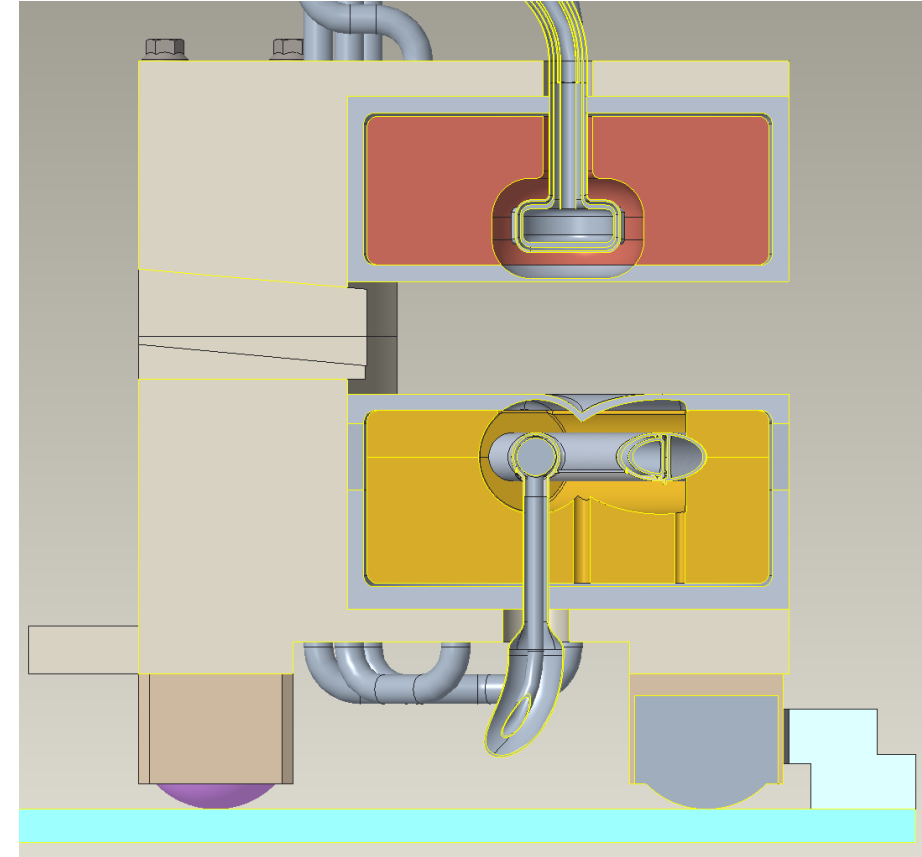
January 10, 2024

Purpose

- Combine expected fabrication tolerances, installation tolerances, and deflections from installation to operation for the moderators to assess worst case moderator alignment
- The worst case alignment will be used in a neutronics analysis in order to determine the resulting performance from the worst case alignment

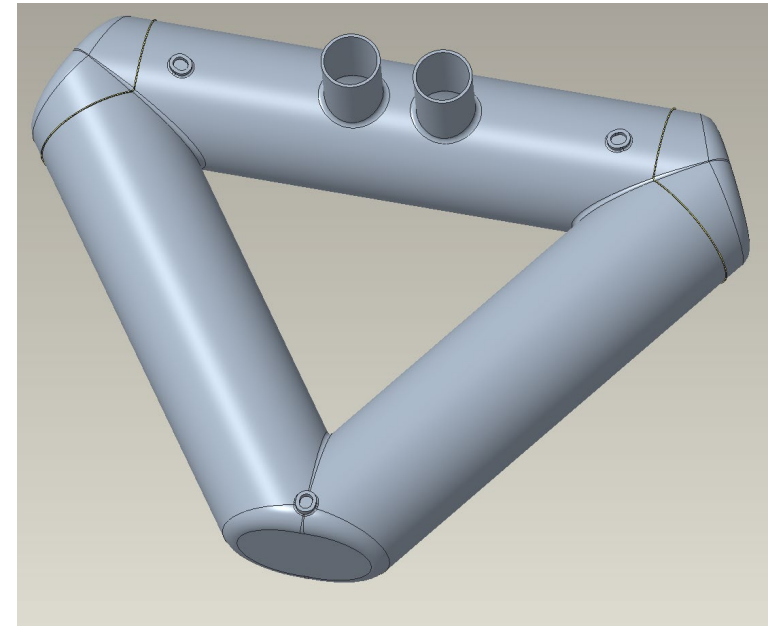
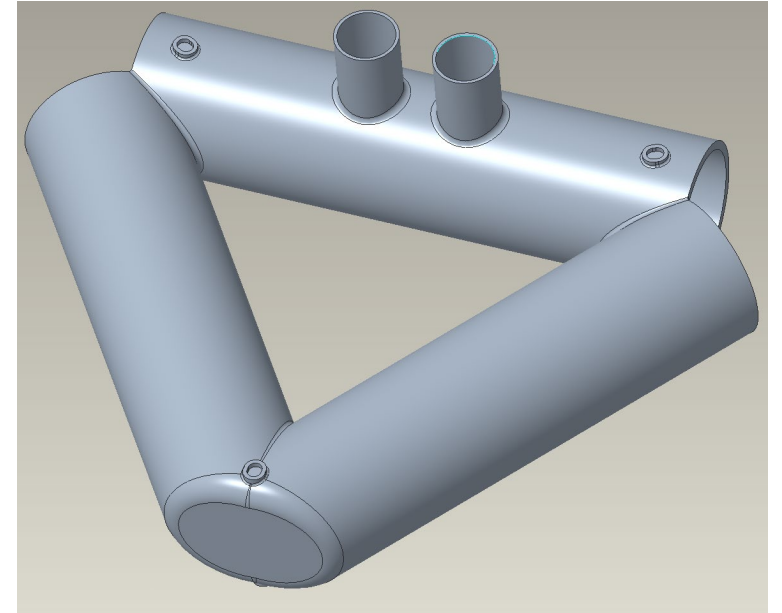
Overall Moderator Alignment

- Tolerance allowance:
 - Moderator Profile Tolerance - $\pm .125$ mm
 - Moderator Assembly Tolerance - $\pm .5$ mm
 - MRA Installation Repeatability - $\pm .25$ mm
 - S&A Inspection Accuracy - $\pm .125$ mm
- We will conservatively assume that these all stack in opposite directions at the moderator so that this misalignment is applied as a pure moderator rotation



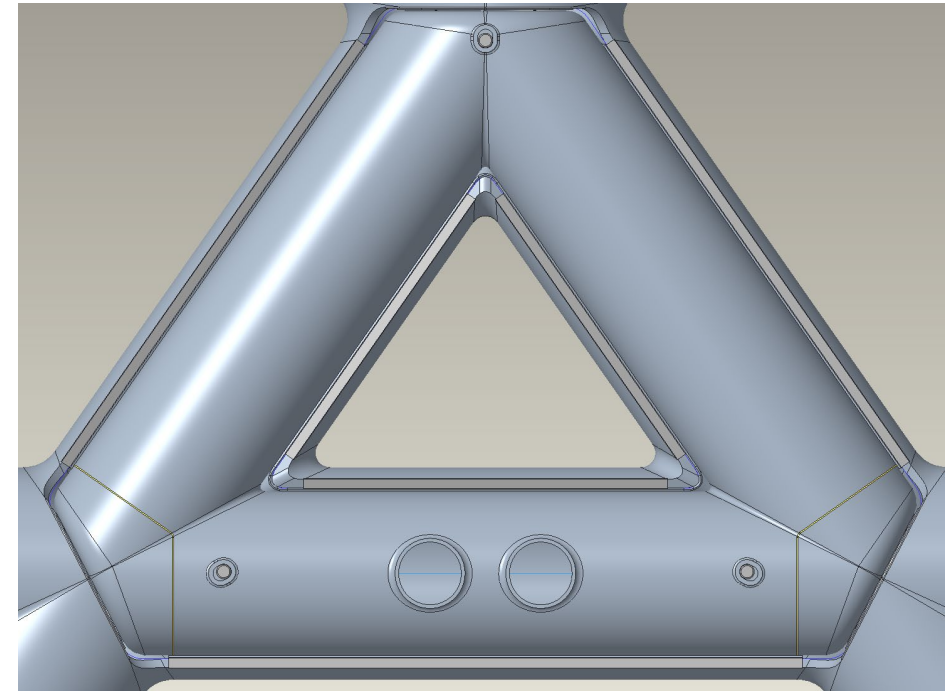
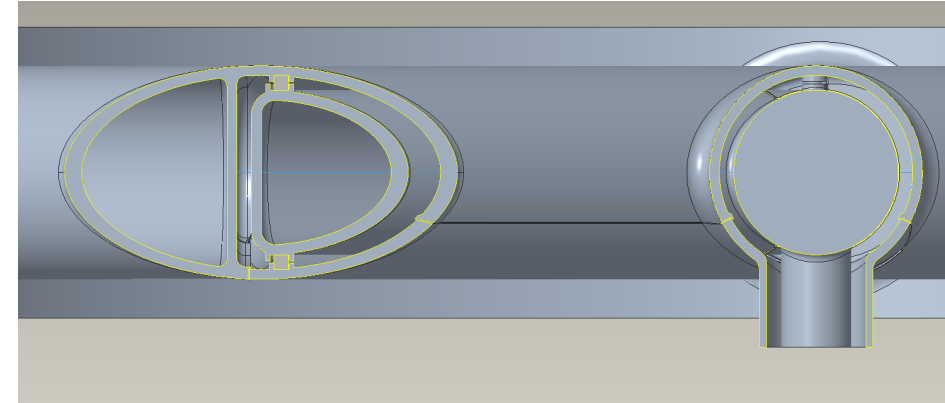
Moderator Profile Tolerances

- Hydrogen vessel bodies machined from single aluminum forging with all alignment features included
 - Expected profile tolerance of 0.1 mm
- Welding of caps will produce some local distortion around welds
 - Expected profile tolerance of 0.125 mm after welding
- Prototypes of both tube and cylinder moderator have confirmed expected tolerances



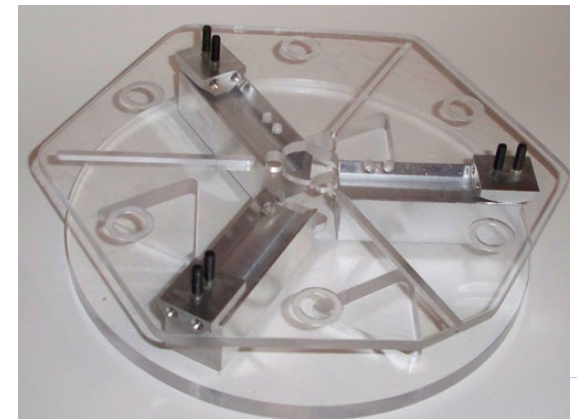
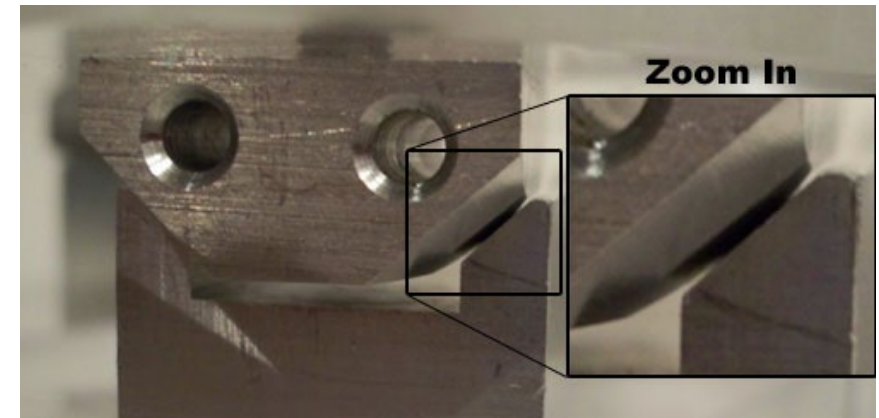
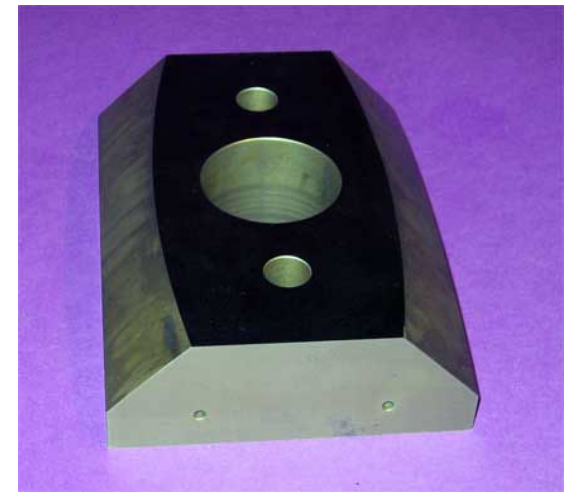
Moderator Assembly Tolerances

- Moderator is located by 6 titanium pins in bosses on the top and bottom of the hydrogen and vacuum vessel
 - Bosses are slotted to allow for shrinkage of the hydrogen vessel (20K operation) relative to the vacuum vessel (300K)
 - Some play is designed to not overconstrain differential expansion
 - Expect +/- .375mm for hydrogen vessel relative to vacuum vessel
- MRA locating features are installed relative to the vacuum vessel faces
 - Expect +/- .125mm for locating features
- Total Assembly tolerance of +/- .5 mm



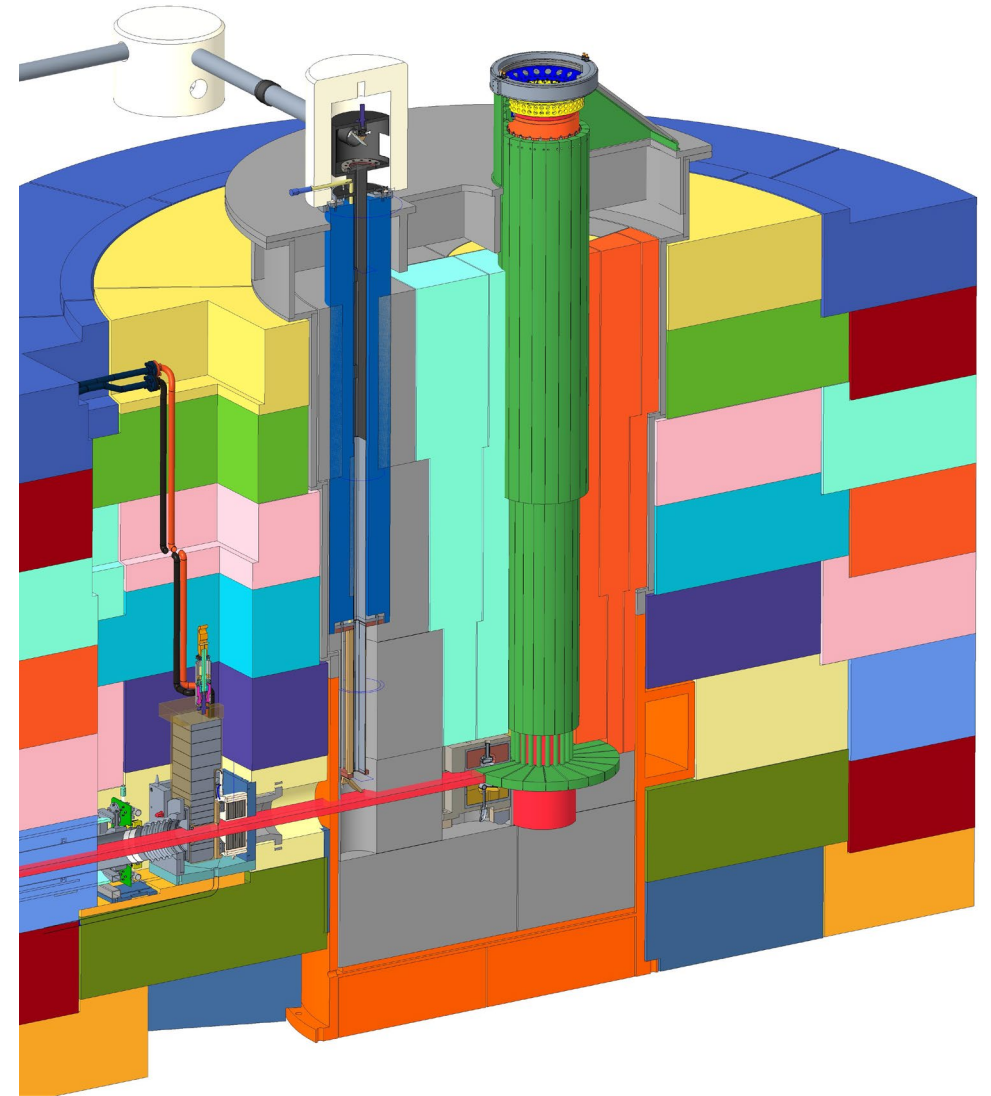
MRA Installation Repeatability

- New alignment scheme uses kinematic mount based on canoe spheres in vees at 120° for carrying heavy load
 - Based on vertical installation allowed by segmented target
 - Previous horizontal installation used alternative alignment scheme
- Initial literature search suggests repeatability of +/- .125 mm for canoe spheres in vees
 - Will maintain previous allowance of +/- .25 mm until design is matured further



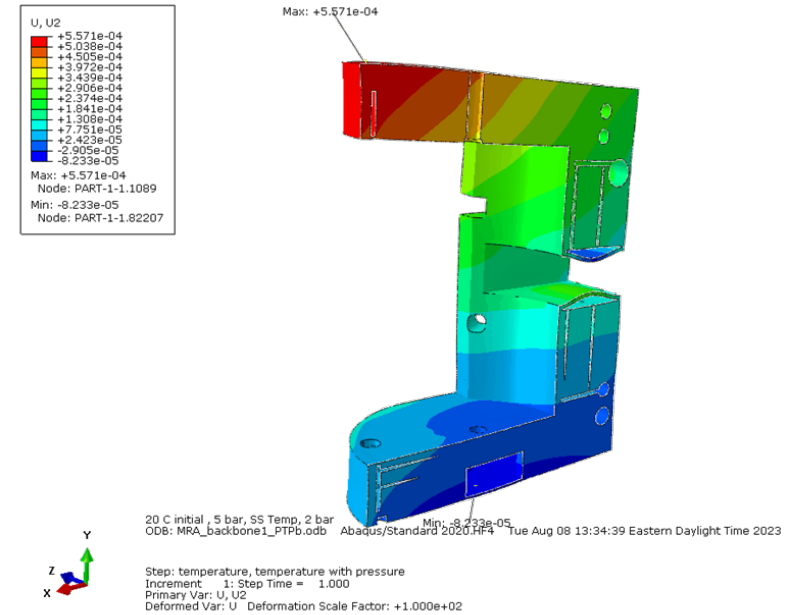
Survey and Alignment Inspection Accuracy

- After as much shielding is stacked as possible, survey and alignment will survey the location of the 3 vee interfaces relative to the target center coordinate system
 - Expected uncertainty of survey of $\pm .125$ mm
- Final machining of locating features on the MRA will await this survey so that moderators are placed as close to ideal locations as possible



Backbone and Shield Block Deflections

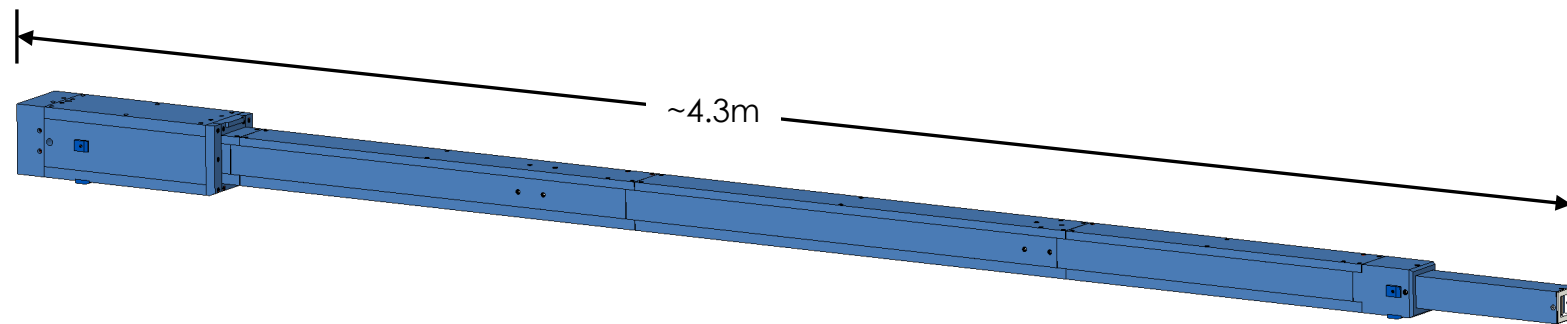
- Thermal distortion is largest contributor to guide landing to reflector differential movement
 - Pressure is only important for Shield Block 1
- Only vertical distortion is considered as other relative motions are less than 0.1 mm
- Differential movement for the upper reflector (0.46 mm) is slightly more than for the lower reflector (0.31 mm), but we will use 0.5 mm for both



Deflections	Upper	Lower	Notes
CV Guide Insert Landings	0.171	0.171	Thermal only - other deflections less than 1e-3 mm
Guide Entrance Total	0.171	0.171	
CV Shield Block Landing	0.107	0.107	Thermal only - other deflections less than 1e-3 mm
CV Shield Block 1	0.252	0.252	
MRA Mount Total	0.359	0.359	At MRA Mount Points
Backbone	0.395	0.009	Deflection of Reflector Mounting Interface
Reflector	-0.122	0.116	Deflection from Mounting to Moderator
MRA Total	0.273	0.125	
Moderator Relative to Guide	0.460	0.312	

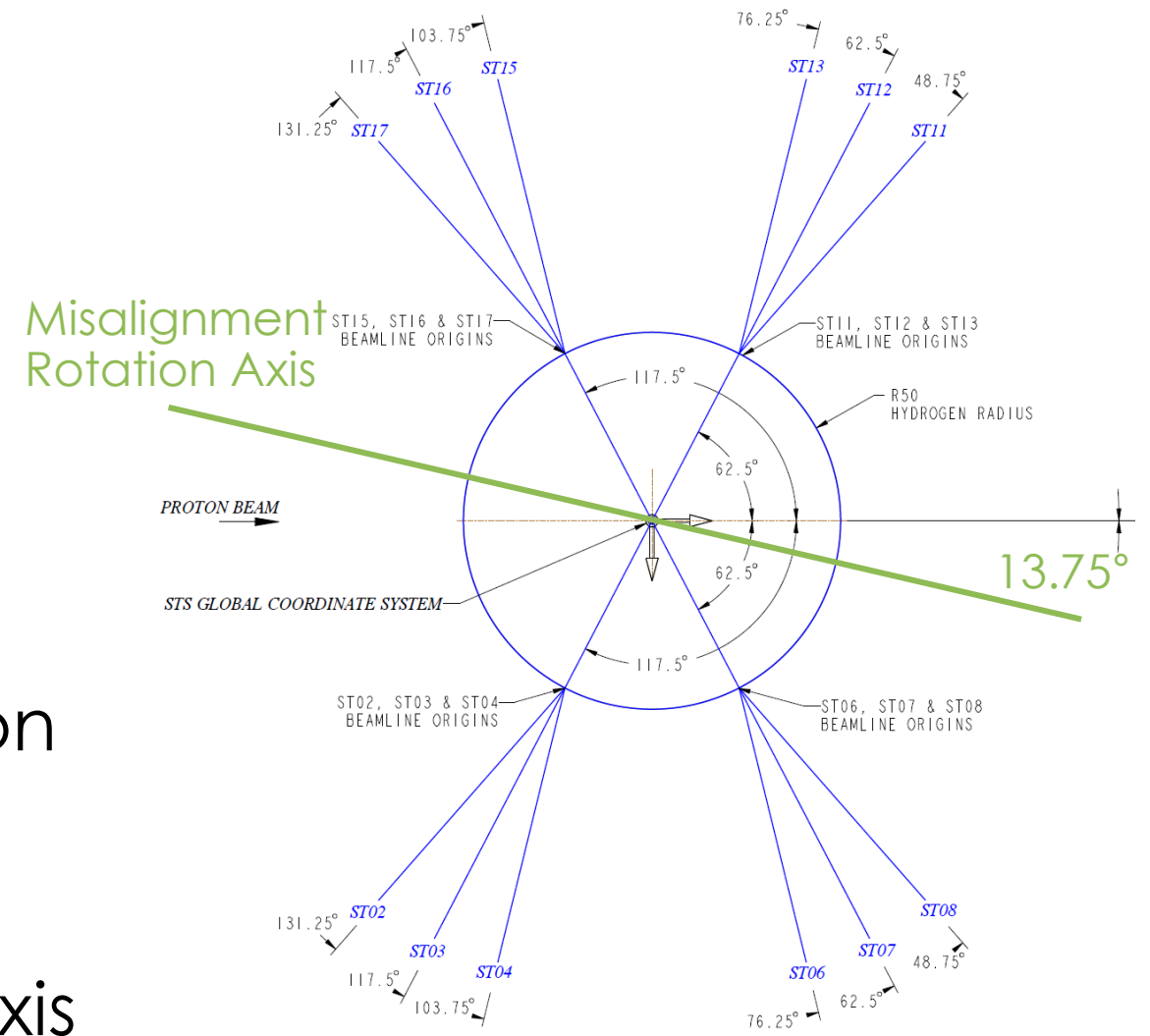
Guide Entrance Alignment

- Instrument systems claims a worst case guide entrance alignment of ± 1 mm from nominal location
- Due to length of optic, rotation resulting from misalignment is assumed to be 0.
- We will assume a vertical misalignment of 1 mm to create a worst case misalignment with the other relative movements



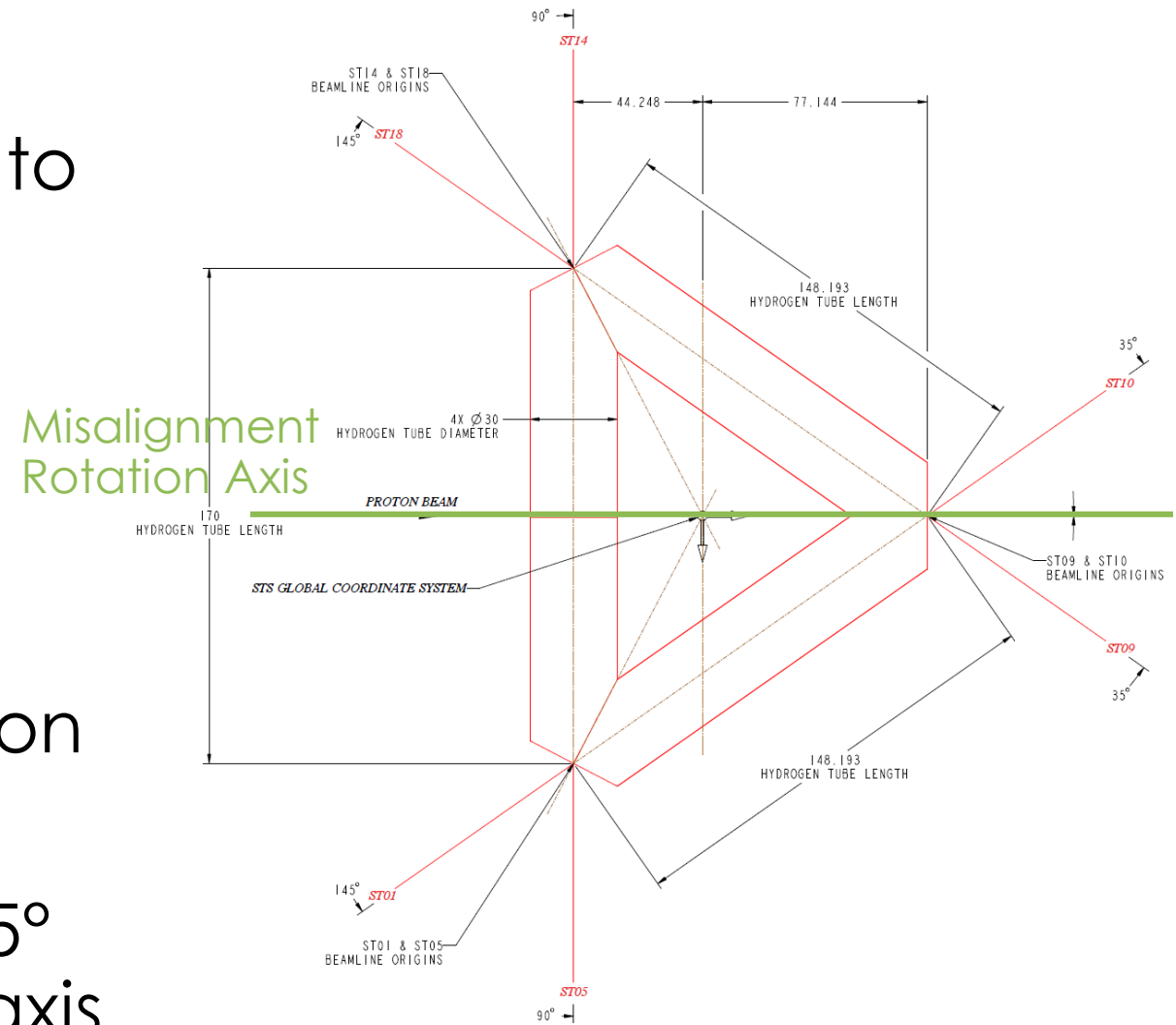
Upper Moderator Rotation

- For worst case misalignment of the reference ST13 beamline, rotation axis should be 13.75° from proton beam axis
- Worst case rotation from 1mm offset of viewed faces gives rotation of 1.15°
- Core vessel and shield block thermal distortion causes rotation of 0.04°
- Therefore, use a rotation of 1.2° around misalignment rotation axis



Lower Moderator Rotation

- For worst case misalignment of the reference ST05 beamline, rotation axis should be parallel to proton beam axis
- Worst case rotation from 1mm offset of viewed faces gives rotation of 0.67°
- Core vessel and shield block thermal distortion causes rotation of 0.04°
- Therefore, use a rotation of 0.75° around misalignment rotation axis



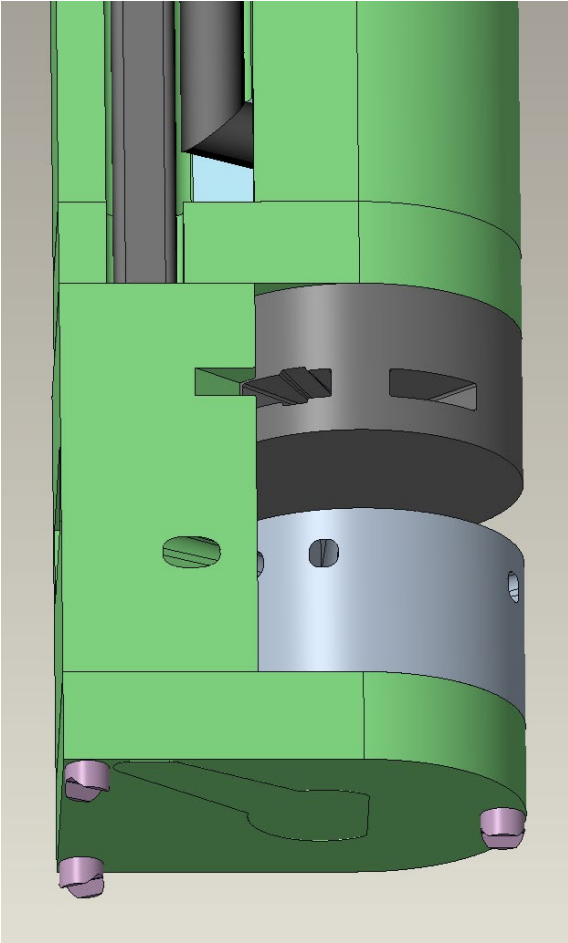
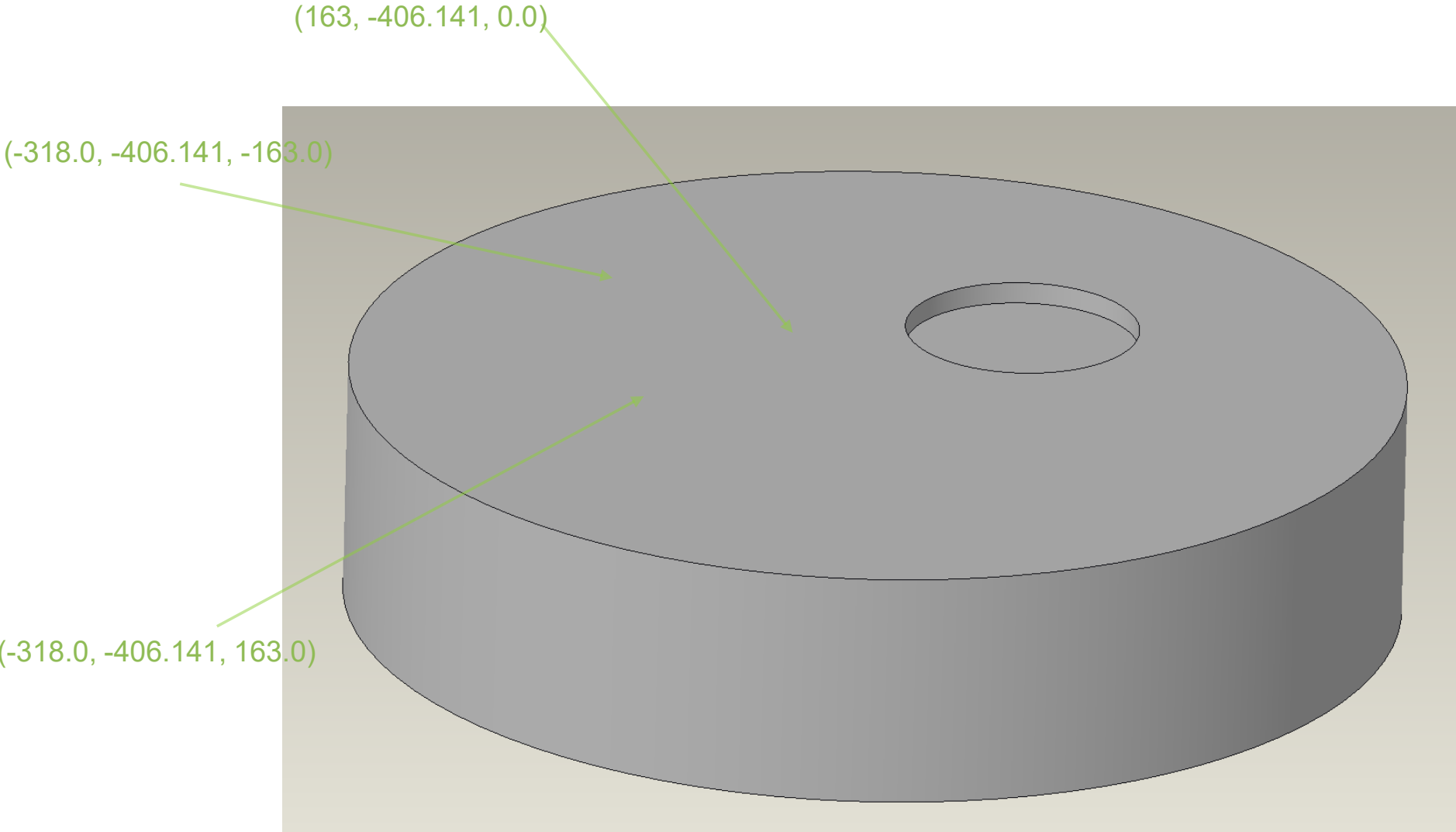
Moderator Vertical Translation

- Backbone/Shield Block Deflections and Guide Entrance Alignment are considered to be in the same direction
 - Results in 1.5mm relative vertical offset
- For preliminary misalignment neutronics model, for simplicity, the guide entrances are left in nominal location and the vertical translation is applied to the moderators
- Reflector vessels and moderators translated 1.5 mm vertically away from target, in addition to previously described rotations
 - This results in the moderators being positioned 1mm further from target than an alignment that meets tolerance requirements
 - Expect preliminary moderator misalignment results to include extra 1% performance loss

Appendix: Core Vessel Deflections from Min-Tsung Kao



MRA Landing Locations – Provide motion in X,Y,Z under pressure, gravity and thermal loads

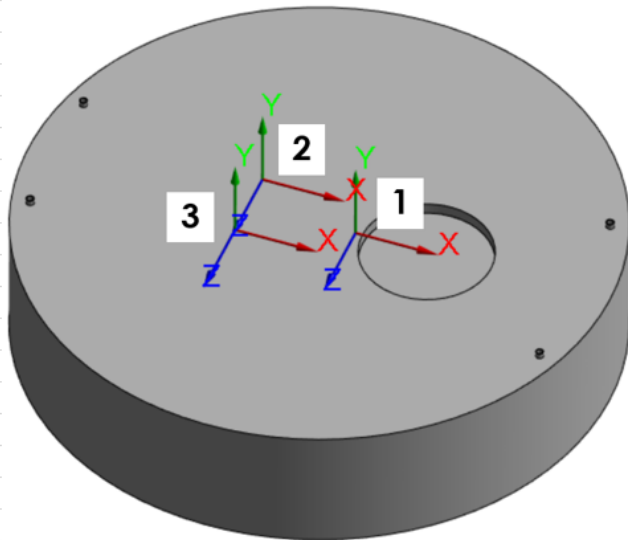


(x, y, z) positions in mm relative to global center

Motion of MRA Landing Locations

Point Corrdinate

	x (mm)	y (mm)	z (mm)
1	163.0	-406.141	0.0
2	-318.0	-406.141	-163.0
3	-318.0	-406.141	163.0



0.00 500.00 1000.00 (mm)
250.00 750.00



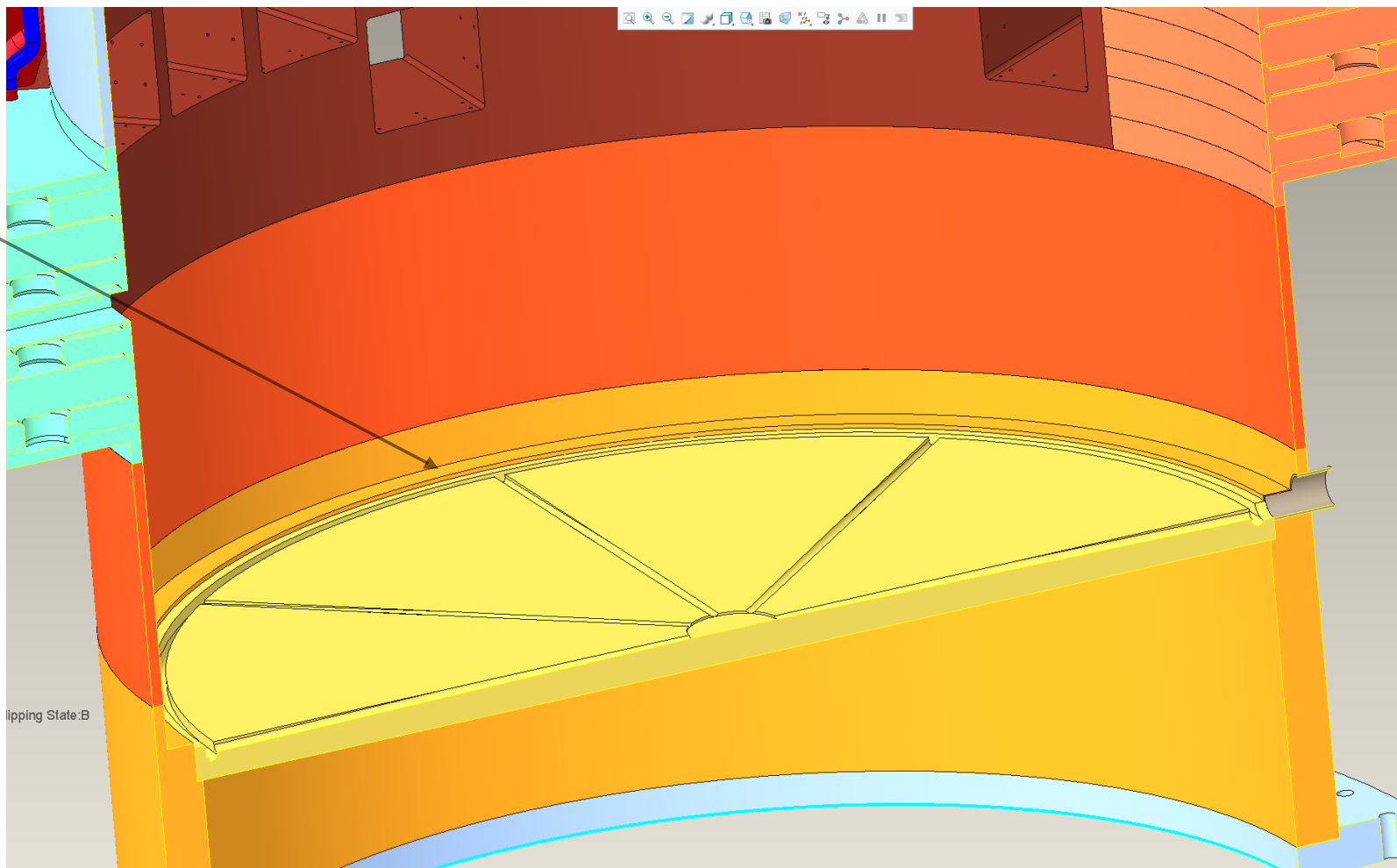
Core Vessel Block #1

Deflection

Point	Load	x (mm)	y (mm)	z (mm)	total (mm)
1	Pressure	8.6864E-04	2.1123E-01	-2.5391E-04	2.1123E-01
	Thermal	9.0757E-02	1.1331E-01	-6.0160E-02	1.5715E-01
	Gravity	-1.1997E-05	-2.1306E-02	-4.0938E-04	2.1310E-02
2	Pressure	-6.4294E-03	1.8988E-01	-4.3310E-03	1.9004E-01
	Thermal	-5.2545E-02	2.5441E-02	-1.0027E-01	1.1602E-01
	Gravity	7.0888E-04	-1.9520E-02	3.9897E-06	1.9533E-02
3	Pressure	-6.4856E-03	1.8968E-01	3.9756E-03	1.8983E-01
	Thermal	-5.2016E-02	2.6167E-02	-2.6275E-02	6.3881E-02
	Gravity	7.1366E-04	-1.9505E-02	-8.3365E-04	1.9536E-02

Core Vessel shielding landing zone – Provide motion in X,Y,Z under pressure, gravity and thermal loads
Could display as a color plot with the minimum and maximum deflections called out?

Motion around this zone



-1000 mm in the Y direction

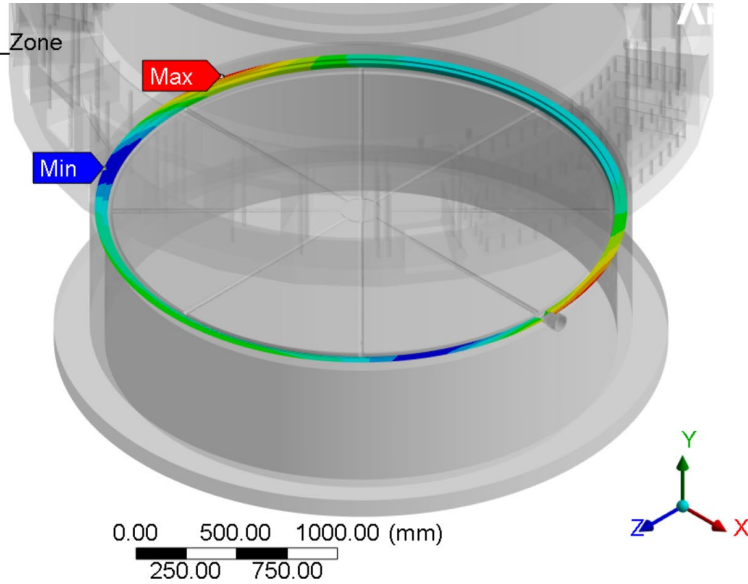
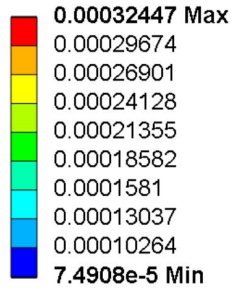
Inside diameter = 2517 centered on global center

Outside diameter = 2642 mm centered on global center

Core Vessel Shielding Landing Zone Deflection - Pressure Only

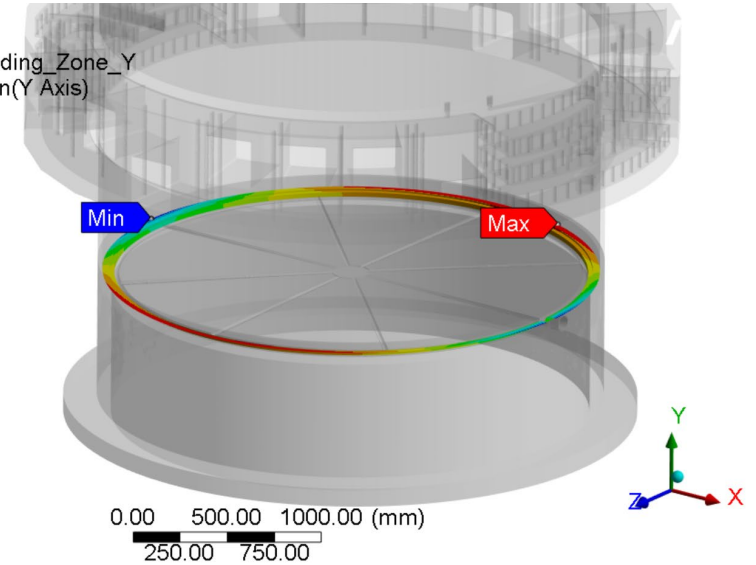
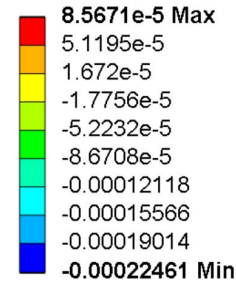
Total Deformation

B: Static Structural
 Total Deformation_Landing_Zone
 Type: Total Deformation
 Unit: mm
 Time: 1 s



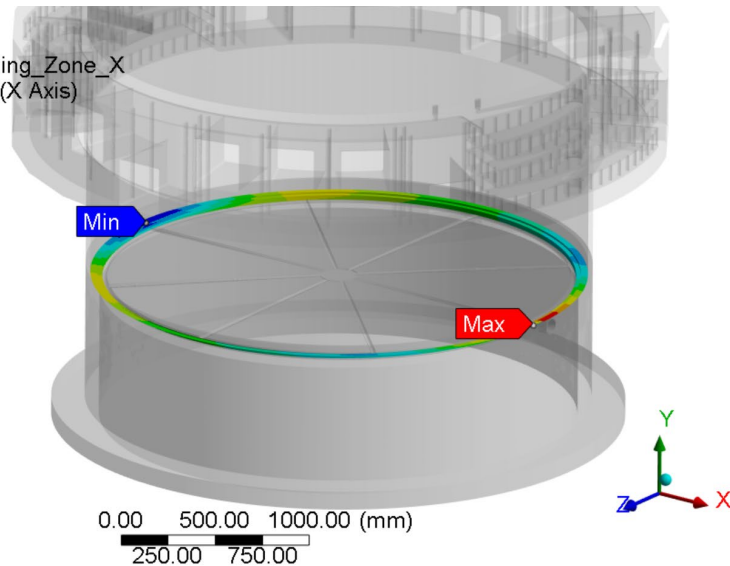
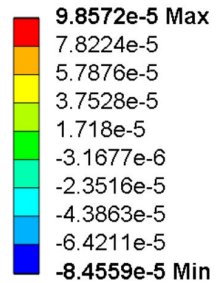
Y - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_Y
 Type: Directional Deformation(Y Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



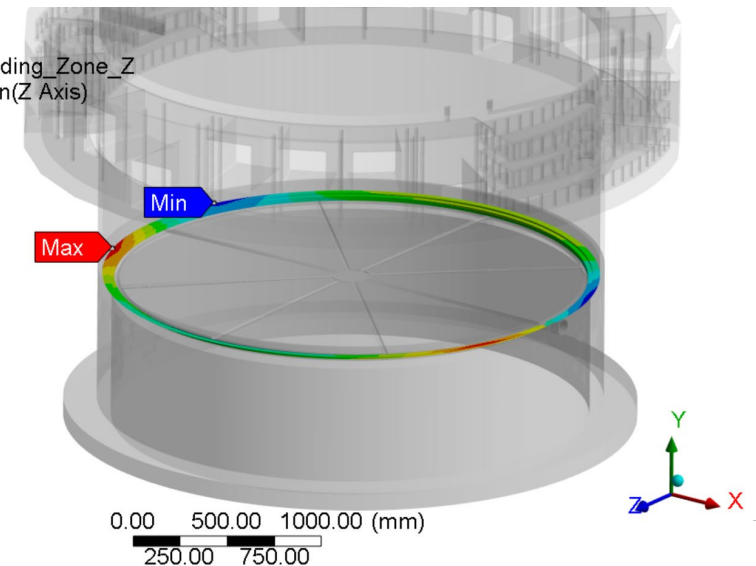
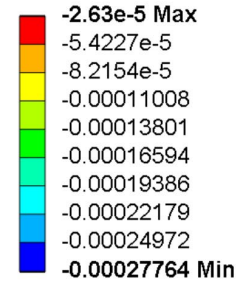
X - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_X
 Type: Directional Deformation(X Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



Z - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_Z
 Type: Directional Deformation(Z Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



Core Vessel Shielding Landing Zone Deflection - Pressure Only

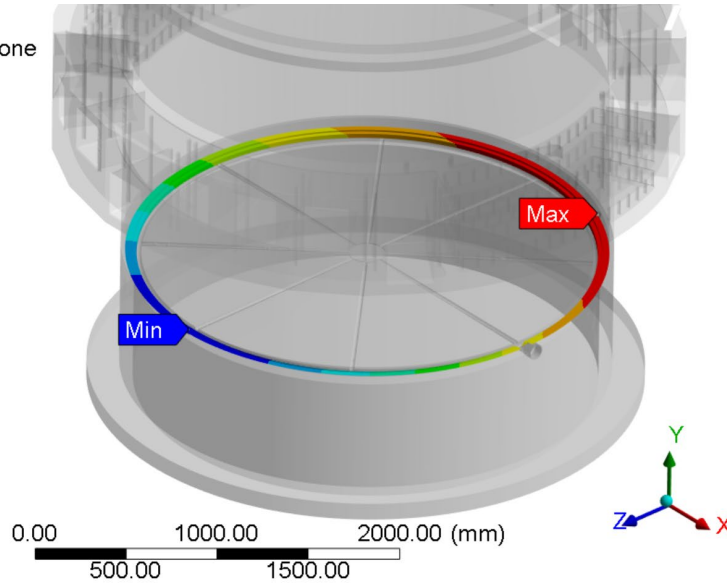
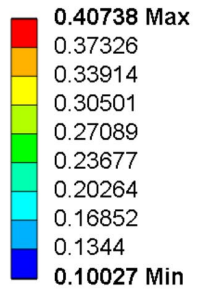
Core Vessel Landing Zone Deflection - Pressure Only

		Location		
	Deflection (mm)	x (mm)	y (mm)	z (mm)
Total Max.	3.245E-04	-1285.2	-1060	-305.31
Total Min.	7.491E-05	-1140.8	-1060	665.99
X-Dir Max.	9.857E-05	1314.9	-1060	44.055
X-Dir Min.	-8.456E-05	-1283.5	-1060	-11.234
Y-Dir Max.	8.567E-05	443.13	-1060	-1244.5
Y-Dir Min.	-2.246E-04	-1321	-1060	-0.071346
Z-Dir Max.	-2.630E-05	-1240	-1060	455.37
Z-Dir Min.	-2.776E-04	-1241.2	-1060	-452.28

Core Vessel Shielding Landing Zone Deflection - Thermal Only

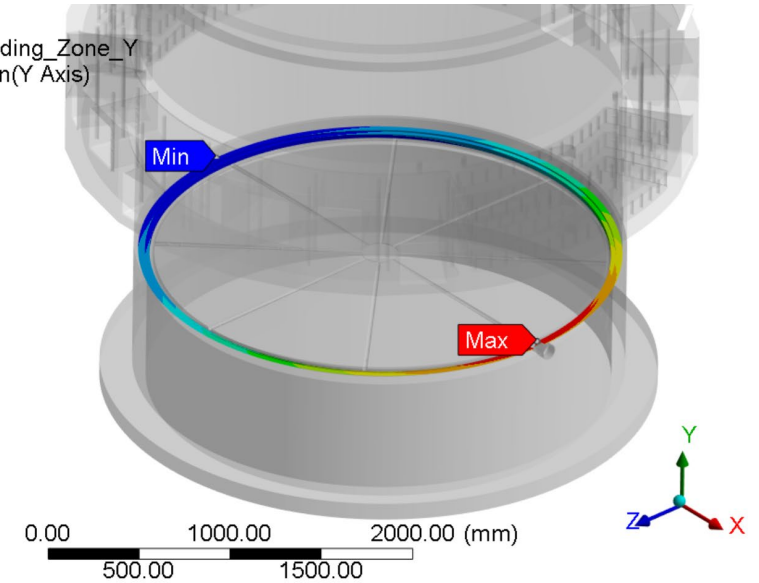
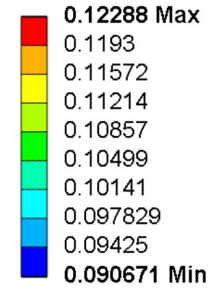
Total Deformation

B: Static Structural
 Total Deformation_Landing_Zone
 Type: Total Deformation
 Unit: mm
 Time: 1 s



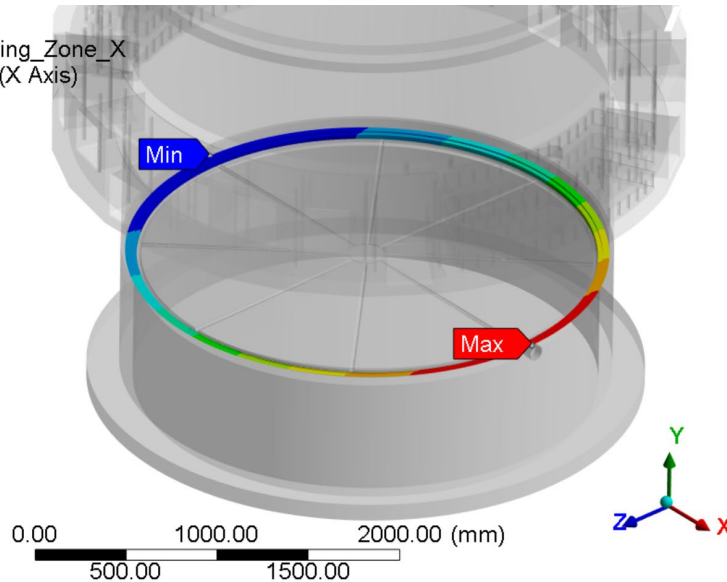
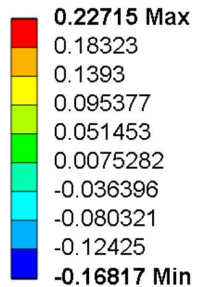
Y - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_Y
 Type: Directional Deformation(Y Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



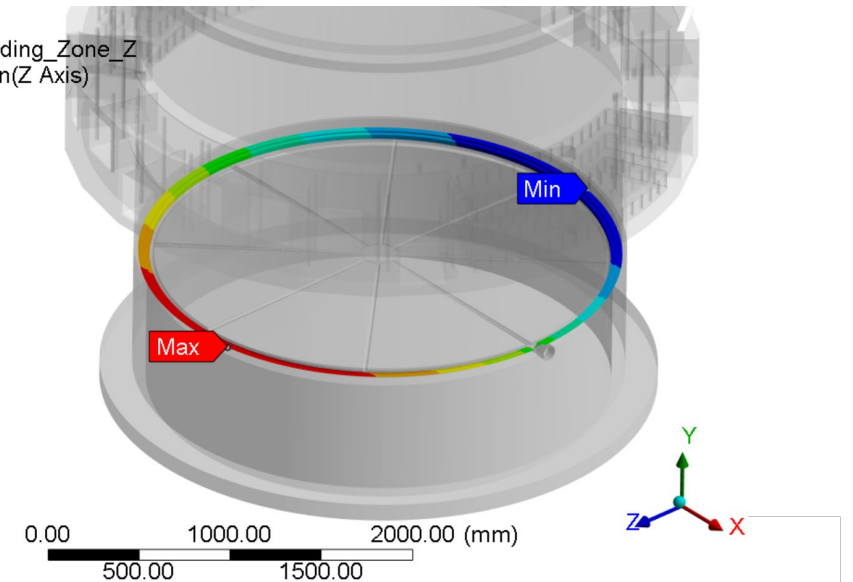
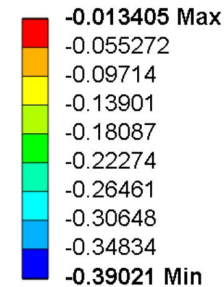
X - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_X
 Type: Directional Deformation(X Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



Z - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_Z
 Type: Directional Deformation(Z Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



Core Vessel Shielding Landing Zone Deflection - Thermal Only

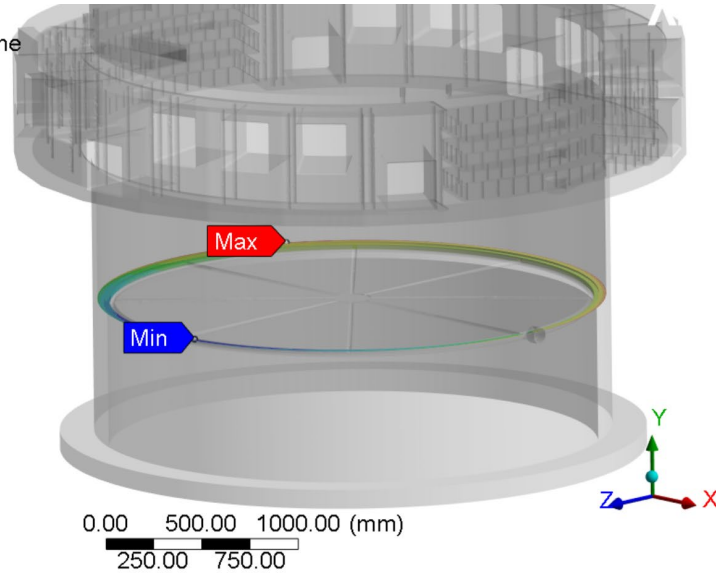
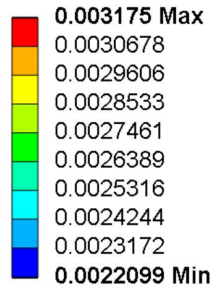
Core Vessel Landing Zone Deflection - Thermal Only

		Location		
	Deflection (mm)	x (mm)	y (mm)	z (mm)
Total Max.	4.074E-01	529.11	-1060	-1210.4
Total Min.	1.003E-01	-29.712	-1095	1258.1
X-Dir Max.	2.272E-01	1320.4	-1060	-38.945
X-Dir Min.	-1.682E-01	-1321	-1060	-10.452
Y-Dir Max.	1.229E-01	1258	-1070	-37.051
Y-Dir Min.	9.067E-02	-1320.5	-1060	36.044
Z-Dir Max.	-1.341E-02	227.41	-1060	1301.3
Z-Dir Min.	-3.902E-01	235.34	-1060	-1299.9

Core Vessel Shielding Landing Zone Deflection - Gravity Only

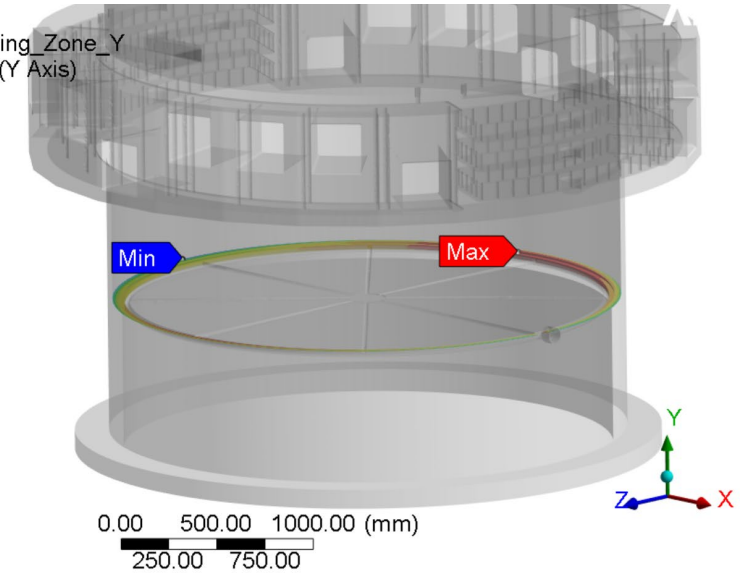
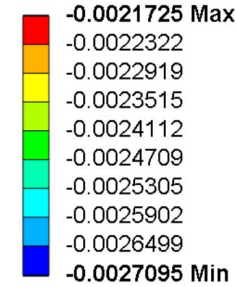
Total Deformation

B: Static Structural
 Total Deformation_Landing_Zone
 Type: Total Deformation
 Unit: mm
 Time: 1 s



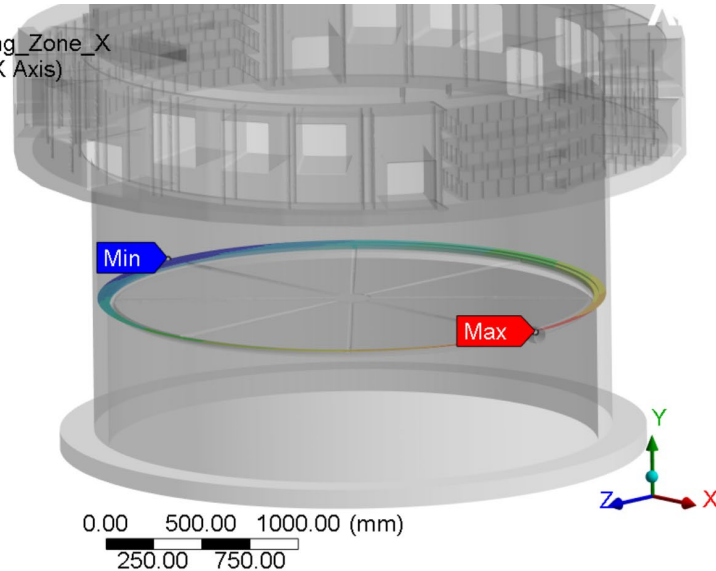
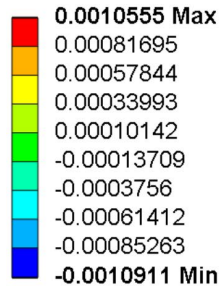
Y - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_Y
 Type: Directional Deformation(Y Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



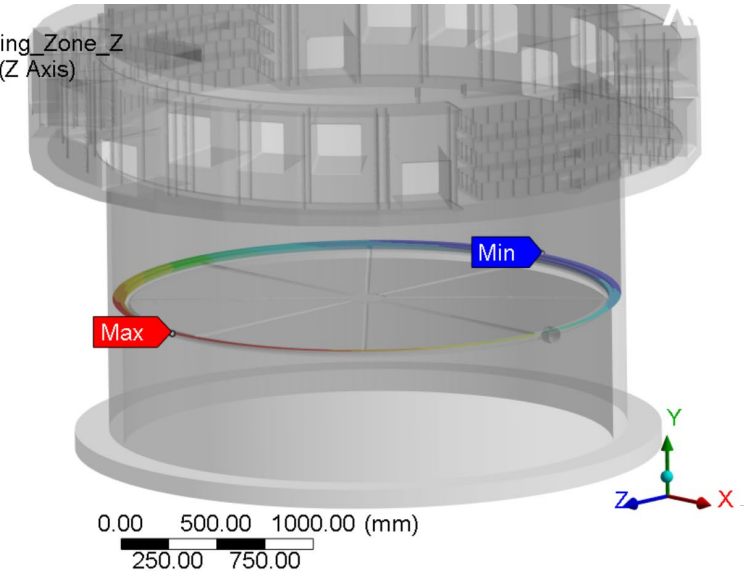
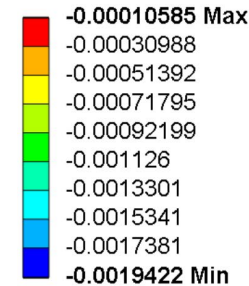
X - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_X
 Type: Directional Deformation(X Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



Z - Deformation

B: Static Structural
 Directional Deformation_Landing_Zone_Z
 Type: Directional Deformation(Z Axis)
 Unit: mm
 Global Coordinate System
 Time: 1 s



Core Vessel Shielding Landing Zone Deflection - Gravity Only

Core Vessel Landing Zone Deflection - Gravity Only

		Location		
	Deflection (mm)	x (mm)	y (mm)	z (mm)
Total Max.	3.175E-03	-1151.1	-1060	-648.16
Total Min.	2.210E-03	138.05	-1060	1276.1
X-Dir Max.	1.056E-03	1320.3	-1060	-44.172
X-Dir Min.	-1.091E-03	-1320.8	-1060	20.816
Y-Dir Max.	-2.173E-03	-178.61	-1060	-1271
Y-Dir Min.	-2.710E-03	-1320.8	-1060	20.816
Z-Dir Max.	-1.059E-04	-96.48	-1060	1317.5
Z-Dir Min.	-1.942E-03	-51.483	-1060	-1320