

# CAD SHIELDING ANALYSIS OF THE INTERNATIONAL SPACE STATION

N. Stoffle<sup>1</sup>, A. Welton<sup>1</sup>, J. Barzilla<sup>1</sup>, R. Gaza<sup>1</sup>,  
K. Lee<sup>2</sup>, N. Zapp<sup>2</sup>

<sup>1</sup> Lockheed Martin, Houston, TX

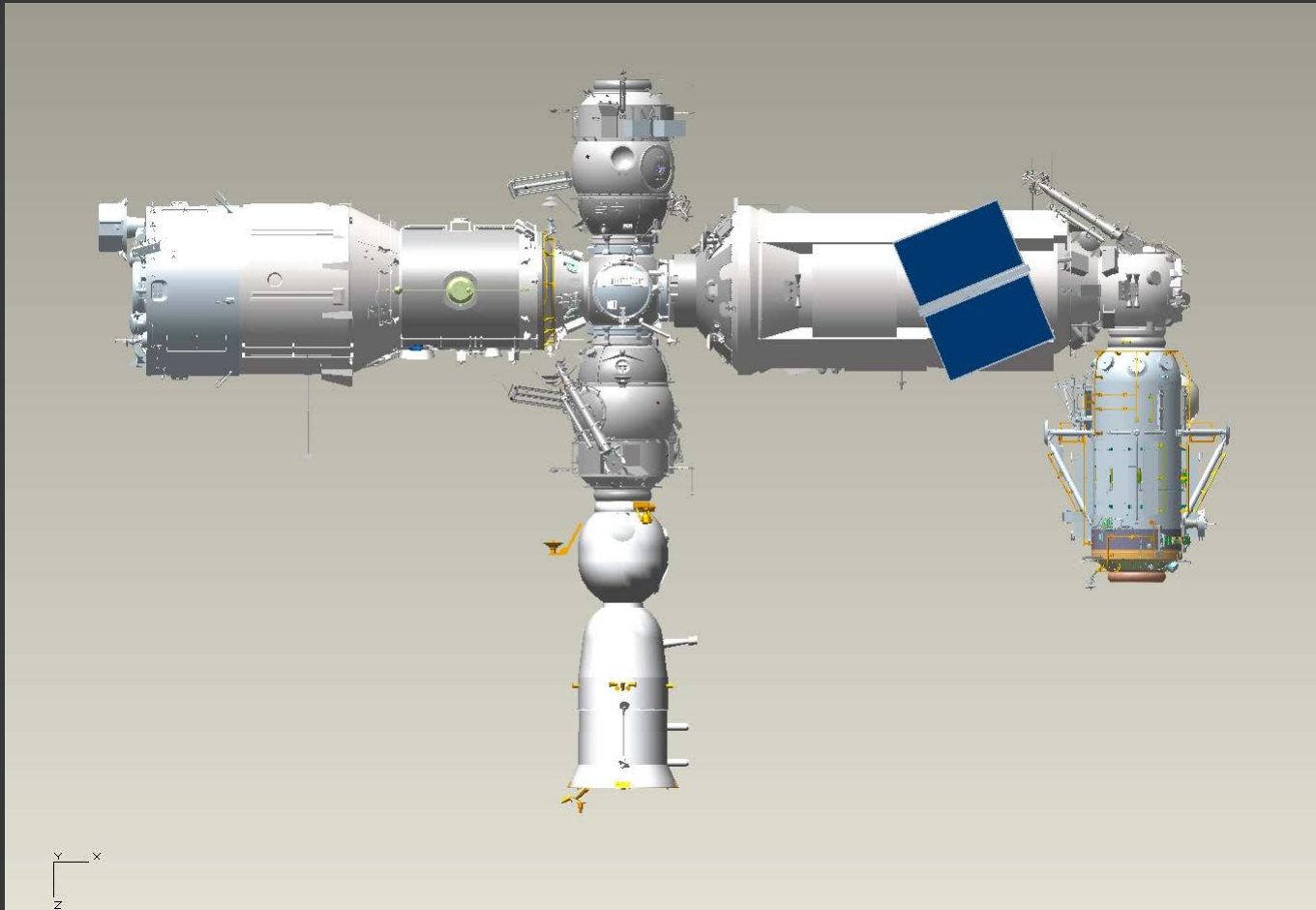
<sup>2</sup> NASA Johnson Space Center, Houston, TX

# Motivation

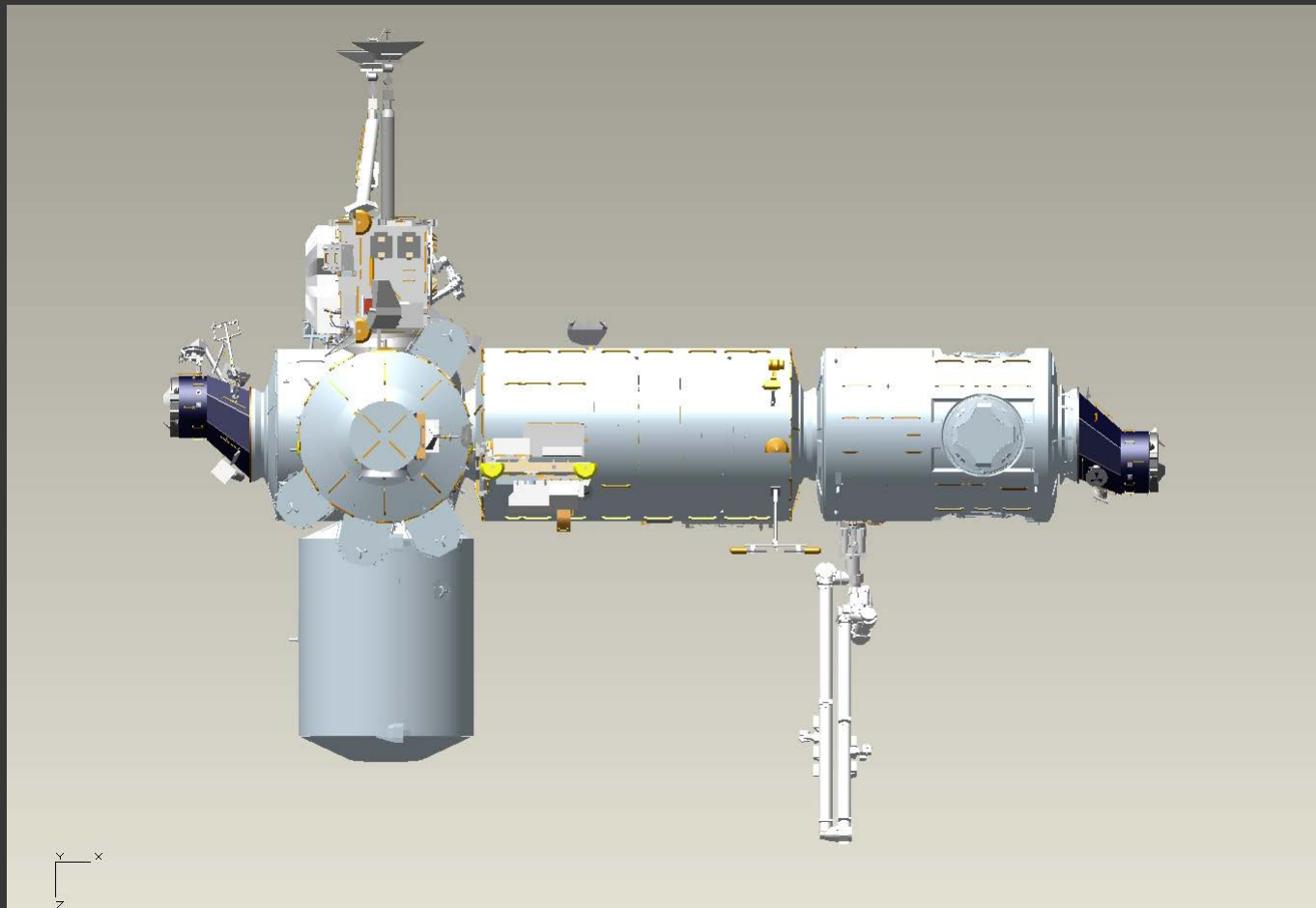
- ⦿ Analysis of shielding strategies
- ⦿ Develop capability to assess vehicle designs
- ⦿ Ultimate goal is to provide near real-time assessment of space weather impact to vehicle crew

# CAD Model Assembly

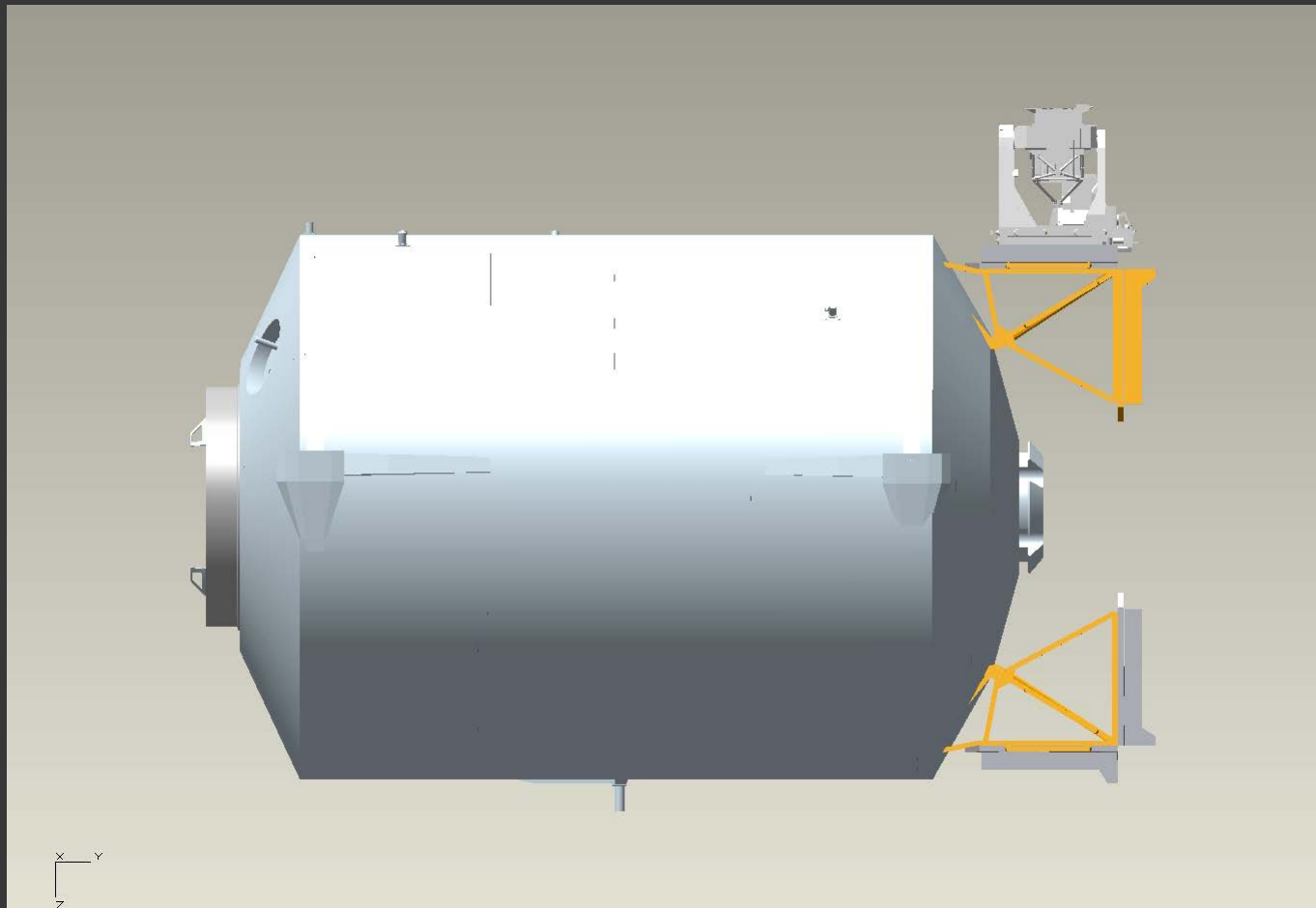
# Russian Segment



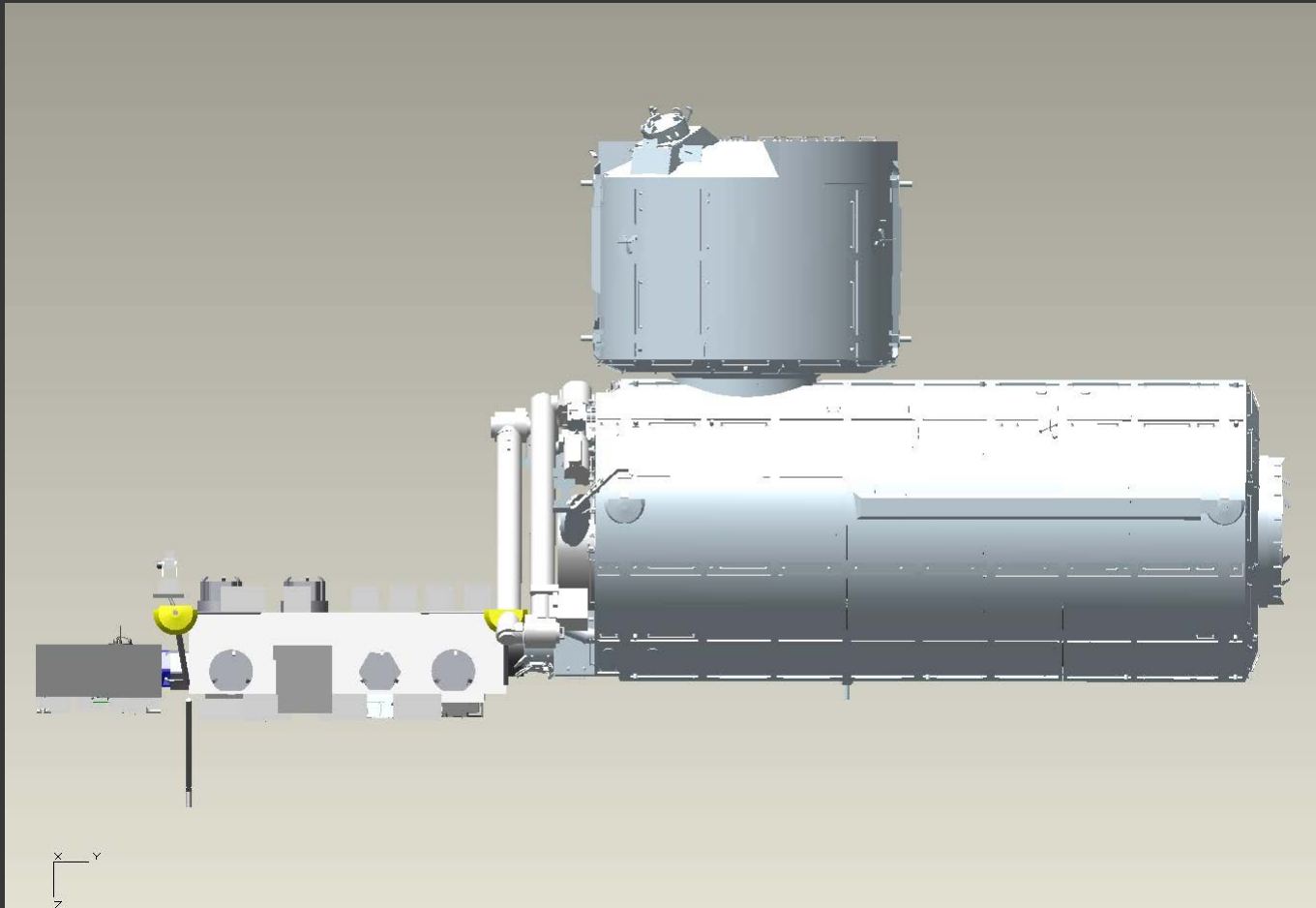
# US Segment



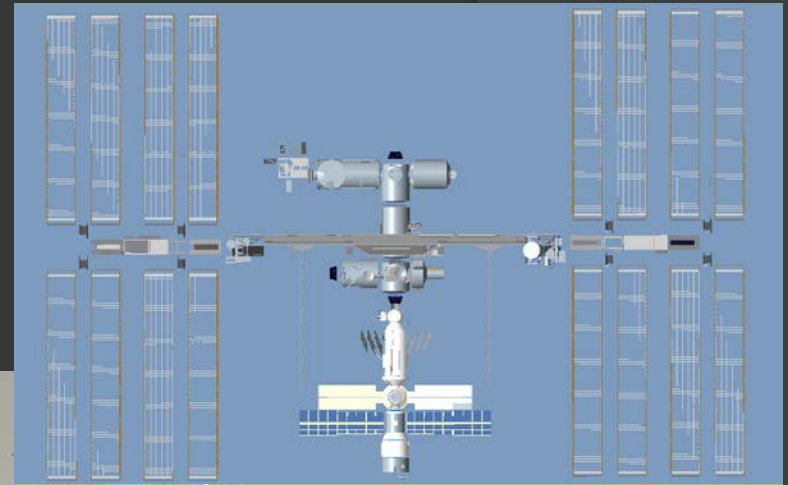
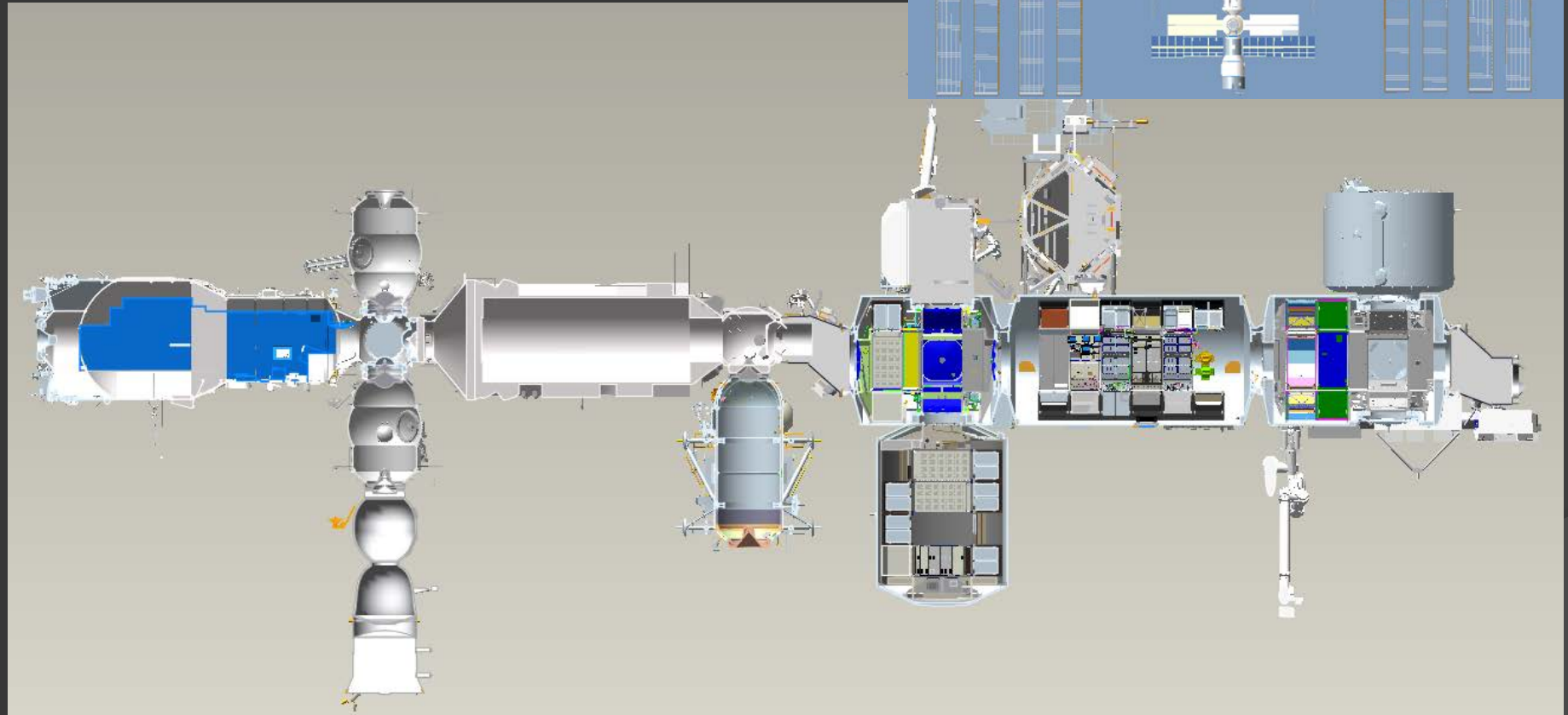
# Columbus



# JEM



# ISS Configuration





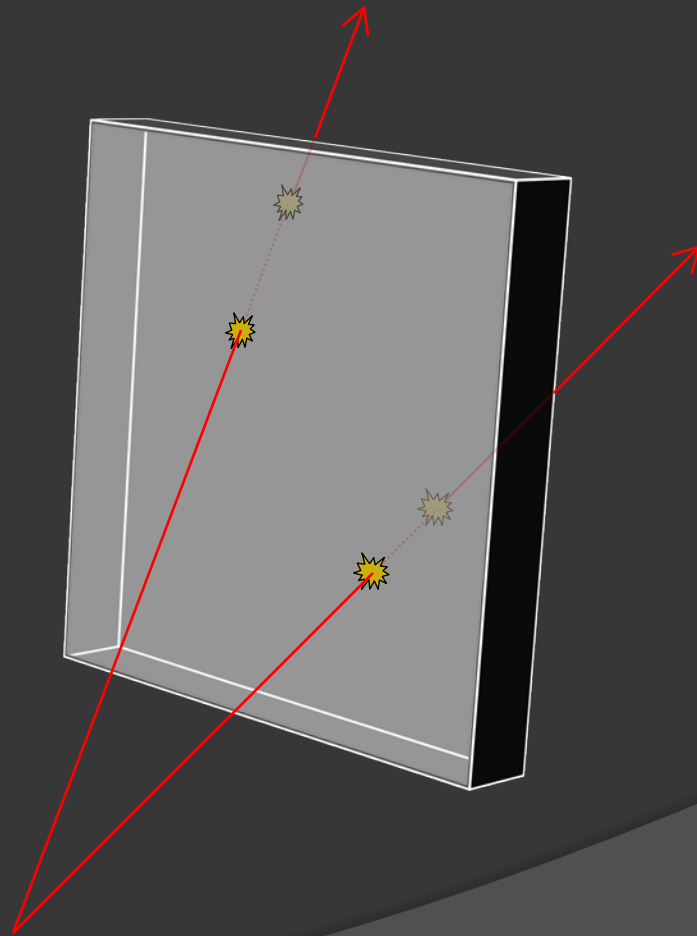
# Shielding Analysis Process

# Model Ray Trace

Ray Direction

Intersected Part Name

Entry and Exit points



# Association of Material Info

Ray#	Phi (rad)	Theta(rad)	Part_Name	Xin	Yin	Zin	Xout	Yout	Zout	
1	_SOL3-98	-412.367432	3.179166	181.549949	-413.627136	3.343885	182.370468			
1	MANIFOLD_SOLID_BREP_349	-413.627136	3.343885	182.370468	-413.682711	3.351152	182.406667			
1	SSVP_A_KON1	-434.947224	6.131695	196.257491	-435.472597	6.200393	196.599697			
1	MANIFOLD_SOLID_BREP_306	-436.362238	6.316722	197.179173	-439.929216	6.783139	199.502554			
1	STA-PASS_KORPUS	-453.952863	8.616868	208.636978	-454.292599	8.661292	208.858268			
1	STA-PASS_KOZHUH	-464.482144	9.993675	215.495316	-464.517562	9.998306	215.518386			
1	STA-PASS_KOZHUH_EVTI	-464.517562	9.998306	215.518386	-464.641215	10.014475	215.598928			
2	001_PMA1_CORE	-397.918554	-14.070346	149.678519	-398.277939	-14.403029	149.357436			
2	_SOL3-98	-402.246514	-18.076747	145.81181	-403.543909	-19.277749	144.652684			2.915
2	MANIFOLD_SOLID_BREP_345	-402.365027	-18.186455	145.705927	-415.195695	-30.063831	134.24268			2.915
3	001_PMA1_CORE	-398.538305	16.860468	155.406625	-398.866061	17.238229	155.24962			2.915
3	_SOL3-98	-403.403667	22.468125	153.075963	-403.750499	22.867872	152.90982			2.915
3	VOL15	-406.145665	25.628463	151.76246	-407.780898	27.513179	150.979131			2.915
3	MANIFOLD_SOLID_BREP_345	-409.414883	29.396455	150.196402	-417.896399	39.171974	146.133488			2.915
4	MANIFOLD_SOLID_BREP_349	-413.622221	-5.918441	176.679238	-414.621948	-6.093876	177.142392			2.915
4	MANIFOLD_SOLID_BREP_306	-457.633432	-13.641664	197.068782	-461.731667	-14.360836	198.967416			2.915
4	MANIFOLD_SOLID_BREP_2748	-486.538433	-18.714004	210.459911	-502.000356	-21.42731	217.623122			2.915
4	R51	-505.151282	-21.980244	219.082885	-506.725655	-22.25652	219.812261			2.915
4	R51	-512.872953	-23.335267	222.660186	-518.730248	-24.363123	225.373758			2.915
4	MANIFOLD_SOLID_BREP_324	-518.679933	-24.354294	225.350448	-545.60455	-29.079109	237.824103			2.915
4	RAD_MLM_S	-737.851594	-62.815216	326.888447	-741.142872	-63.39278	328.413232			2.915
5	_SOL3-98	-404.030944	-1.275609	138.16868	-404.132014	-1.27886	138.048779			2.915
5	MANIFOLD_SOLID_BREP_345	-412.177744	-1.537654	128.504282	-412.804999	-1.55784	127.759793			2.915
5	MANIFOLD_SOLID_BREP_348	-412.608404	-1.551259	128.00251	-413.991371	-1.596002	126.35237			2.915
5	MANIFOLD_SOLID_BREP_343	-413.991371	-1.596002	126.35237	-414.588457	-1.615208	125.644031			2.915
6	001_PMA1_CORE	-372.242838	-20.176385	152.044764	-367.918753	-27.773986	147.919845			2.915
	0.098 PRT			_SOL1-346			AL			2.915
	0.098 PRT			_VOL15			AL			2.915
	0.098 PRT			MANIFOLD SOLID BREP 348			AL			2.915
	0.098 PRT			MANIFOLD SOLID BREP 349			AL			2.915
	0.098 PRT			_SOL8			AL			2.915
	0.098 PRT			_SOL10			AL			2.915
	0.098 PRT			_SOL14			AL			2.915
	0.098 PRT			ASM						2.915
	0.098 PRT			ASM						2.915
	0.098 PRT			SOL12			AL			2.915

$$T_{eq} = T_m * \rho_m * R_{Al}/R_m$$

Density

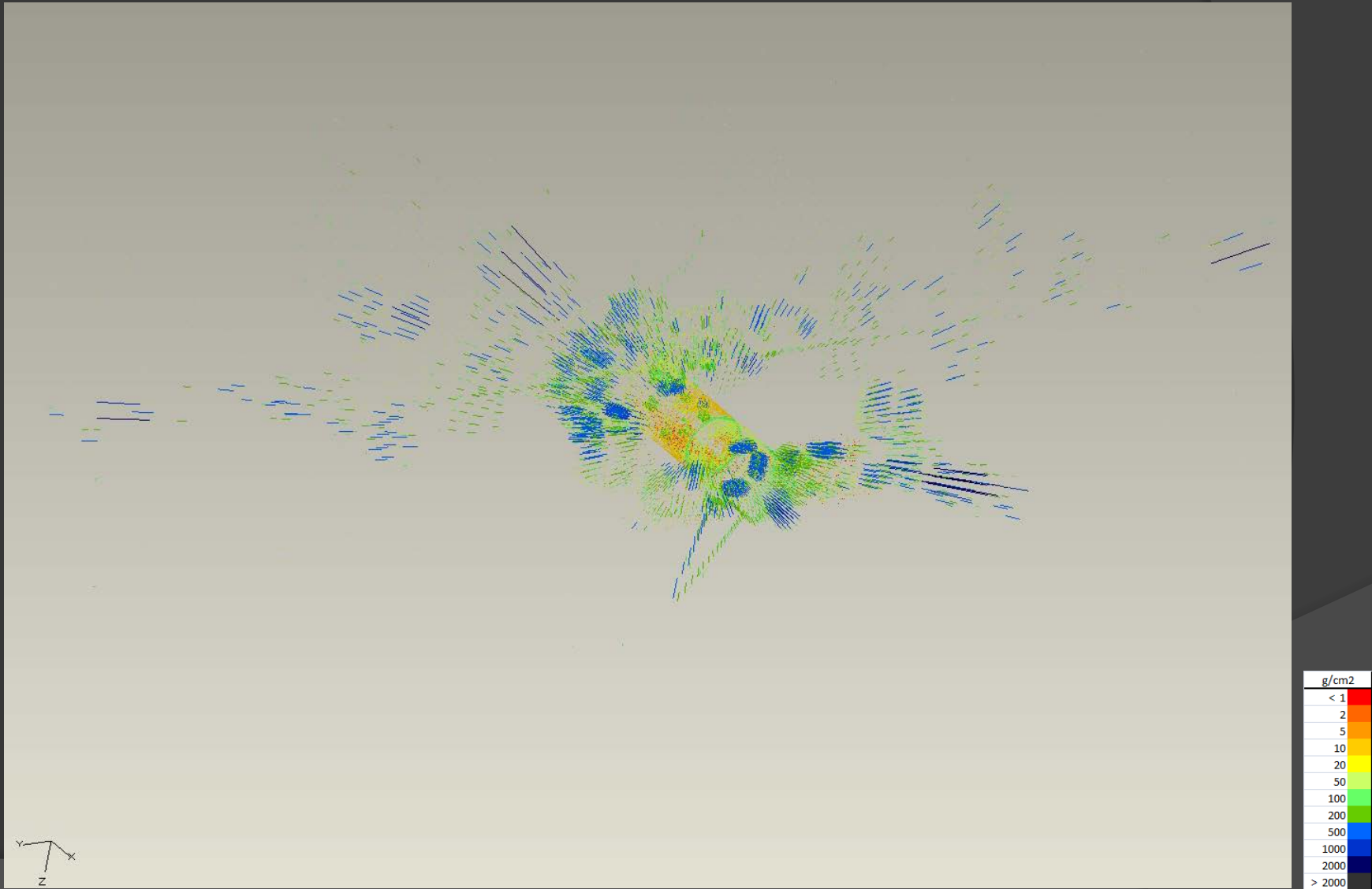
50MeV proton Range

# Output

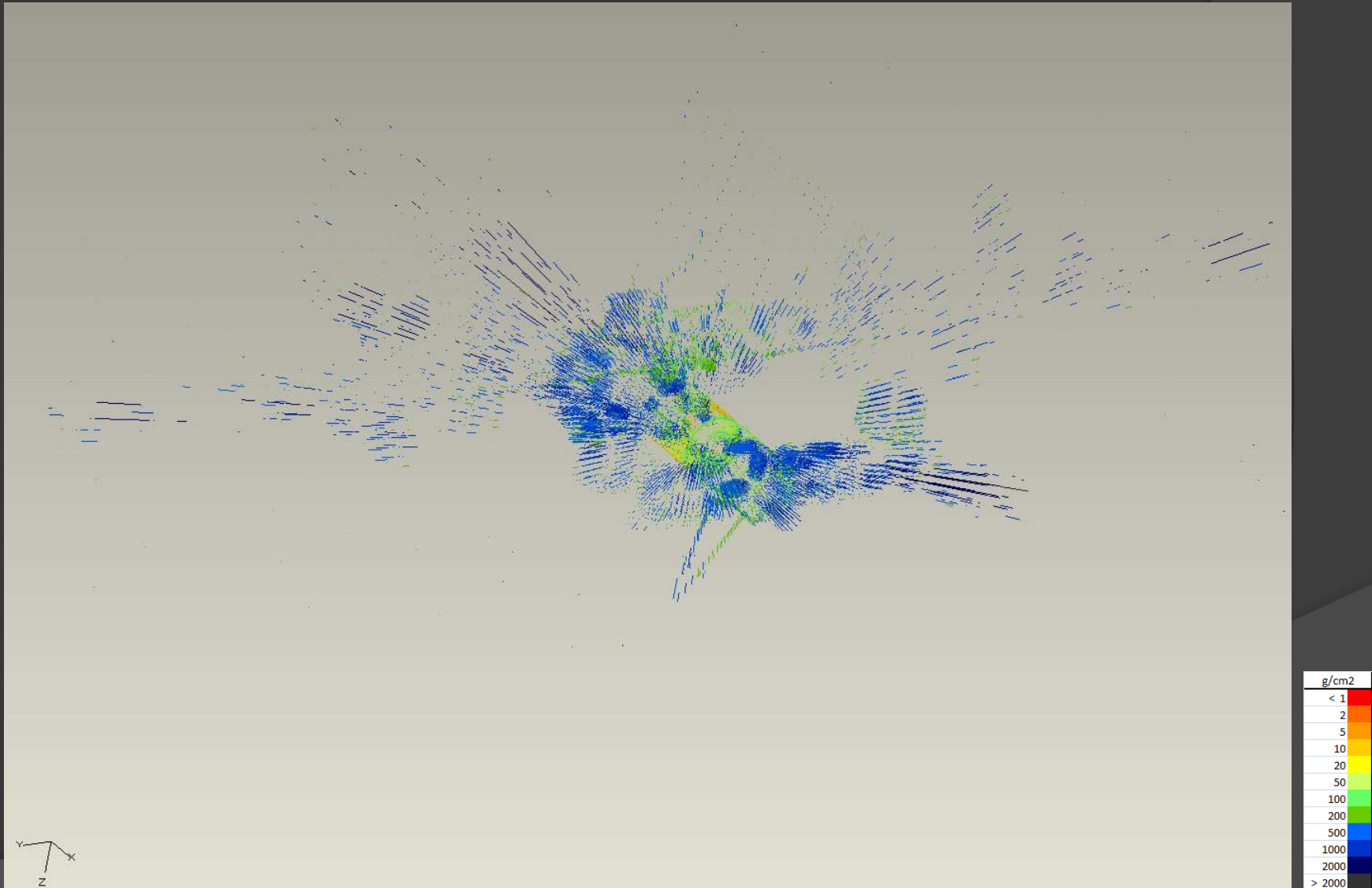
```
1 Shield file for full model
2 The following are the order of the output data in each row.
3 Theta, Phi, Placeholder, Aluminum Equivalent Thickness (g/cm2)
4 Number of Rays: 10000
5 x: -1103.38 y: -0.839281 z: 163.19
6 ==> Aluminum <==
7
8
9 0.997335 -0.130021 0 42.236
10 2.15112 0.746835 0 24.2212
11 1.87498 -0.856157 0 59.3308
12 1.14271 0.173715 0 13.8905
13 2.44096 0.0321553 0 22.8057
14 2.0117 -1.05334 0 41.6385
15 0.645341 -0.538259 0 2.68607
16 0.623566 0.103448 0 96.0866
17 2.78039 1.48189 0 19.6081
18 1.10677 -1.23662 0 11.5822
19 1.00225 -0.26687 0 7.8391
20 2.87835 -0.610345 0 29.3227
21 1.98701 -0.341752 0 26.4583
22 1.99895 1.36891 0 11.1834
23 2.52488 1.07079 0 11.6579
24 2.17302 -1.00015 0 12.8424
25 2.16155 -0.65529 0 22.0723
26 1.41798 -0.0457424 0 41.0452
27 0.62105 -0.435377 0 7.12241
28 1.43084 1.16349 0 11.6848
29 2.64203 -1.01026 0 11.3638
30 3.11351 1.38211 0 18.8595
```

```
1 Shield file for full model
2 The following are the order of the output data in each row.
3 Theta, Phi, Placeholder, Polyethylene Equivalent Thickness (g/cm2)
4 Number of Rays: 10000
5 x: -1103.38 y: -0.839281 z: 163.19
6 ==> Poly <==
7
8
9 0.997335 -0.130021 0 0
10 2.15112 0.746835 0 0
11 1.87498 -0.856157 0 0
12 1.14271 0.173715 0 0
13 2.44096 0.0321553 0 0
14 2.0117 -1.05334 0 0
15 0.645341 -0.538259 0 0
16 0.623566 0.103448 0 0
17 2.78039 1.48189 0 0
18 1.10677 -1.23662 0 0
19 1.00225 -0.26687 0 0
20 2.87835 -0.610345 0 0
21 1.98701 -0.341752 0 0
22 1.99895 1.36891 0 0
23 2.52488 1.07079 0 0
24 2.17302 -1.00015 0 0
25 2.16155 -0.65529 0 0
26 1.41798 -0.0457424 0 0
27 0.62105 -0.435377 0 0
28 1.43084 1.16349 0 0
29 2.64203 -1.01026 0 0
30 3.11351 1.38211 0 0
31 0.646131 0.906018 0 0
```

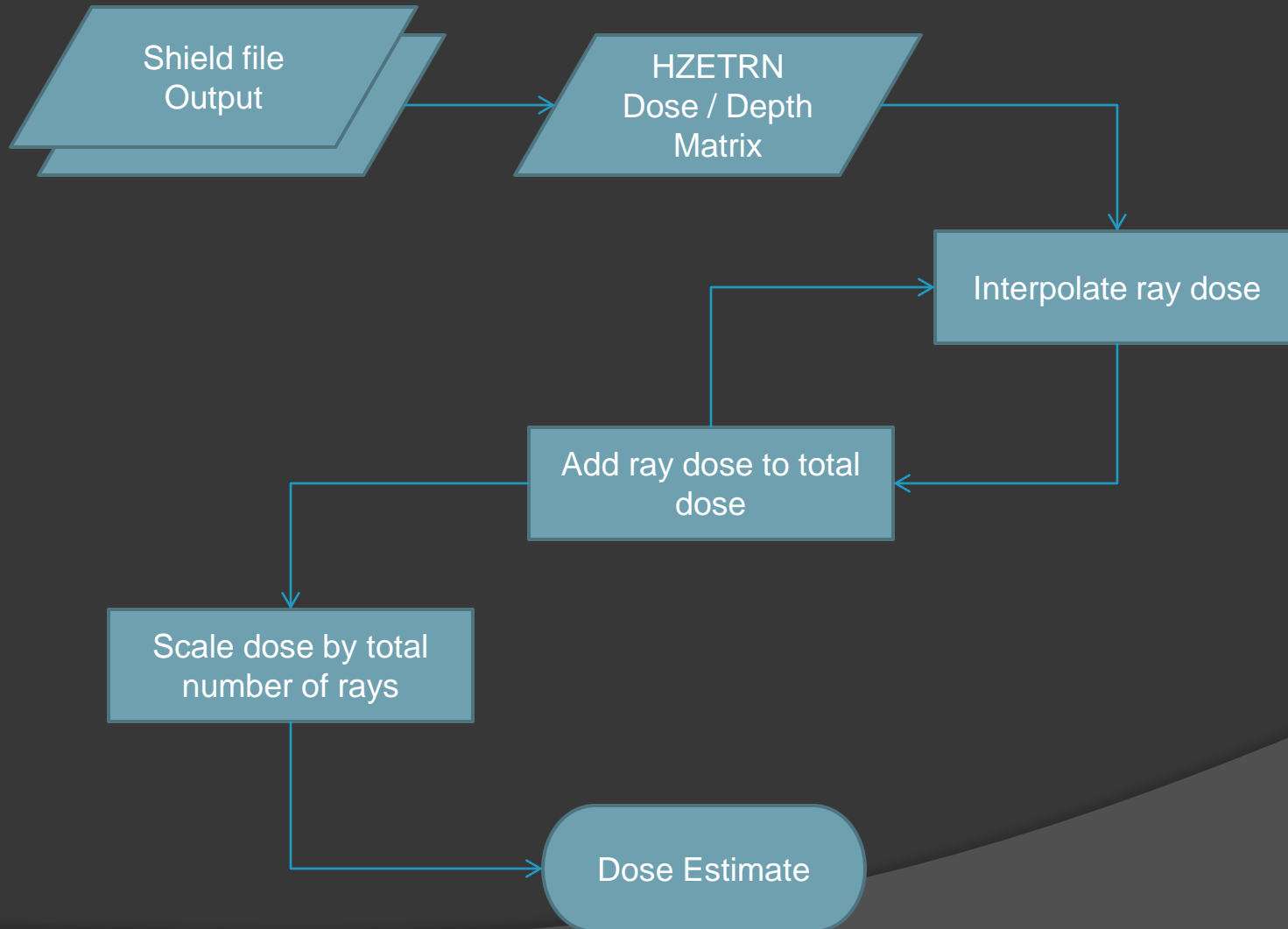
# Visualizations



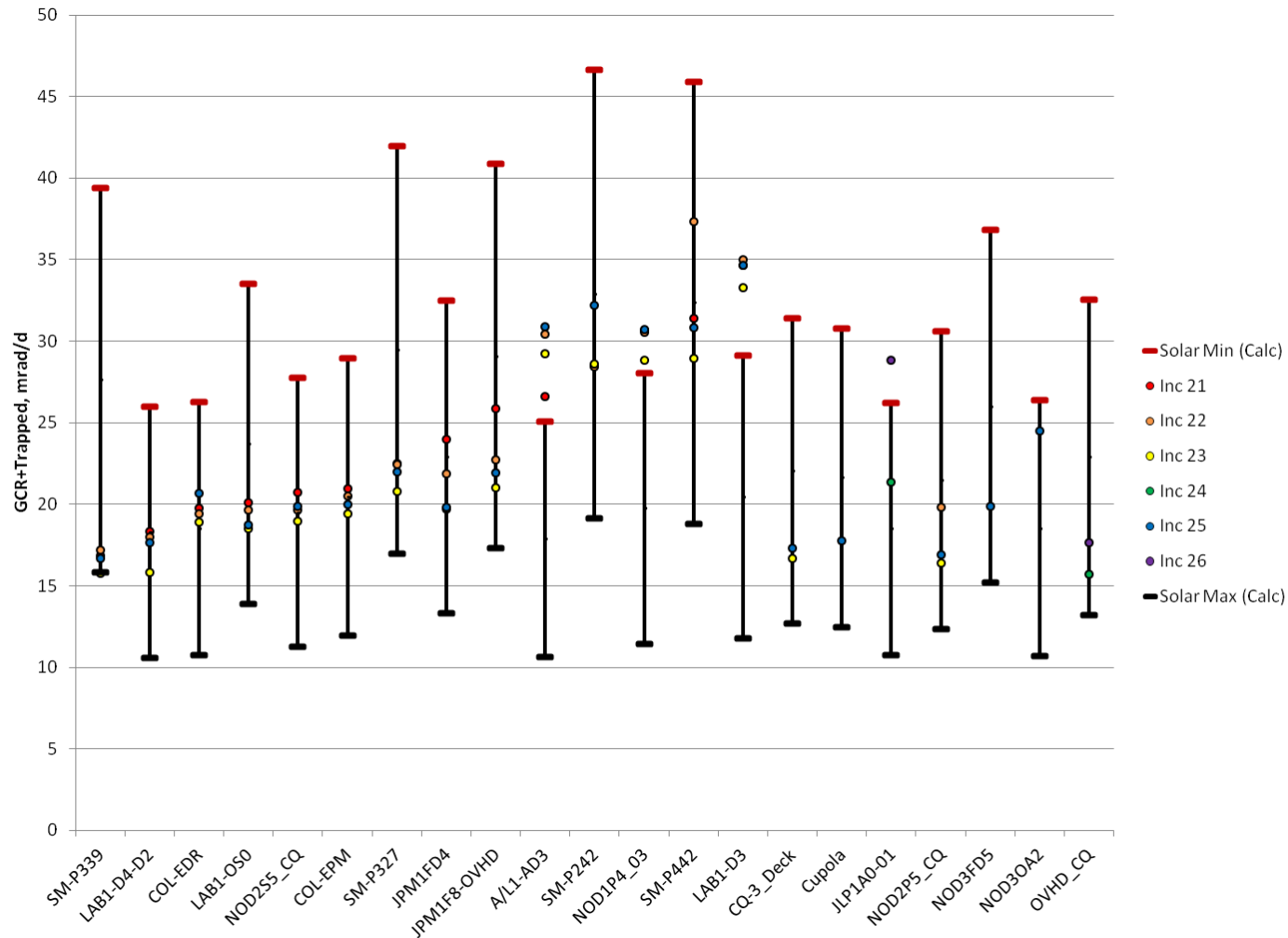
# Visualizations



# Single Point Dose Estimation

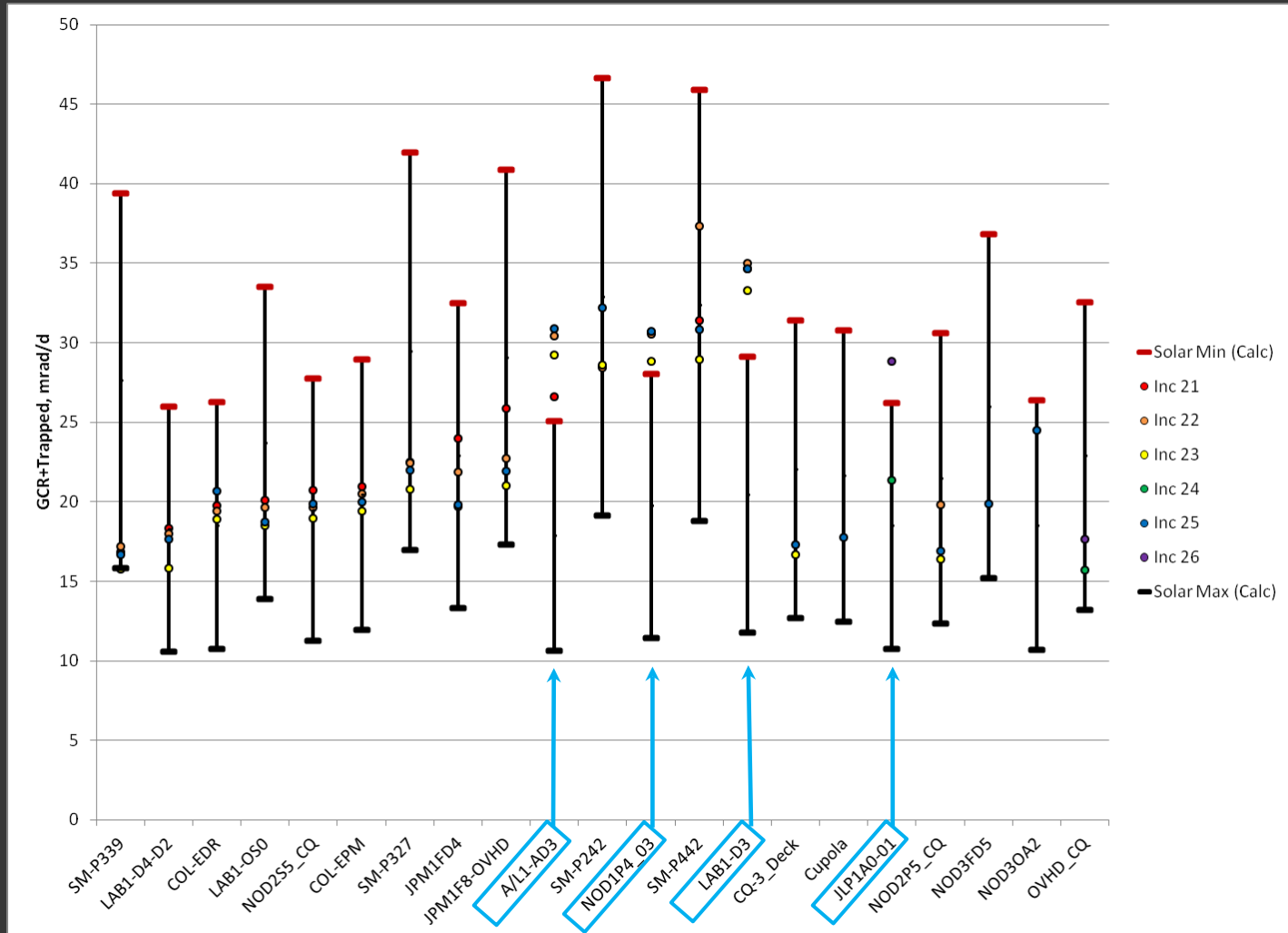


# Comparison to RAM Data

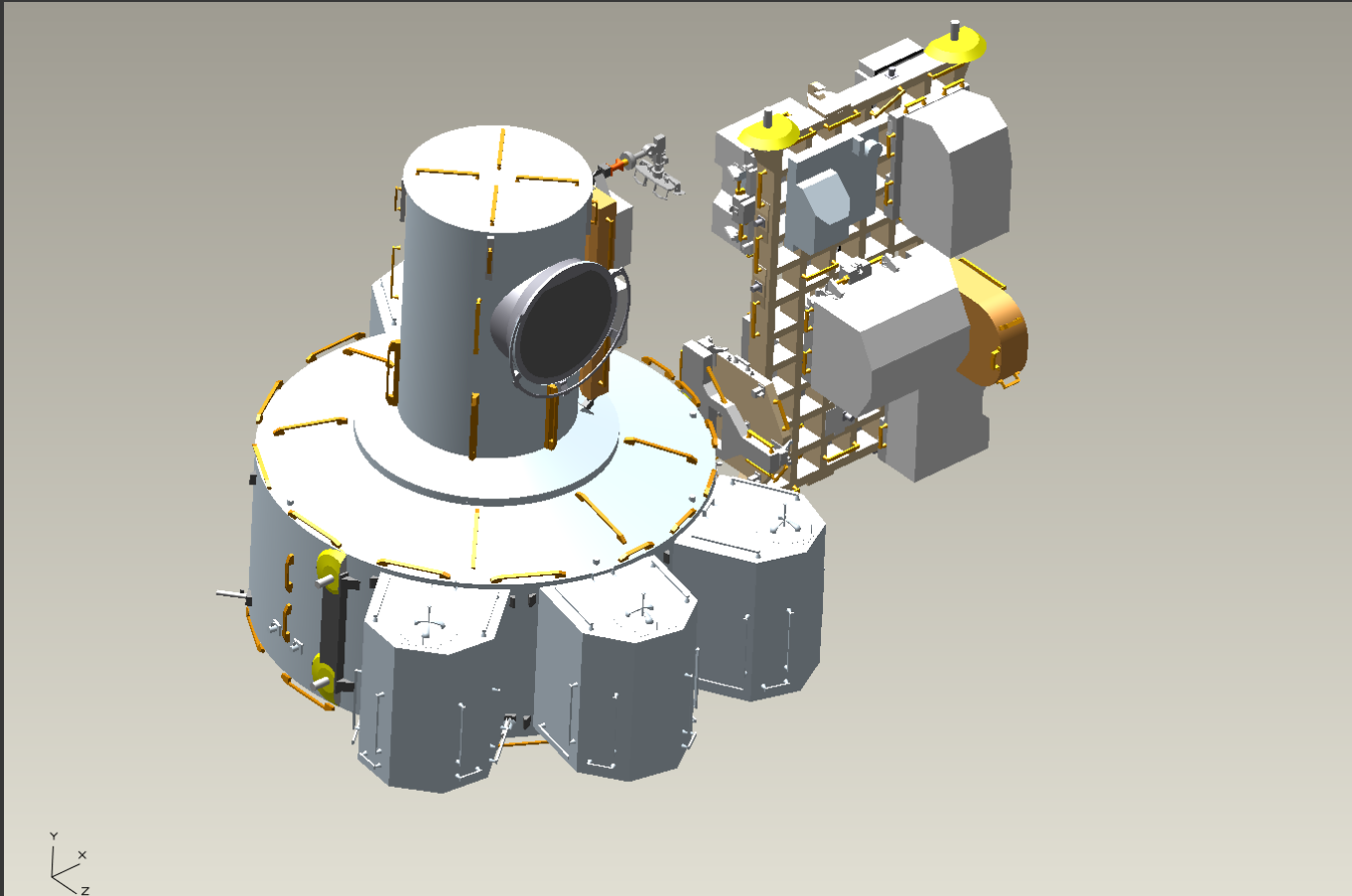




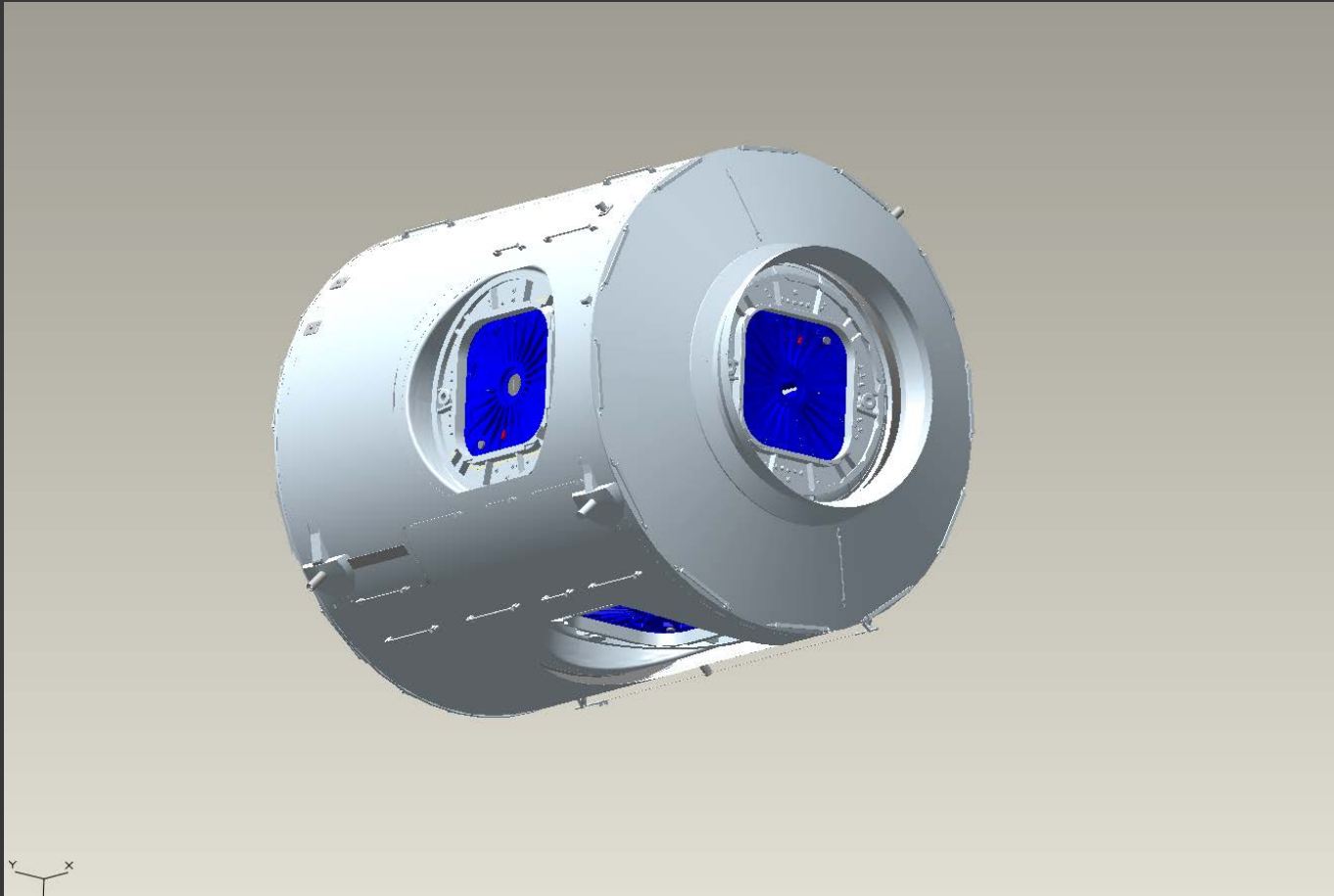
# Comparison to RAM Data



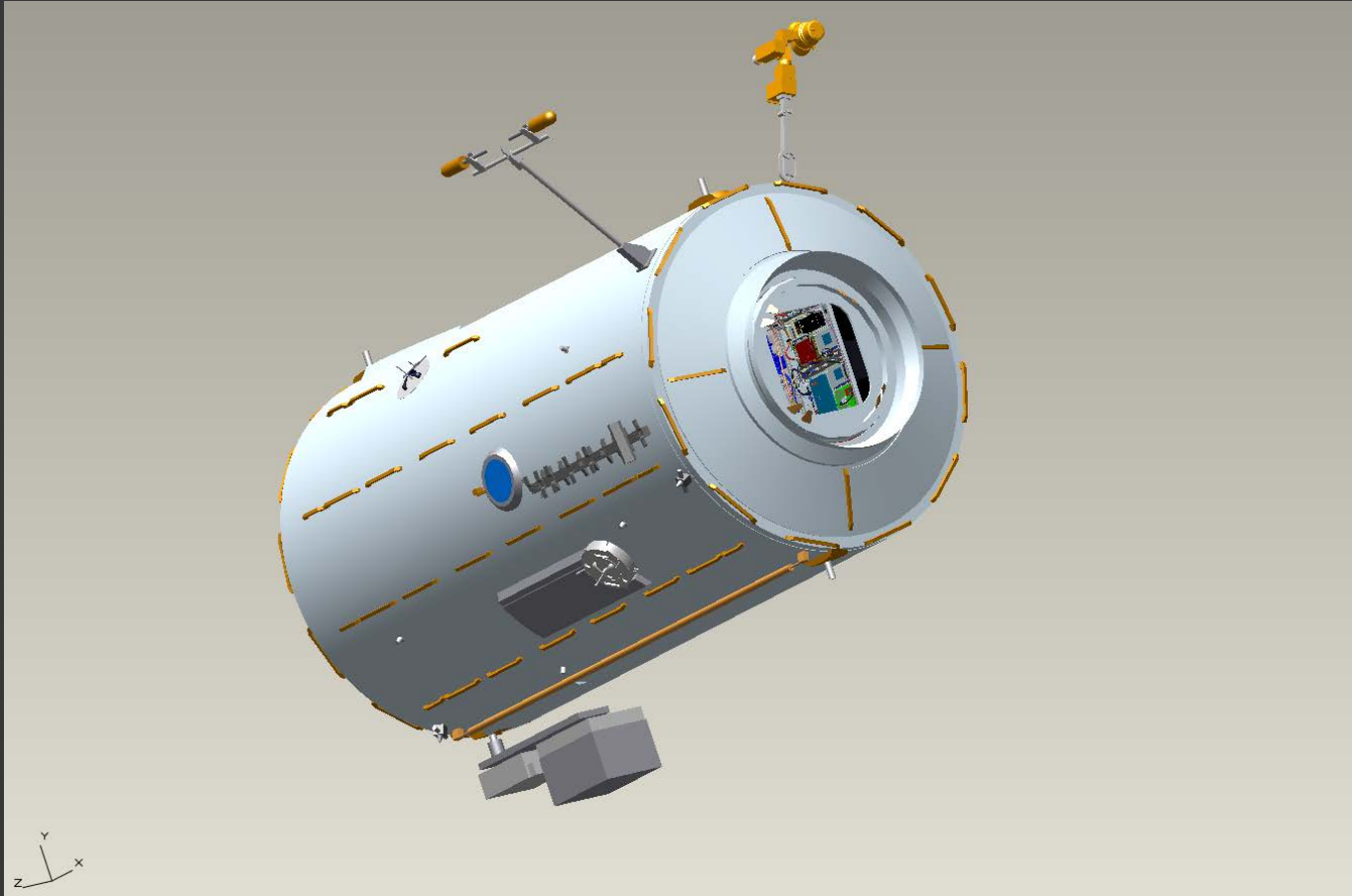
# A/L1-AD3



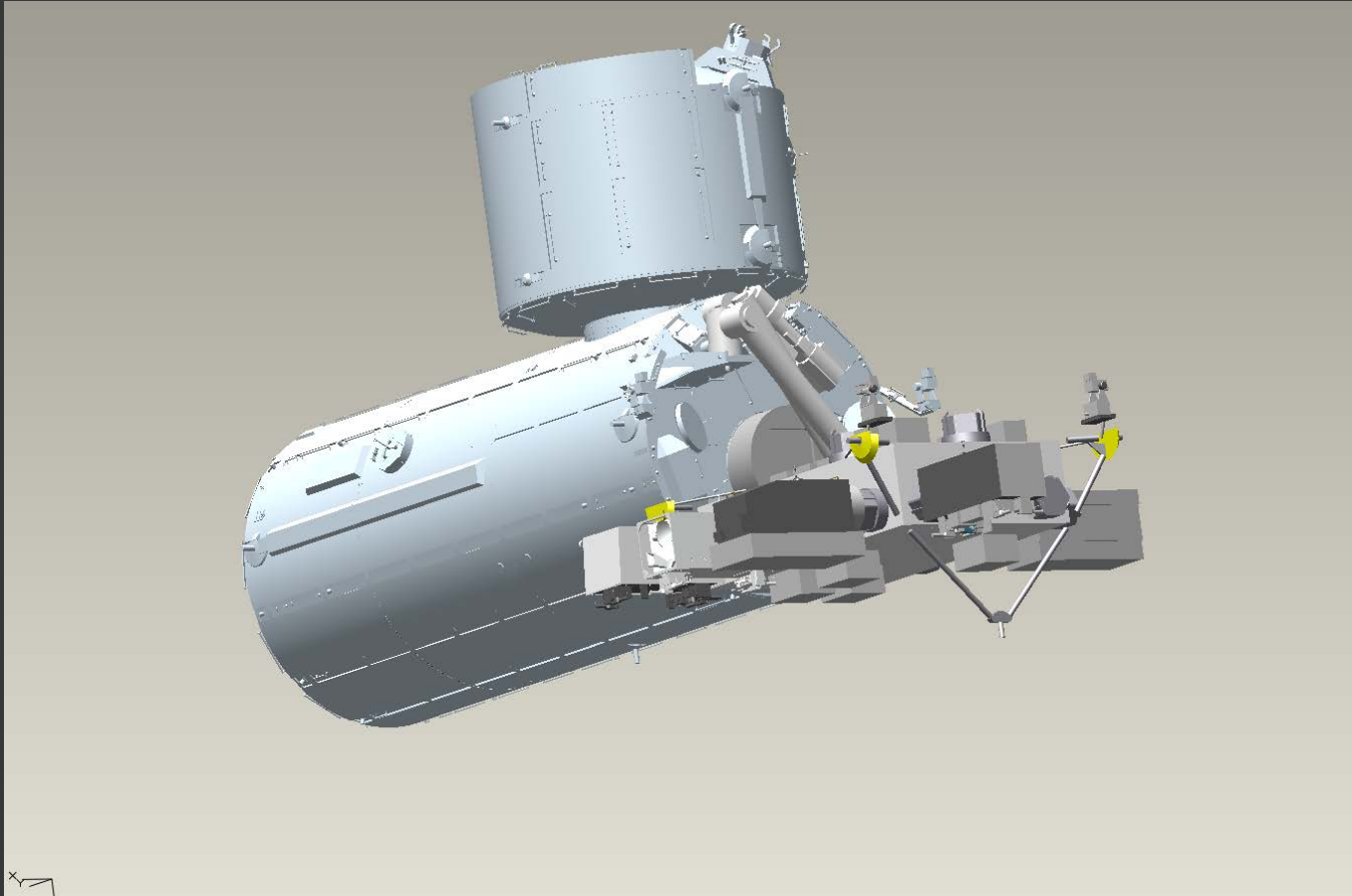
# NOD1P4\_03



# LAB1-D3

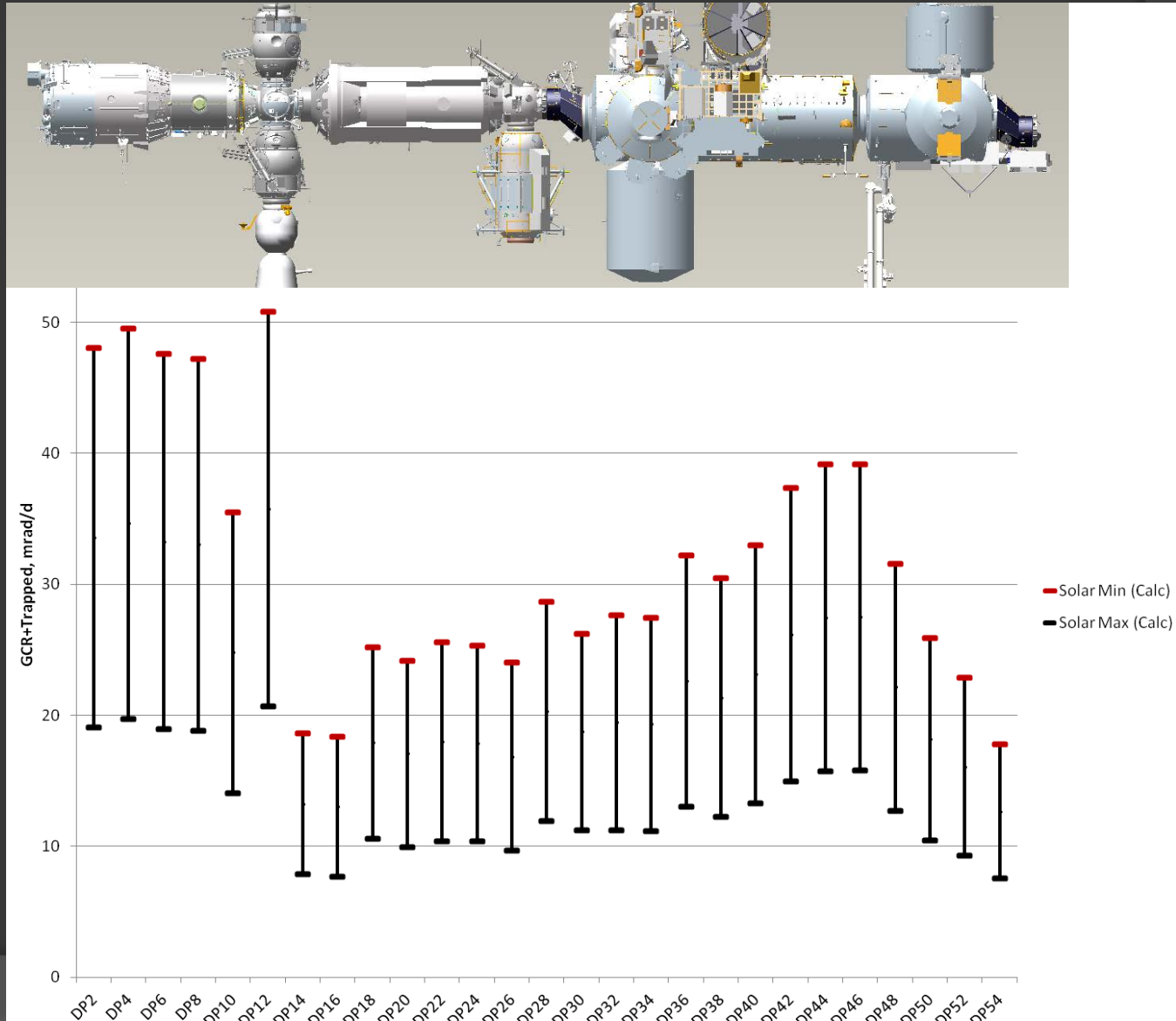


# JLP1A0-01

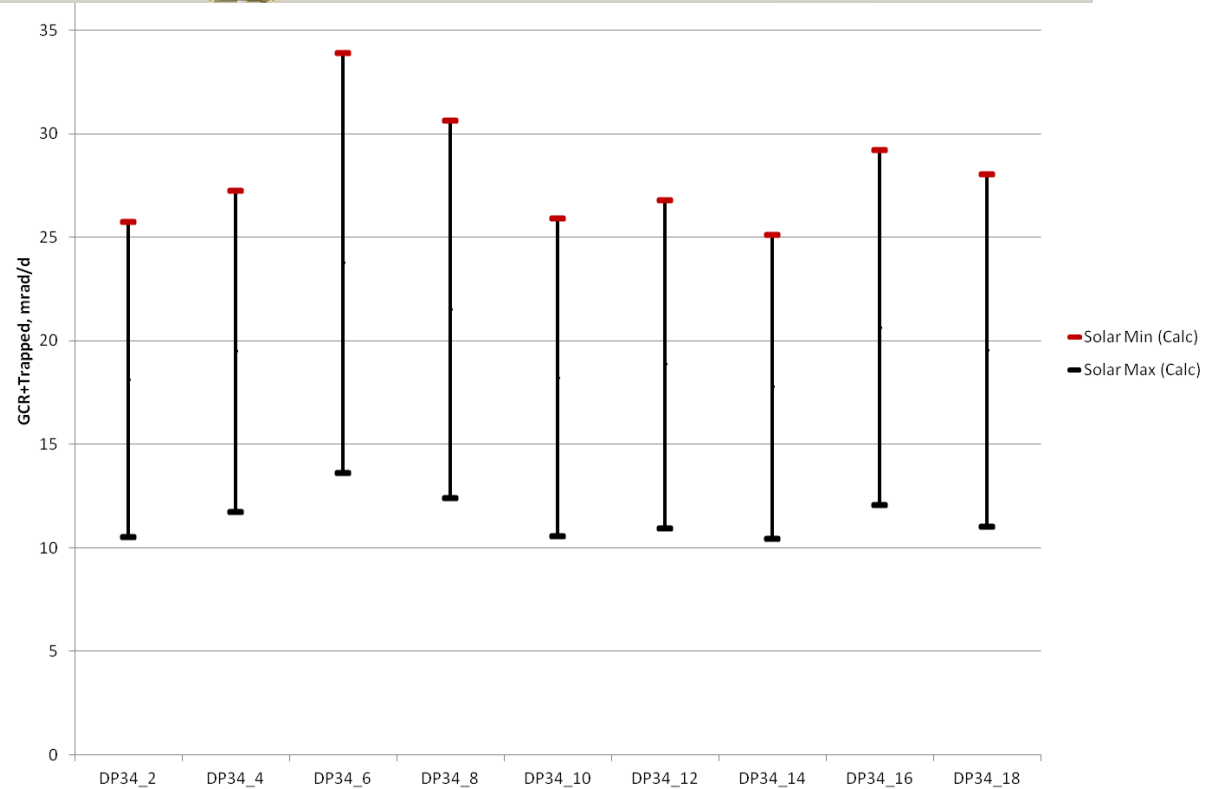
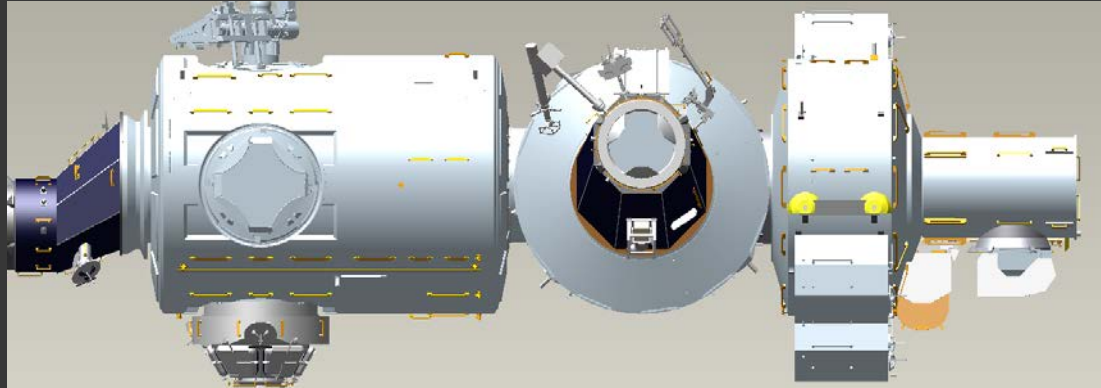


# ISS CAD Shielding Survey

# Primary Axis

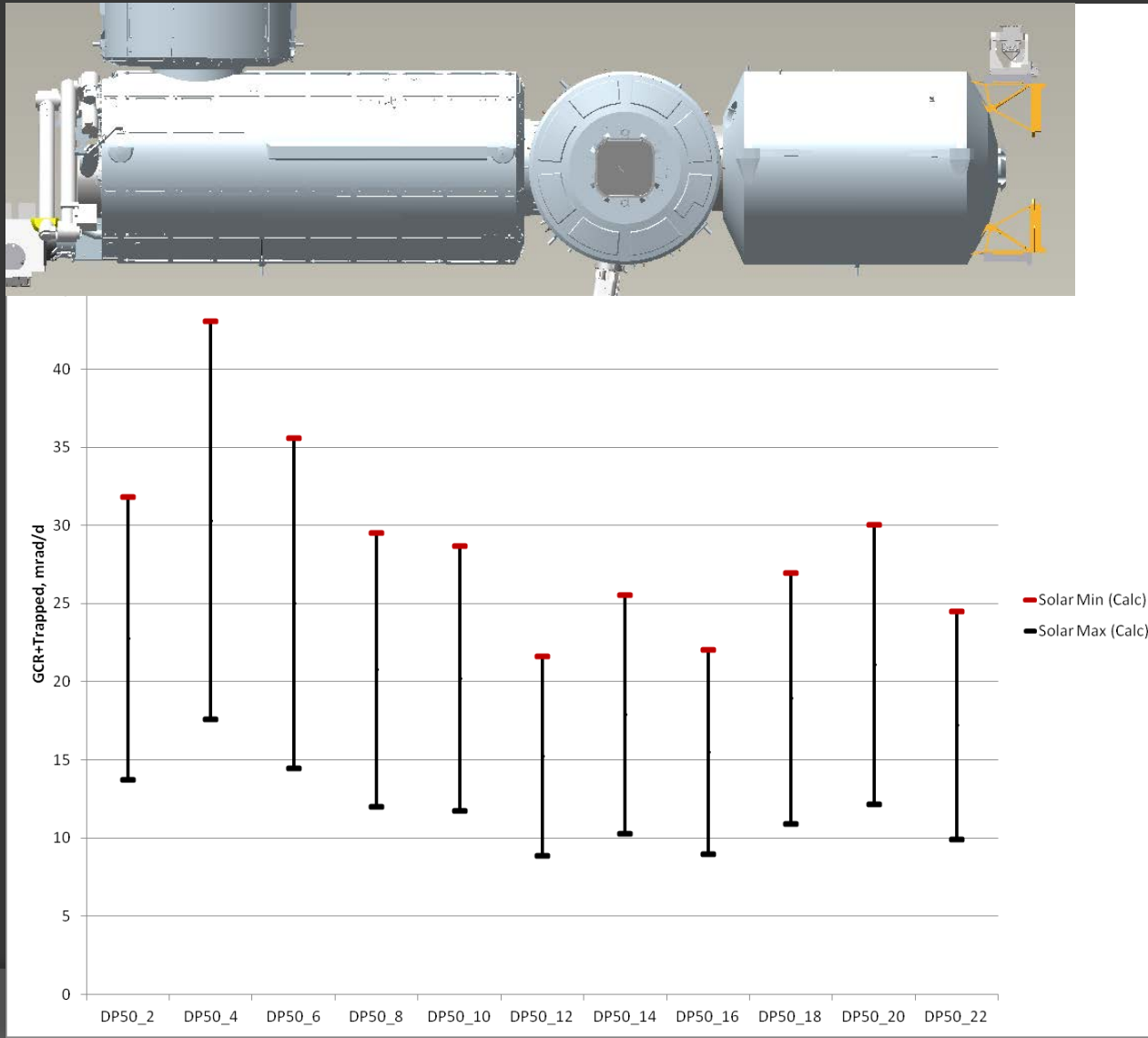


# Node1 Axis



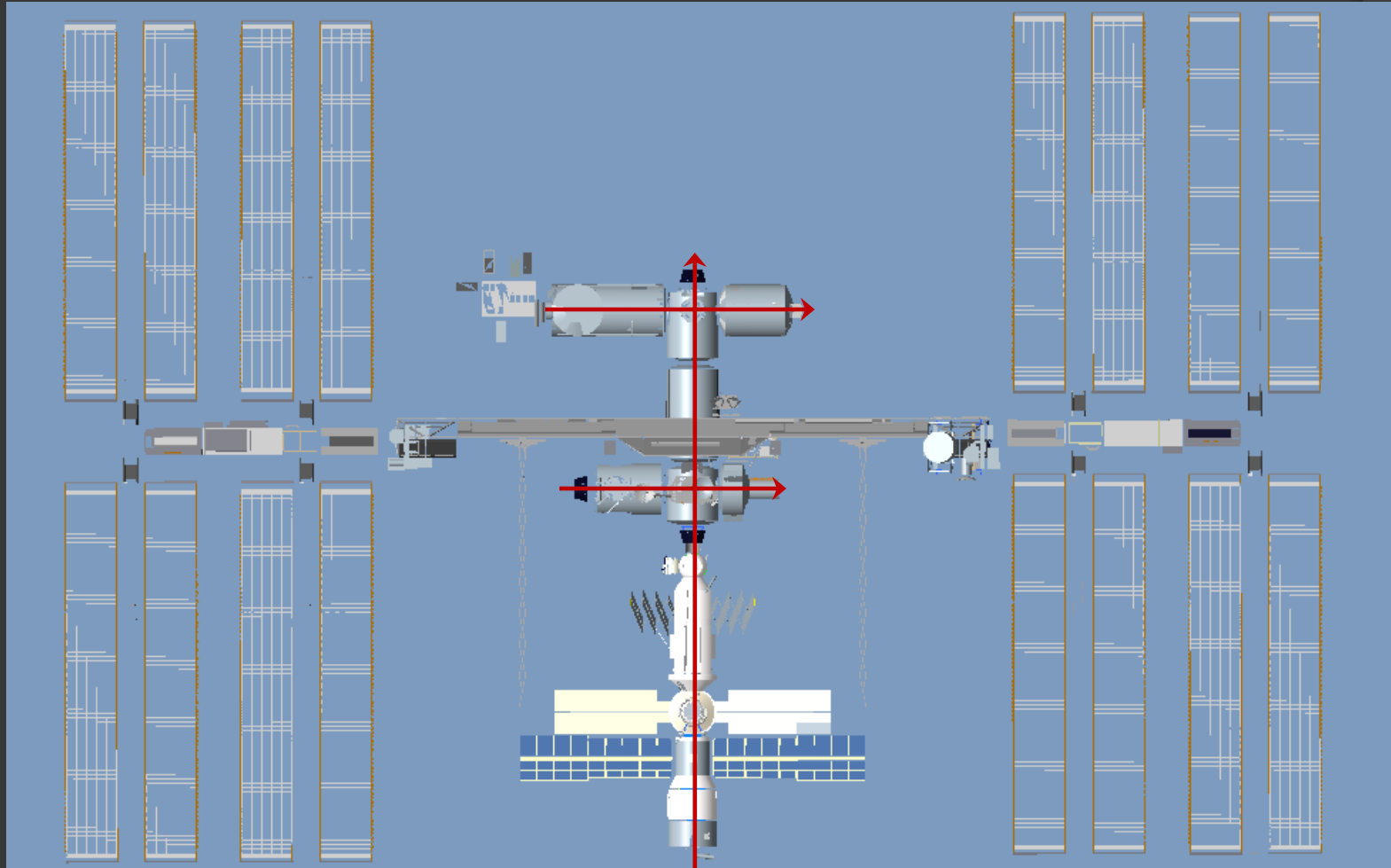


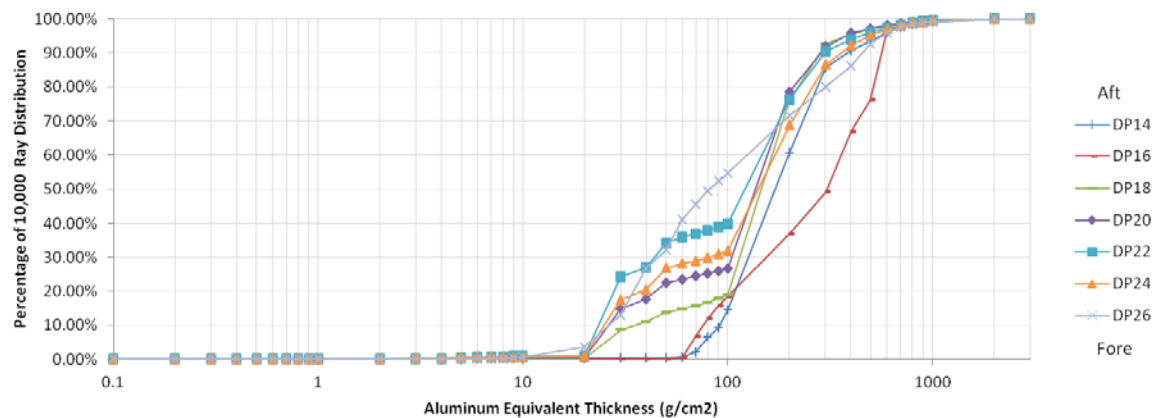
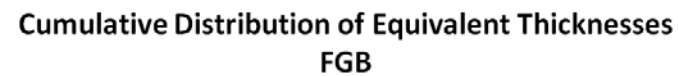
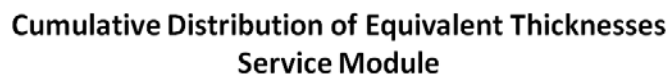
# Node2 Axis



# Mass Distributions

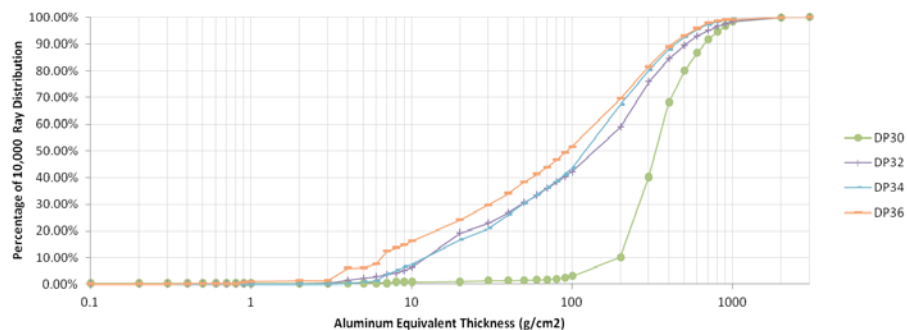
# ISS Survey



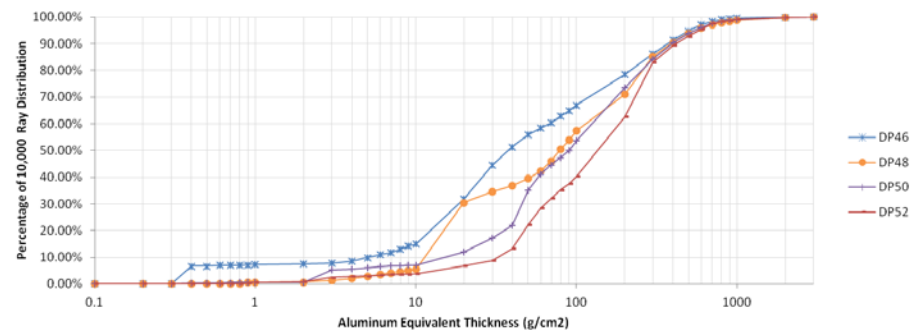




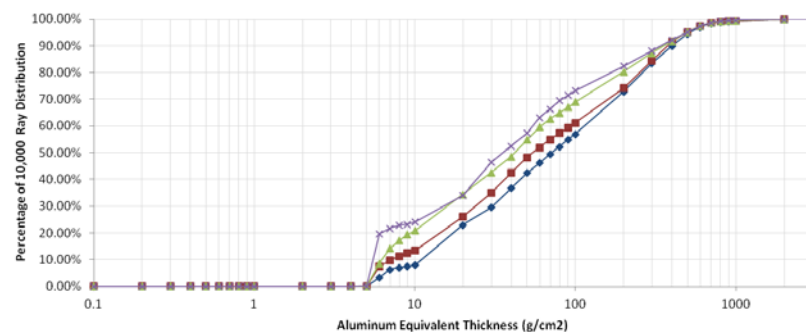
**Cumulative Distribution of Equivalent Thicknesses  
Node1**

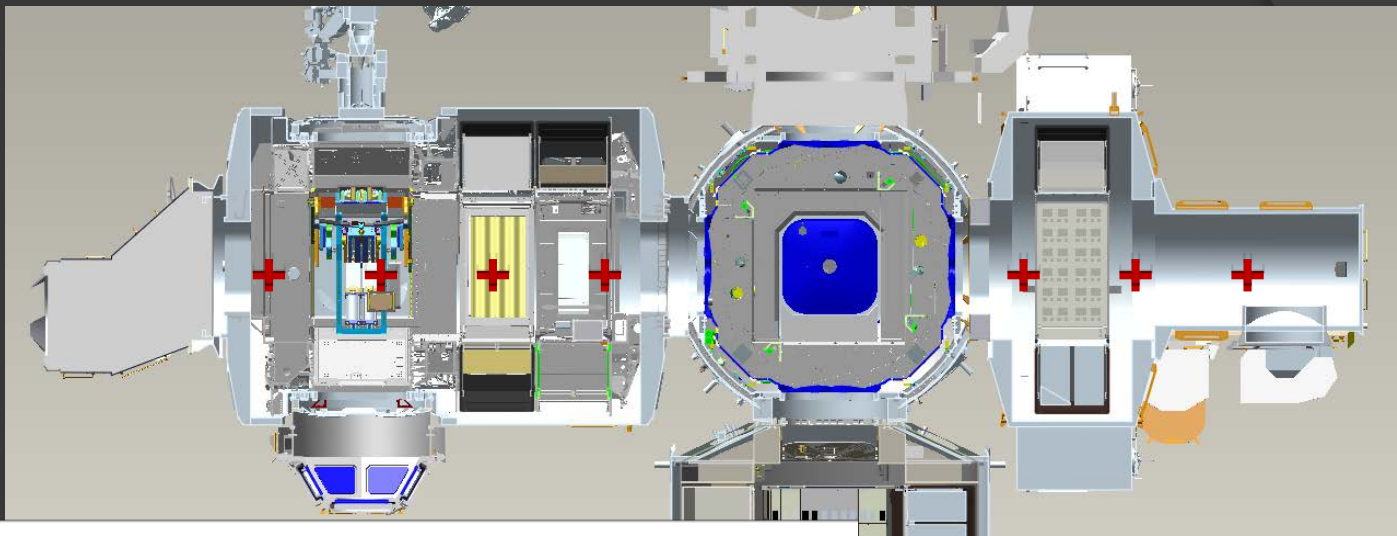


**Cumulative Distribution of Equivalent Thicknesses  
Node2**

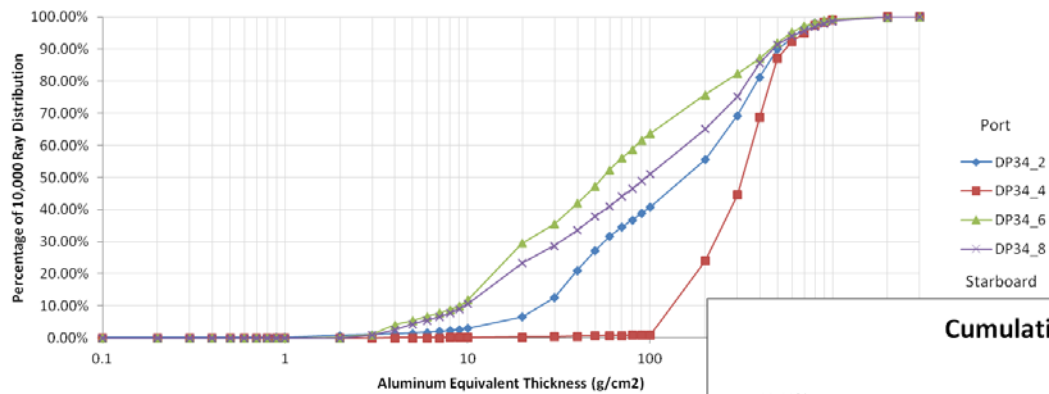


**Cumulative Distribution of Equivalent Thicknesses  
US Lab**

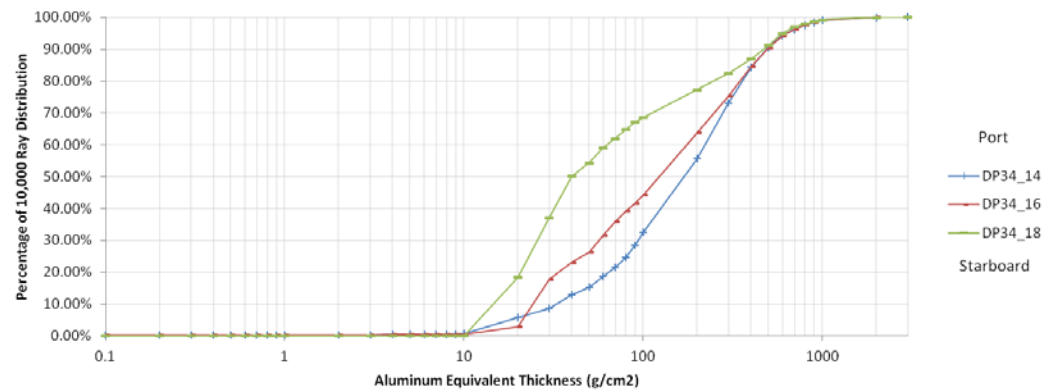


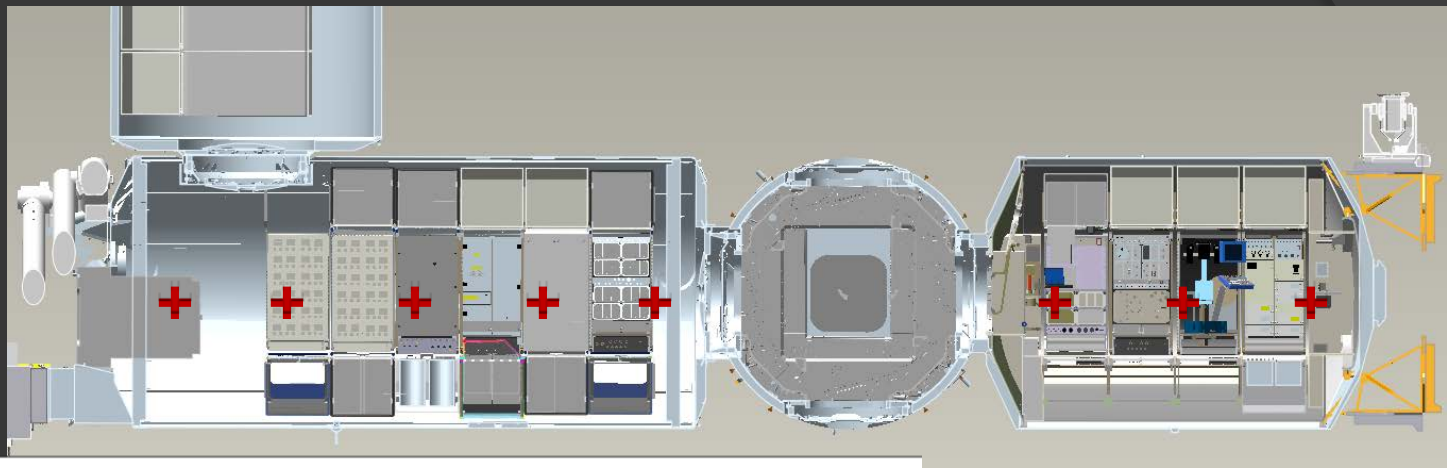


**Cumulative Distribution of Equivalent Thicknesses  
Node3**

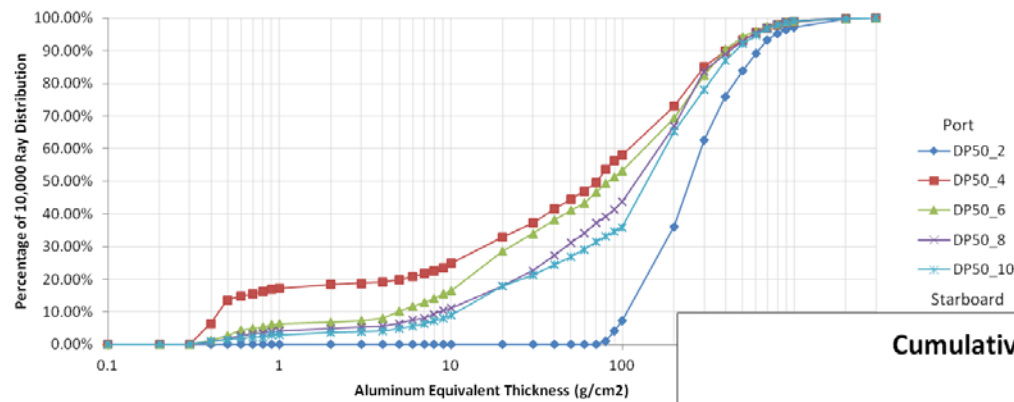


**Cumulative Distribution of Equivalent Thicknesses  
US Airlock**

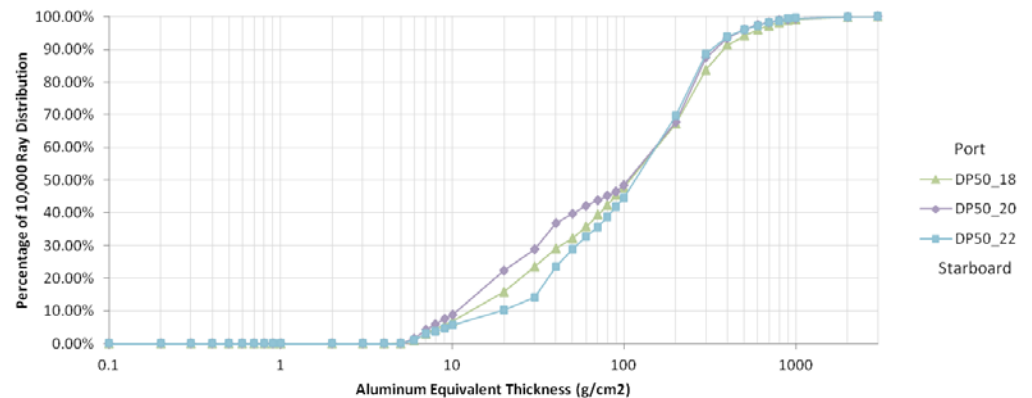




**Cumulative Distribution of Equivalent Thicknesses  
JPM**



**Cumulative Distribution of Equivalent Thicknesses  
Columbus**



# Current Limitations and Forward Work



# Material Assignment Limitations

- ⦿ Material assignment from parts database
  - Issues with model name associations
  - Comprehensive database yet to be found
- ⦿ HZETRN limitations on Dose Calculation
  - Currently used HZETRN limited in matrix dimension for interpolation

# Updates to US Module Model Fidelity

- ⦿ Refine Pressure shell thicknesses
  - Currently using crude estimates
  - High Fidelity external model archives are available
- ⦿ Resolve issues with rack hardware represented as surfaces (no volume)

# IP Module and Visiting Vehicle Model Fidelity

- Included models are a “best guess” based on information derived from on-orbit imagery and stripped down models
- Availability of ProE, IGES, STP format models for internal structure, rack, and equipment would help refine these segments of the model