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DATE:	October 10, 2002	**Action Item #: 1608**
RE:	Robotic Ops Near or Inside the AMS Magnetic Field	
CC:	Gene Cook/OZ, Bob Miley/OZ, Victor Sanders/TBE, William Corley/TBE, Richard Golick/OZ, Trent Martin/LM, Ken Bollweg/LM, Monica Visinsky/OSS, Shakeel Razvi/OM, RS Library	
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The MAGIK Robotic Analysis Team has re-assessed the robotic operations near the Alpha Magnetic Spectrometer (AMS) from MAGIK Action Item (AI) #1321, "AMS 6 Gauss Keep Out Zone." AI #1321 identified several Orbital Replacement Units (ORUs) on the S1 and S3 Integrated Truss Segments (ITS) which, when removed or replaced by the Special Purpose Dexterous Manipulator (SPDM), the SPDM must penetrate the 6 Gauss magnetic field box, as defined in ISS Electromagnetic Effects Panel Tailoring/Interpretation Agreement (EMEP TIA) # 0310, Rev F.

Assumptions:

- This analysis addresses kinematic feasibility by analyzing manipulator configurations during robotic tasks. These manipulator configurations are driven by numerous constraints such as clearance with Orbiter or ISS structure, and manipulator joint limits and singularities. Areas not addressed in this document – lighting, EVA/EVR tasks, viewing, thermal and/or pressure effects on elements, and dynamics – could have a significant influence on manipulator configurations and overall feasibility.
- 3D graphical models used in this analysis are a result of the MAGIK Team's "best efforts" to obtain/create accurate models reflecting actual volumetric dimensions of the various ISS elements. "Best efforts" include obtaining models directly from the ISS CAD Modeling Team, the hardware designers, or a 3rd party (a source other than the hardware designers), or creating models from hardware designer or customer provided drawings/information.
- Specific model pedigrees may be obtained from the MAGIK Team upon request.
- The trajectories and specific robot joint angles used in this analysis are not necessarily the final configurations that will be used on-orbit.
- The distance from the SPDM task arm grasp fixture to the SPDM stabilization fixture must be greater than 36 inches.

The results of AI #1321 were based on analysis performed by the Boeing Huntington Beach EVA group and their suggested stabilization fixtures used for specific ORU remove & replace (R&R). This memo is a documentation of MAGIK analysis performed to determine kinematic feasibility of ORU R&R using alternate SPDM stabilization fixtures, and therefore keeping the SPDM out of the 6 Gauss magnetic field. Based on the EVA group's information, the following ORUs were listed in AI #1321 as requiring the SPDM to enter inside the 6 Gauss box for an R&R operation:

S1:

RPCMs 1-8 (ISS Nadir)
DDCU
RJMC #2 (ISS Nadir)
MDM #5 (ISS Nadir)

S3:

MDMs 1 and 2
RPCMs 1-8
MT Stop

After further analysis, the MAGIK Team has determined that nearly all of these ORUs can be replaced using the SPDM while based on alternate stabilization fixtures. In addition to determining kinematic feasibility of the R&R from an alternate stabilization point, a more accurate 6 Gauss envelope was created and used instead of the conservative 6 Gauss box. This analysis has determined that the following ORUs will require the SPDM to enter into the 6 Gauss envelope:

S1:

None (all are accessible without entering the 6 Gauss Skin)

S3:

RPCMs 3 and 4

EXP:

SPDM access to the three payloads closest to the AMS (ISS port side of the pallet) requires penetrating the 35 Gauss envelope. SPDM access to the three payloads farthest away from the AMS (ISS starboard side of the pallet) does not require penetration of the 35 Gauss envelope, but does require penetration of the 6 Gauss envelope.

MAGIK Magnetic Field Envelope/Skin Development:

35 Gauss Envelope/Skin Development:

- High fidelity 3D CAD model of AMS 35 Gauss magnetic field was received from Ross Harold/Lockheed in December 2001.
- High Fidelity model was re-modeled by MAGIK in low fidelity.
  - See Figure 1
  - MAGIK envelope encompasses AMS envelope, and therefore, is more conservative

6 Gauss Envelope/Skin Development:

- No 3D CAD model of the 6 Gauss field was provided to MAGIK, however, a database of field readings at many points around the AMS was provided to MAGIK by Lockheed in December 2001.
- The database points for 6 Gauss magnetic strength were plotted in three axes.
- The MAGIK low fidelity 35 Gauss envelope was then scaled equally in all three axes until it encompassed the 6 Gauss plotted points.
- This new envelope represents the MAGIK low fidelity 6 Gauss skin.
  - See Figure 2

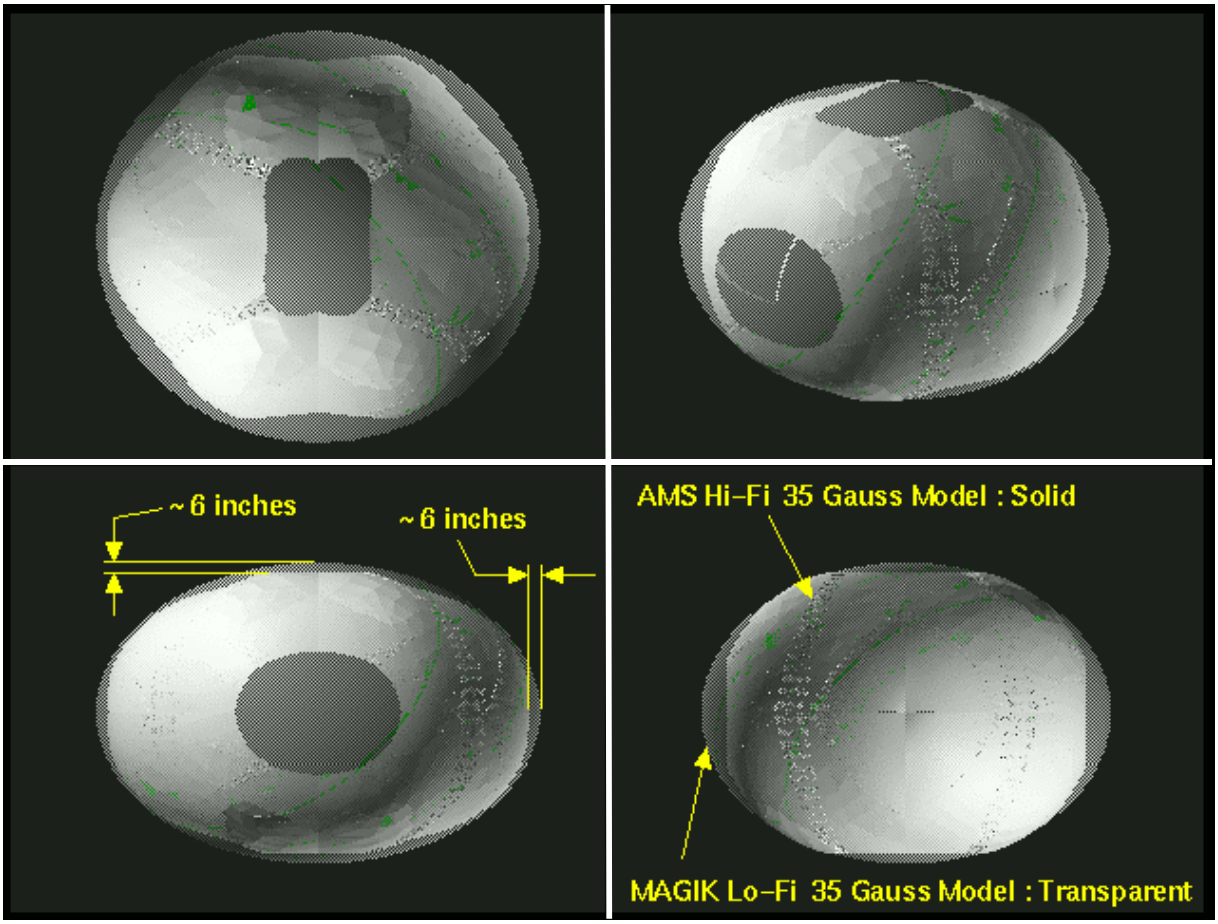

Figure 1: AMS High Fidelity and MAGIK Low Fidelity 35 Gauss Envelopes/Skins

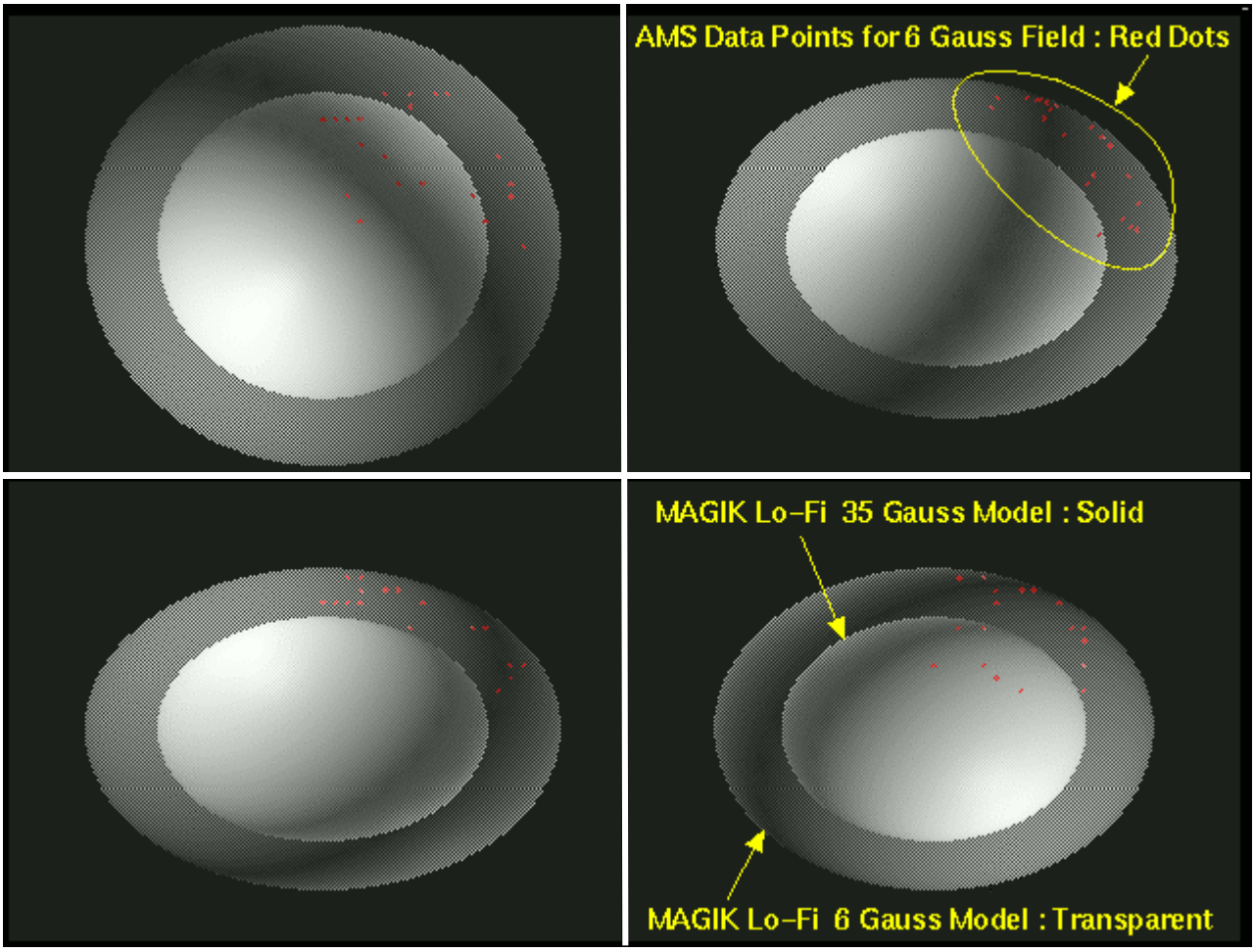

Figure 2: MAGIK Low Fidelity 35 & 6 Gauss Envelopes/Skins and Plotted Points from AMS 6 Gauss Database

Figure 3 and Figure 4 show the MAGIK magnetic field skins and the original 6 Gauss box as they relate to the AMS and surrounding structure. Figure 5 shows the magnetic field skins and the surrounding ORUs located on S1 and S3.

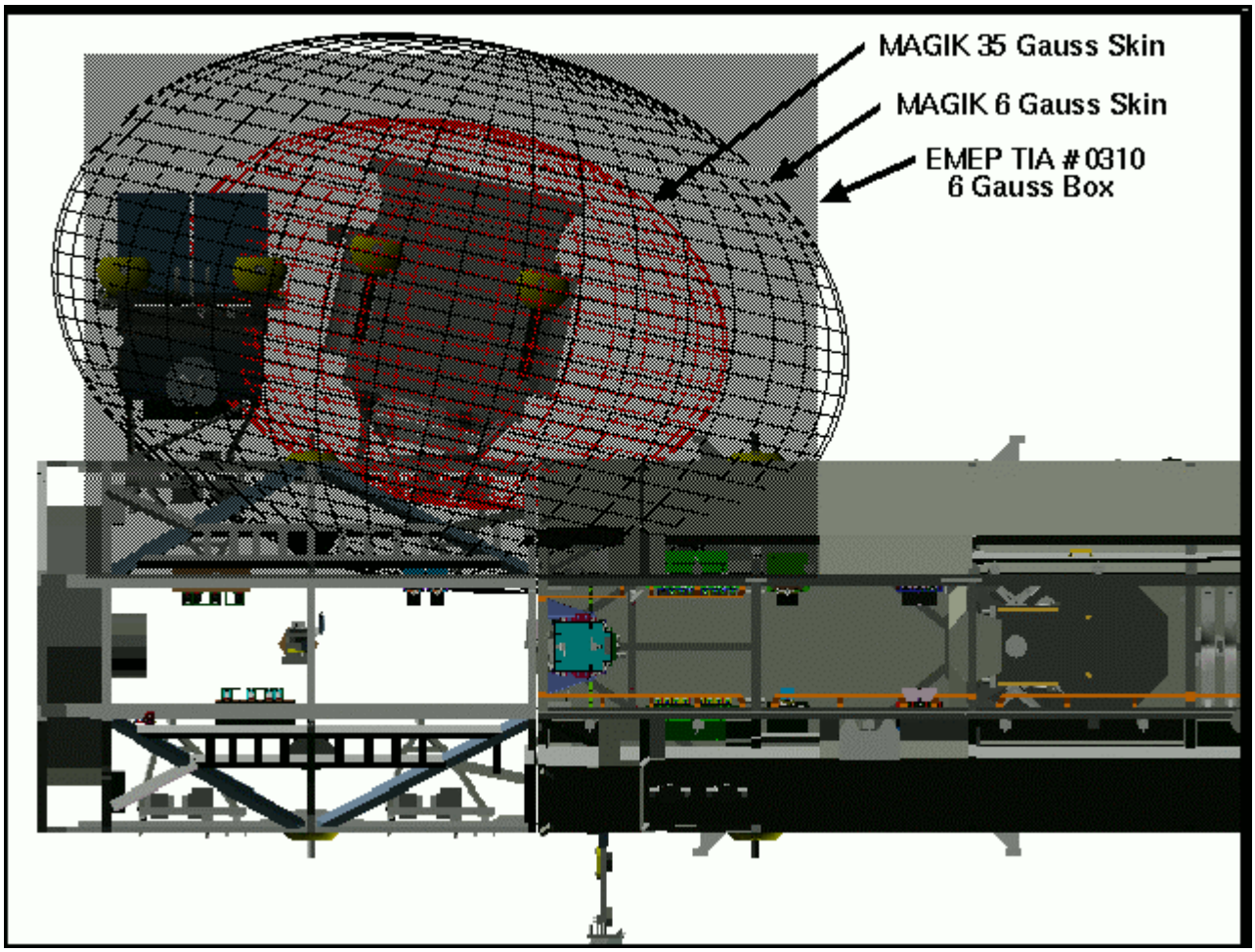

Figure 3: Magnetic Field Skins
ISS Front View

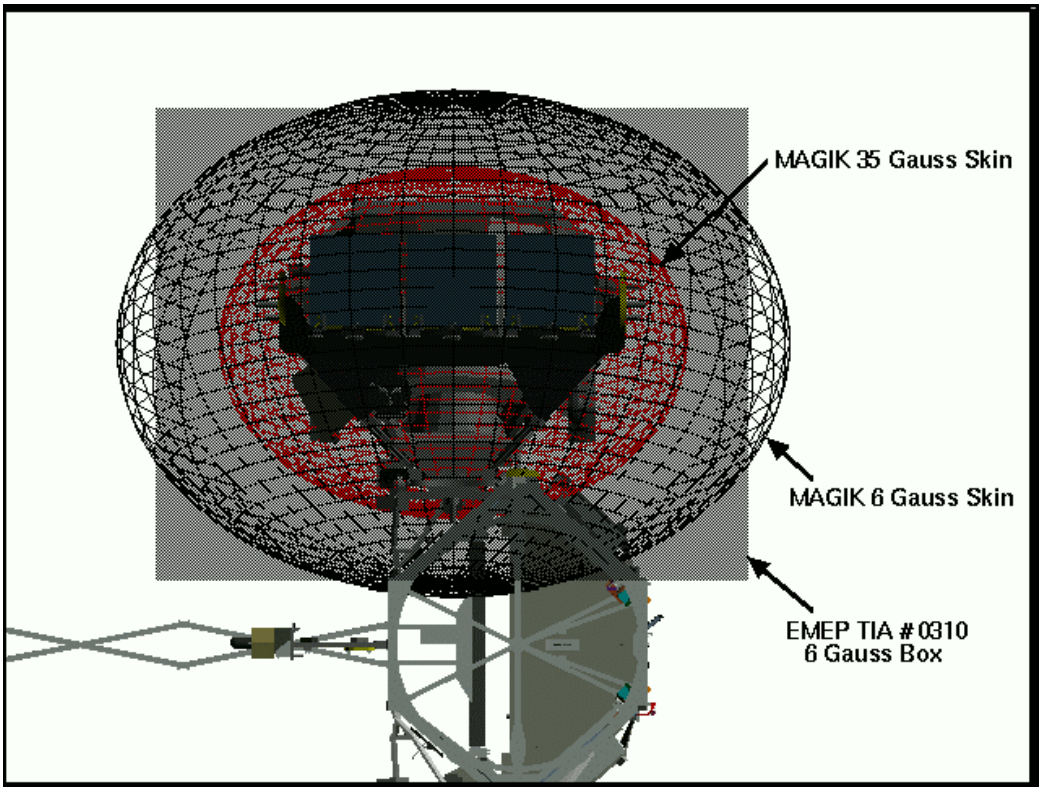

Figure 4: Magnetic Field Skins
ISS Starboard View

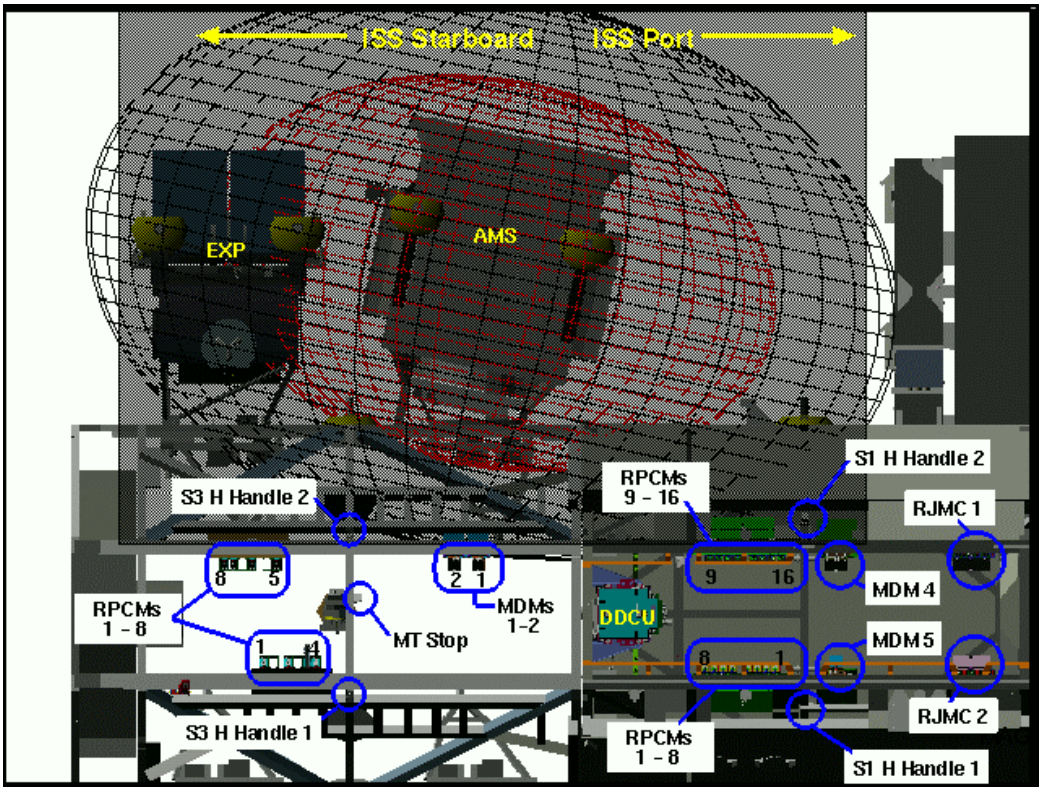

Figure 5: AMS Magnetic Field Skins and Surrounding S1/S3 ORUs
ISS Front View

The following table illustrates the kinematic feasibility of accessing each ORU on S1 and S3 and whether the SPDM must enter into the magnetic field envelopes.

	SPDM Stabilization H Handle	SPDM Clear of 6 Gauss Box?	SPDM Clear of 6 Gauss Skin?	Figure #
S1				
RPCM 1	**S1 HH #2***	NO	yes	Figure 6, Figure 7
RPCM 2	**S1 HH #2***	NO	yes	
RPCM 3	S1 HH #1	NO	yes	Figure 8
RPCM 4	S1 HH #1	NO	yes	
RPCM 5	S1 HH #1	NO	yes	
RPCM 6	S1 HH #1	NO	yes	
RPCM 7	S1 HH #1	NO	yes	
RPCM 8	S1 HH #1	NO	yes	
RPCM 9	S1 HH #1	yes	yes	Figure 9
RPCM 10	S1 HH #1	yes	yes	
RPCM 11	S1 HH #1	yes	yes	
RPCM 12	S1 HH #1	yes	yes	
RPCM 13	S1 HH #1	yes	yes	
RPCM 14	S1 HH #1	yes	yes	
RPCM 15	S1 HH #1	yes	yes	
RPCM 16	S1 HH #1	yes	yes	
MDM 5	**S1 HH #2***	NO	yes	Figure 10, Figure 11
DDCU	S1 HH #1	yes	yes	
RJMC 1	S1 HH #1	yes	yes	Figure 12
RJMC 2	S1 HH #1	yes	yes	Figure 13
S3				
MT Stop	S3 HH #1	NO	yes	Figure 14, Figure 15
RPCM 1	S3 HH #1	NO	yes	Figure 16, Figure 17
RPCM 2	S3 HH #1	NO	yes	
RPCM 3	**S3 HH #2***	NO	**NO**	Figure 18, Figure 19
RPCM 4	**S3 HH #2***	NO	**NO**	
RPCM 5	S3 HH #1	yes	yes	Figure 20
RPCM 6	S3 HH #1	yes	yes	
RPCM 7	S3 HH #1	yes	yes	
RPCM 8	S3 HH #1	yes	yes	
MDM 1	S3 HH #1	yes	yes	
MDM 2	S3 HH #1	yes	yes	

* - The distance from the ORU grasp fixture to HH #1 is less than 36 inches, and therefore, HH #2 must be used to stabilize.

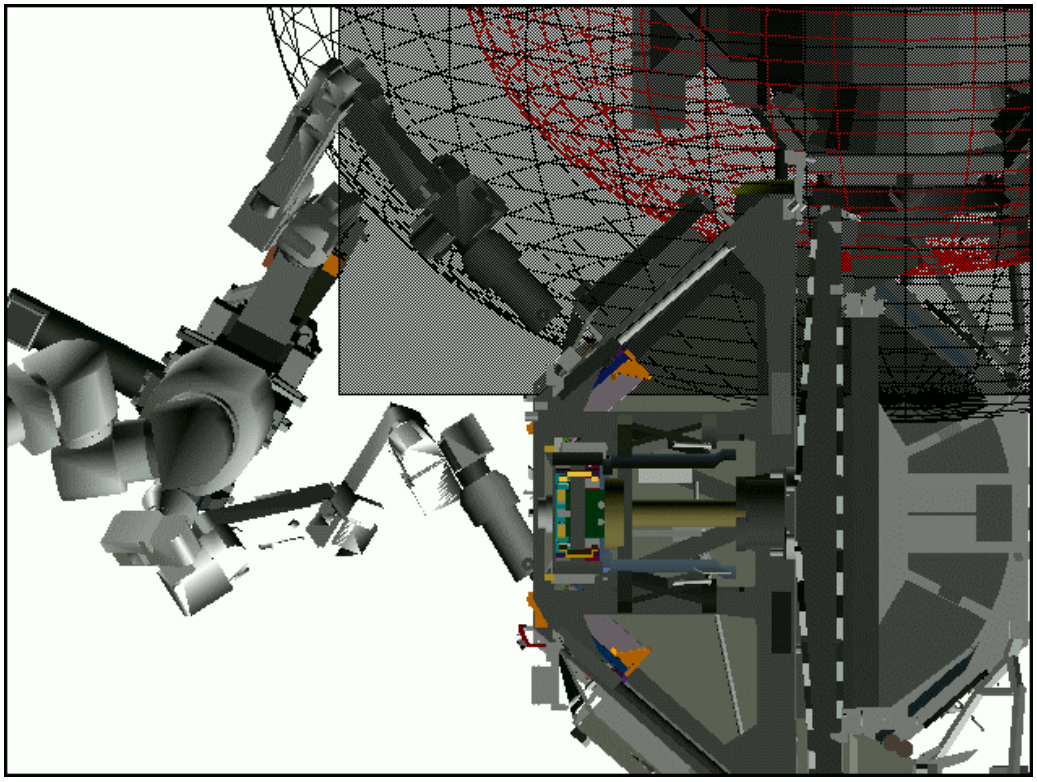

Figure 6: SPDM Access to S1 RPCM 1
ISS Port View

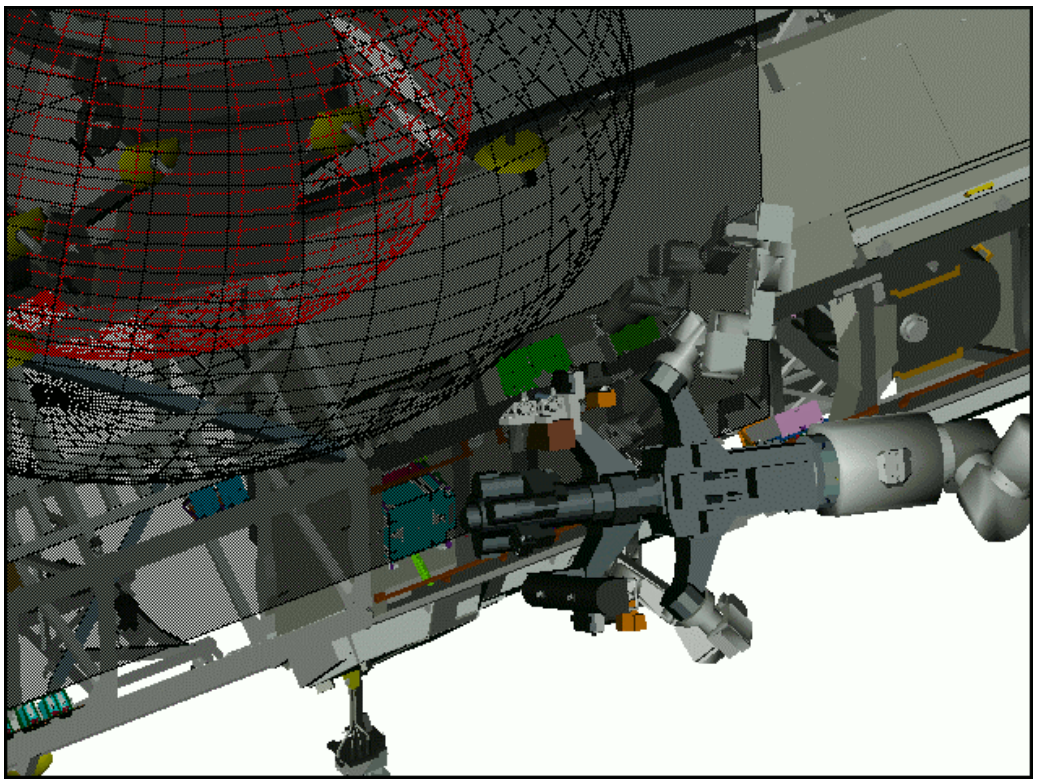

Figure 7: SPDM Access to S1 RPCM 1
Isometric View Looking ISS Nadir-Aft

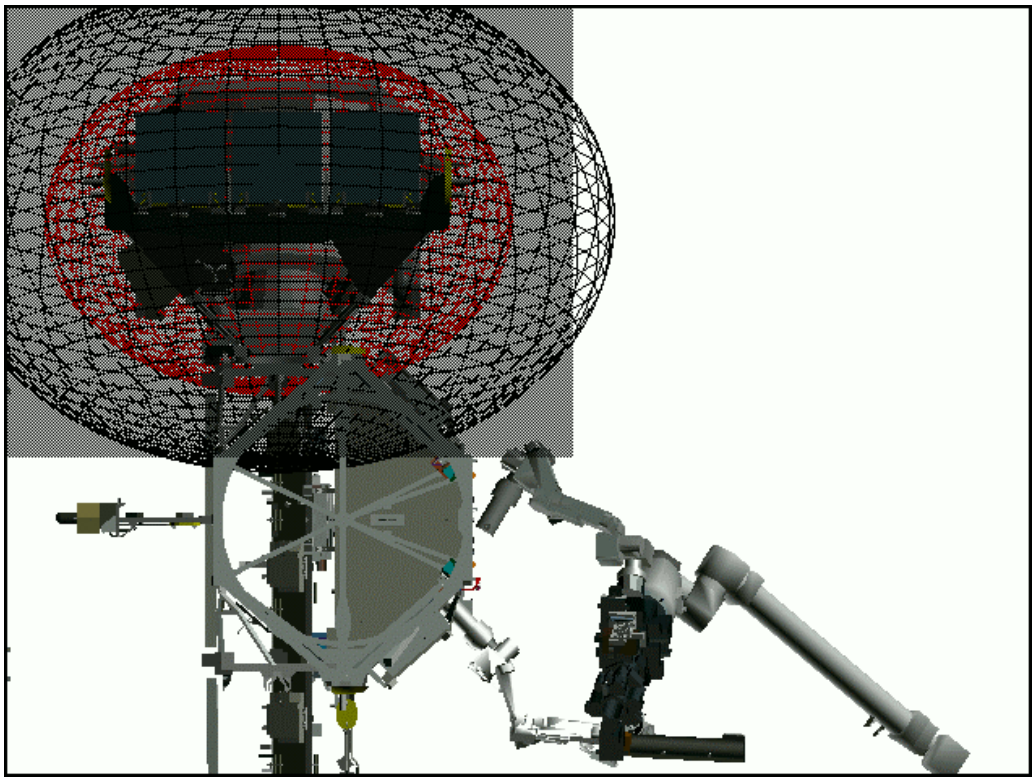

Figure 8: SPDM Access to S1 RPCM 3
ISS Starboard View

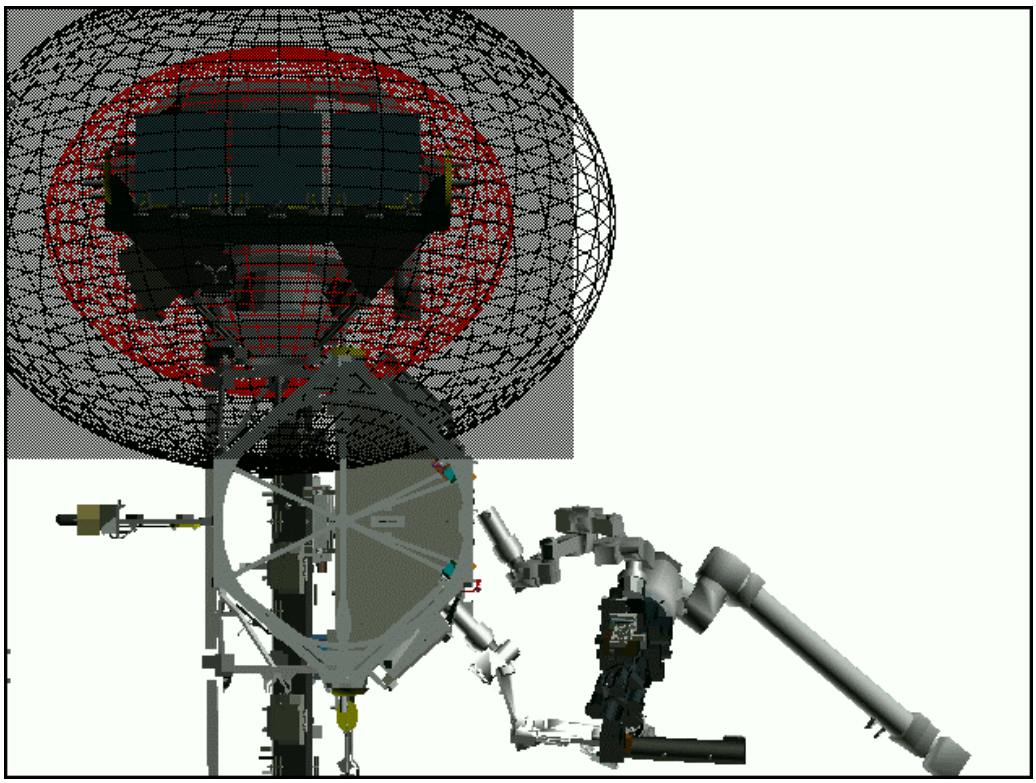

Figure 9: SPDM Access to S1 RPCM 9
ISS Starboard View

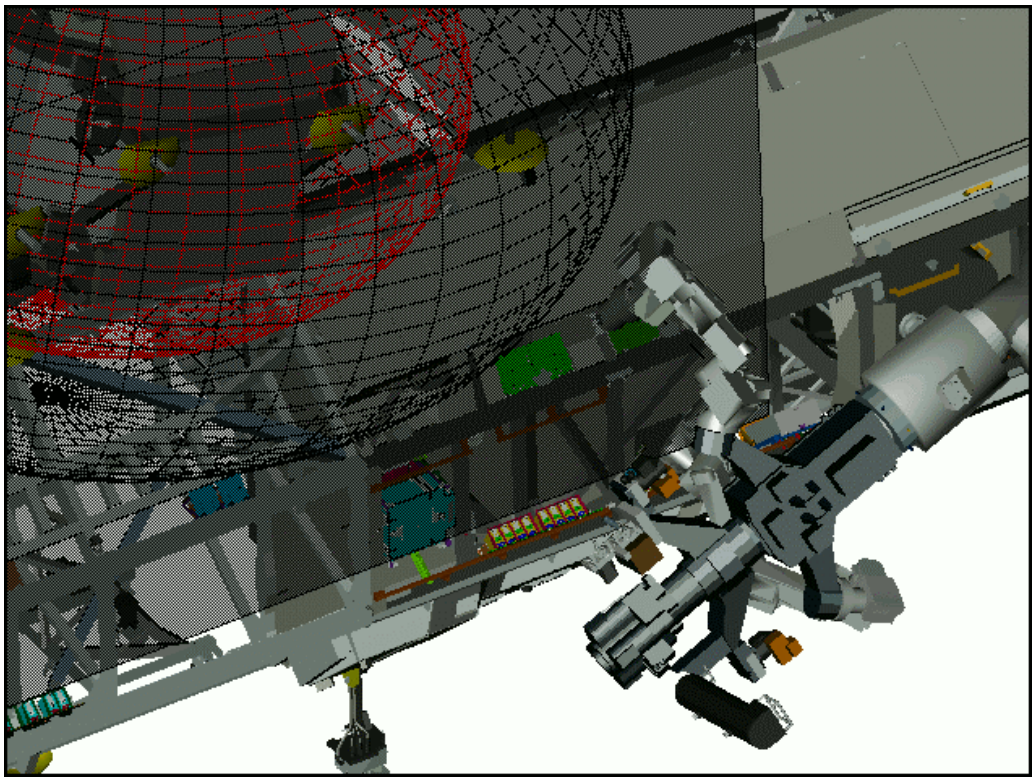

Figure 10: SPDM Access to S1 MDM 5
Isometric View Looking ISS Nadir-Aft

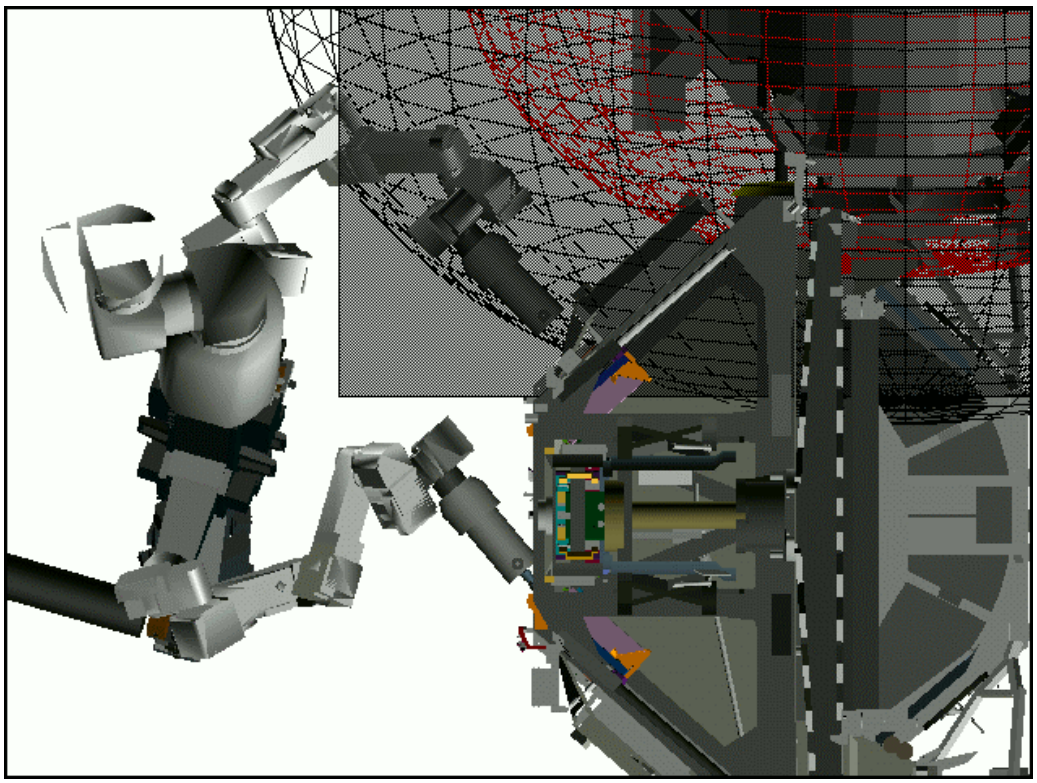

Figure 11: SPDM Access to S1 MDM 5
ISS Port View

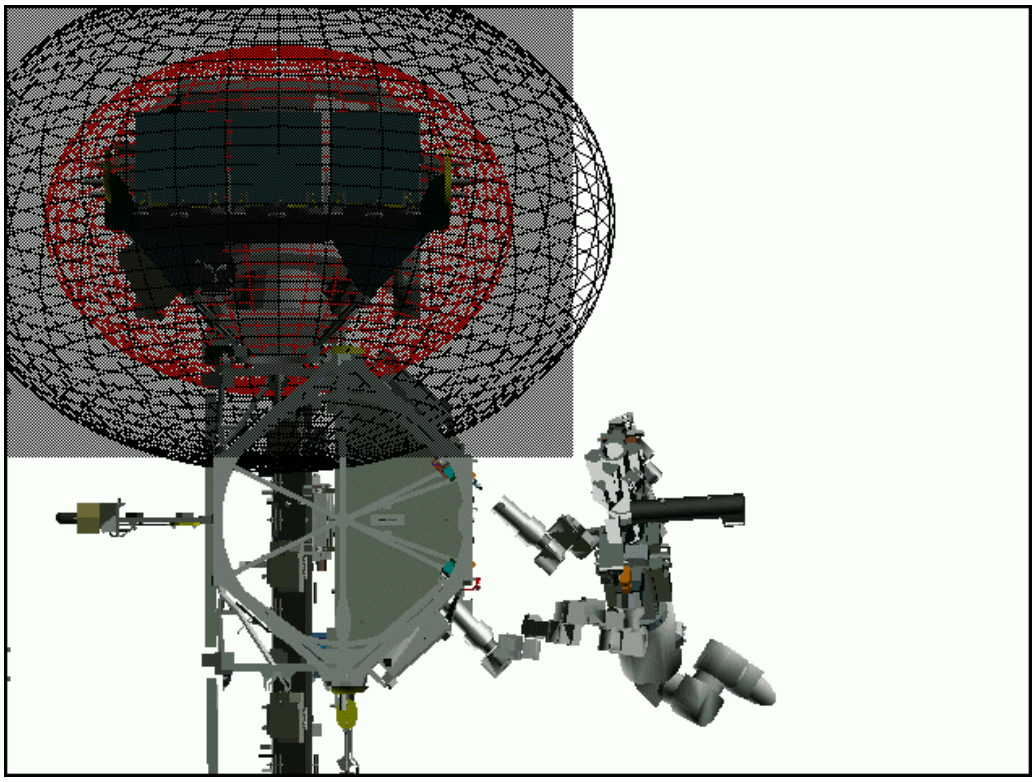

Figure 12: SPDM Access to S1 RJMC 1
ISS Starboard View (SSRMS Clipped from View for Clarity)

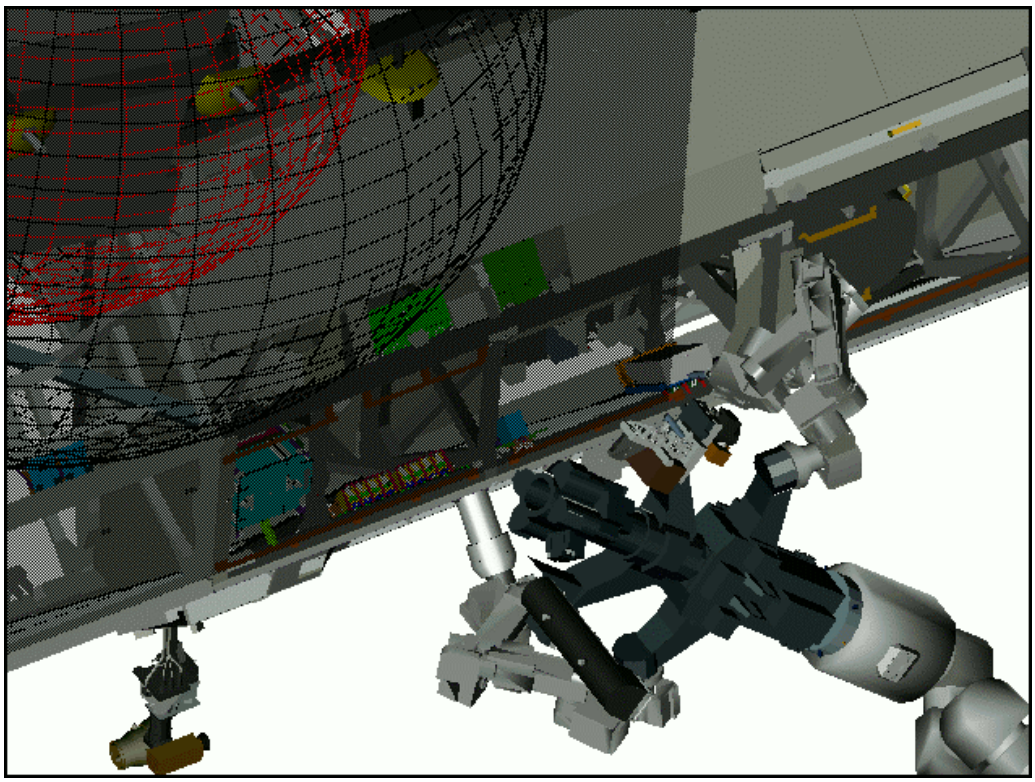

Figure 13: SPDM Access to S1 RJMC 2
Isometric View Looking ISS Nadir-Aft

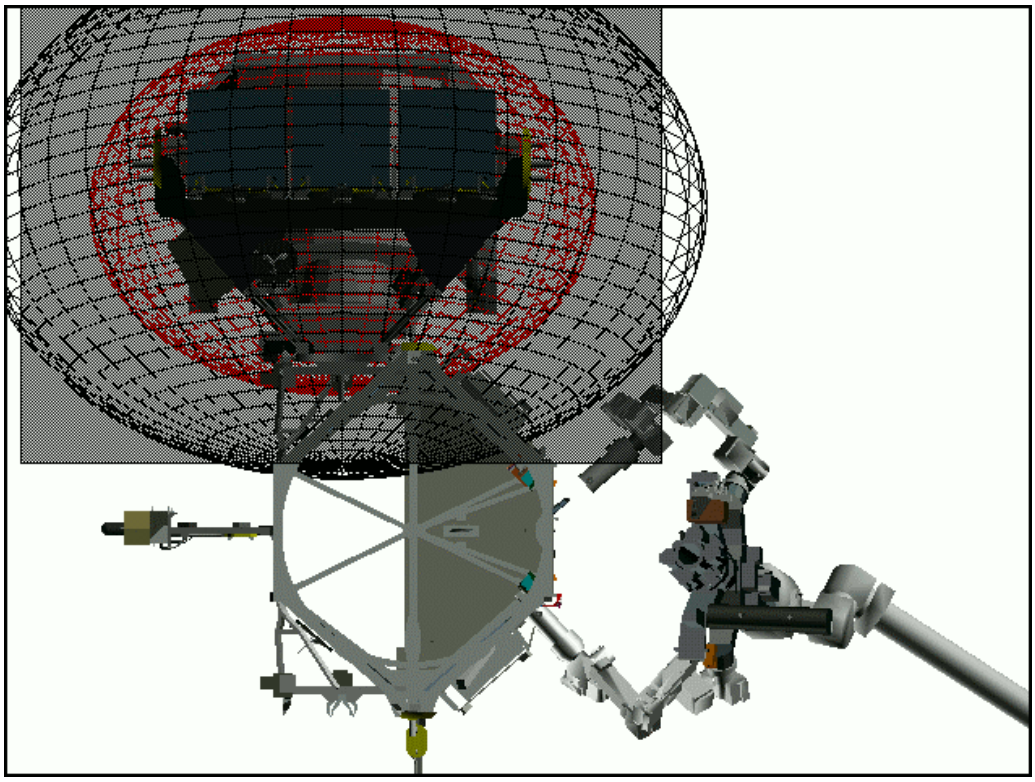

Figure 14: SPDM Access to MT Stop
ISS Starboard View

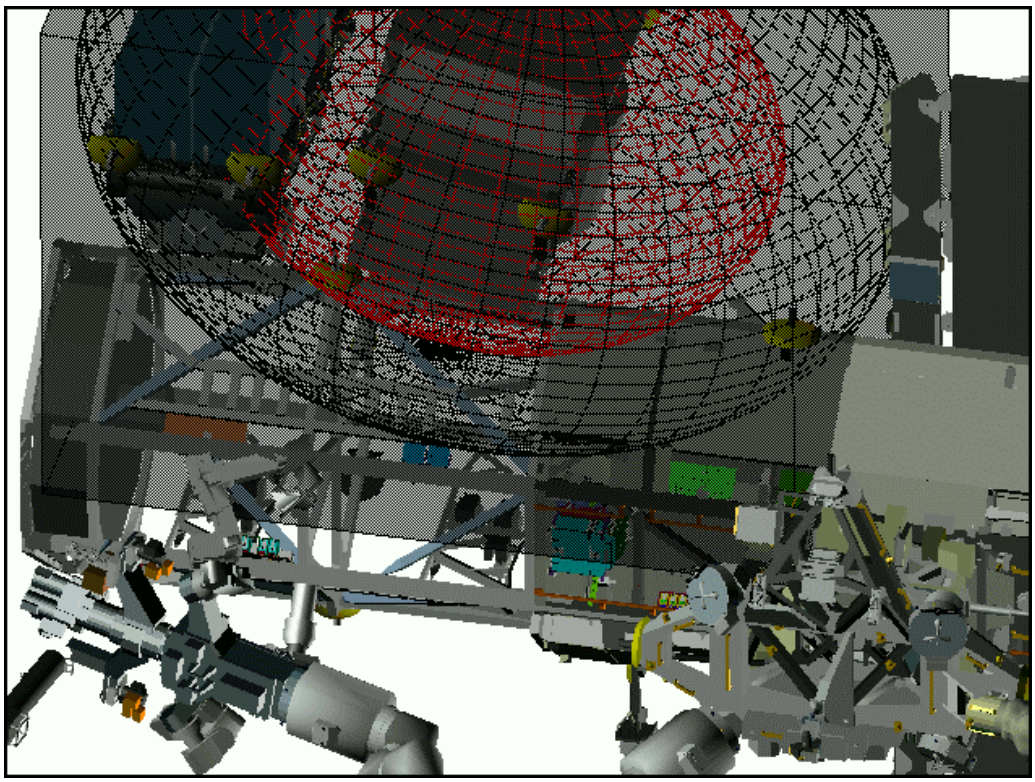

Figure 15: SPDM Access to MT Stop
Isometric View Looking ISS Nadir-Aft

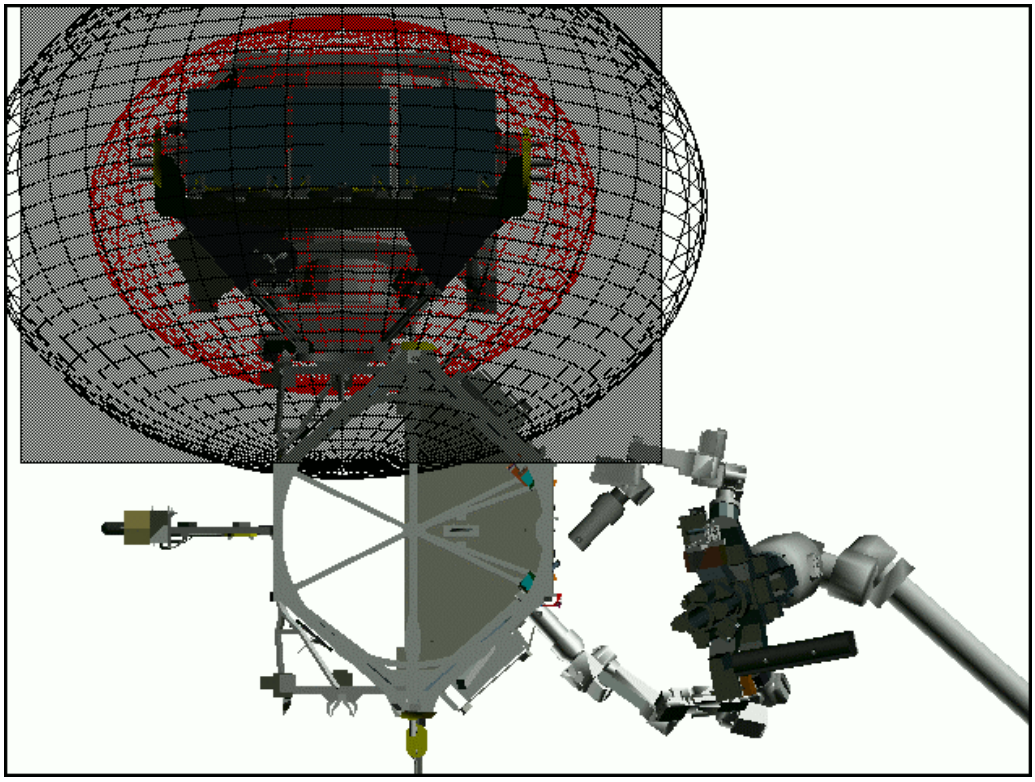

Figure 16: SPDM Access to S3 RPCM 1
ISS Starboard View

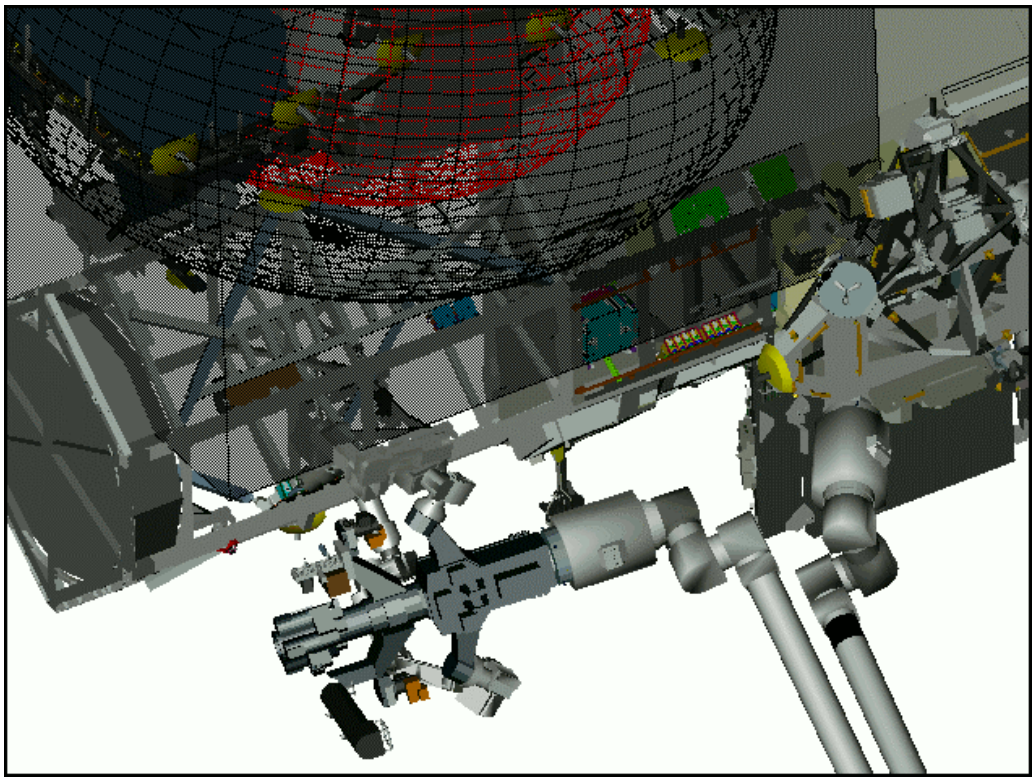

Figure 17: SPDM Access to S3 RPCM 1
Isometric View Looking ISS Nadir-Aft

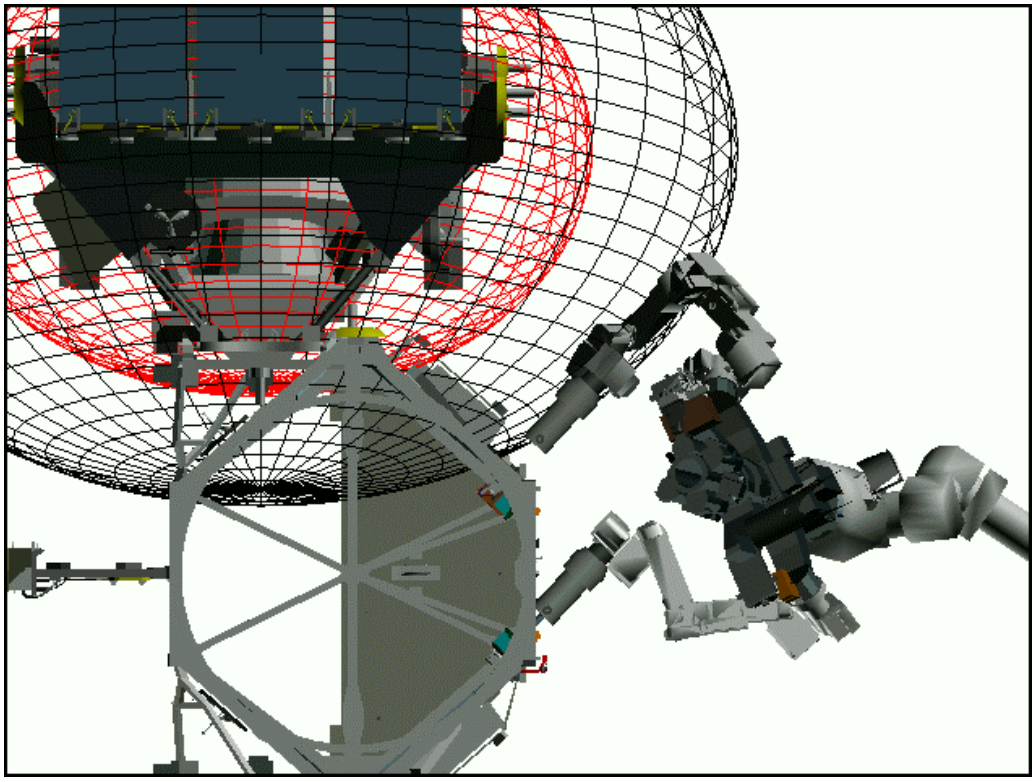

Figure 18: SPDM Access to S3 RPCM 3
ISS Starboard View

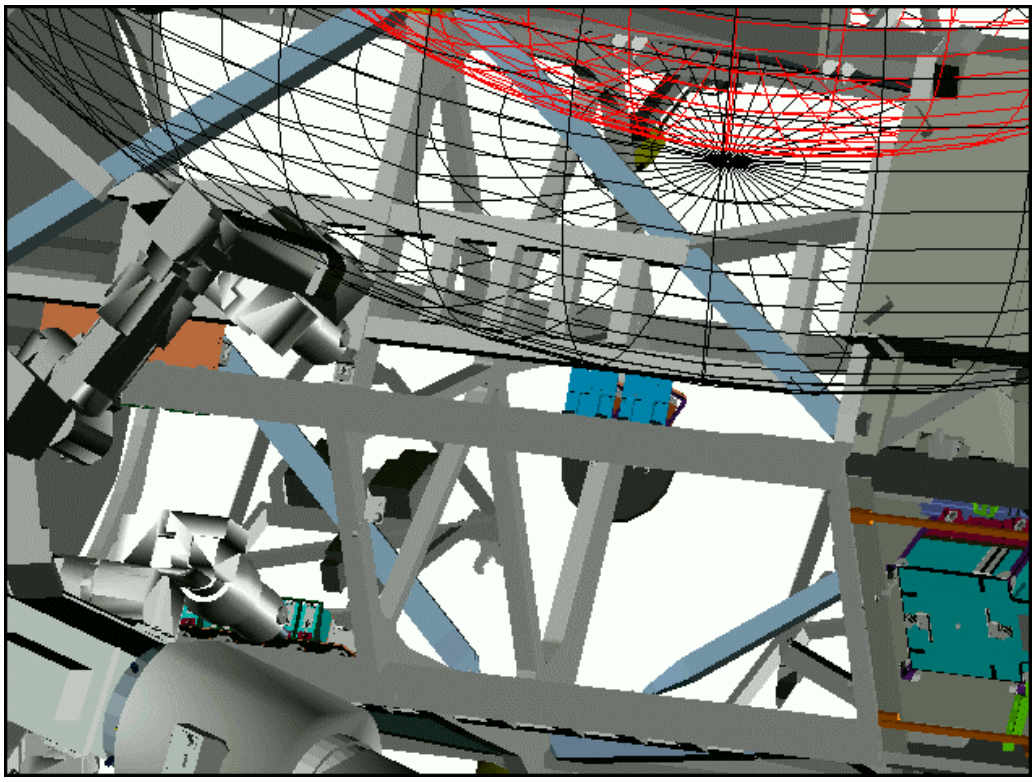

Figure 19: SPDM Access to S3 RPCM 3
Isometric View Looking ISS Nadir-Aft

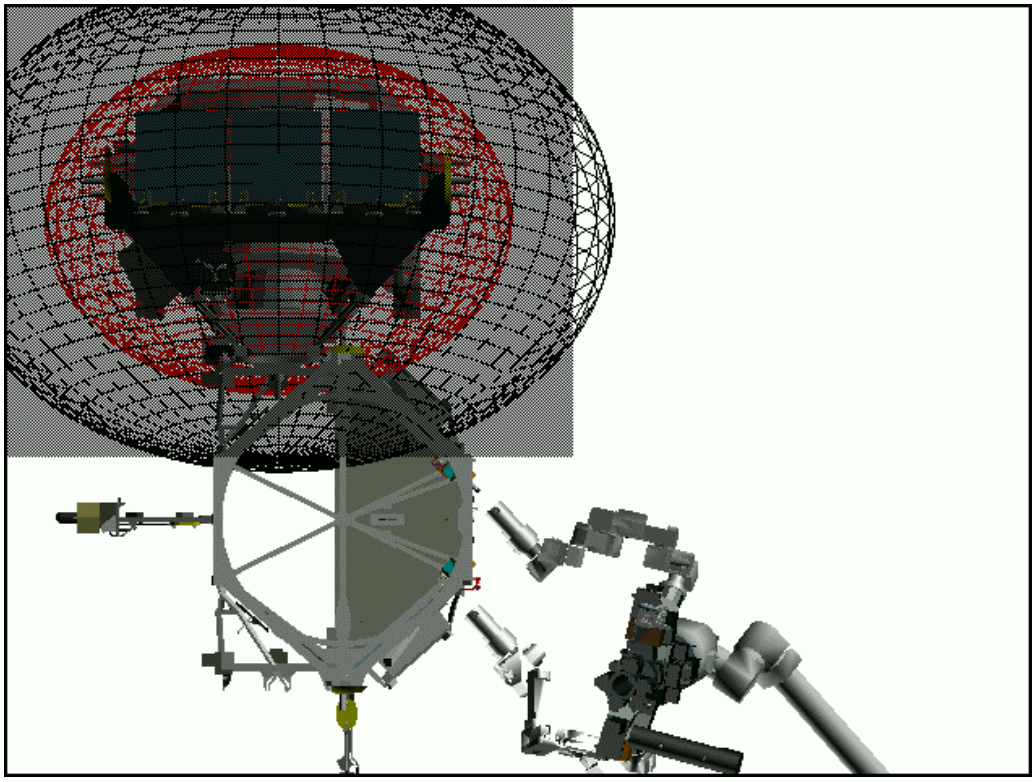

Figure 20: SPDM Access to S3 RPCM 5
ISS Starboard View