6. AMS FLIGHT OPERATIONS SCENARIO

6.1 PRELAUNCH OPERATIONS

The AMS-02 requires power and data/command capability prior to launch. By utilizing AMS-02 supplied Ground Support Equipment, AMS-02 personnel monitor the 1553 Bus data for telemetry including temperature/pressure measurements and system operating characteristics. Health and Status of the Super Fluid Helium (SFHe) Tank is monitored by ground controllers and compared to trend data established over the lifetime of the experiment. This monitoring will continue until at least T-9 minutes at which time AMS-02 ground controllers will make a "Go/No Go" decision for launch based on the health and status of the SFHe Tank. Trend data for the tank will be collected from initial assembly throughout all ground operations to a good baseline measurement of boil-off.

The only identified potential hazard has been defined as a rupture of the vacuum case just prior to launch that would lead to increased pressures in the SFHe Tank during ascent. If the tank was to over-pressurize and rupture the tank burst disks between liftoff plus 30 seconds and liftoff plus one minute, the payload bay could experience over-pressurization and the aft-bulkhead and payload bay doors could be damaged. If the burst disks were to rupture at any other time, no hazard has been identified. Health and status of the SFHe tank will be determined by a minimum of three measurements of temperature and pressure within the SFHe Tank. These measurements will be made available to the Mission Control Center (MCC) and the Launch Control Center (LCC) as desired; however, the "Go/No Go" call will be made by the AMS Project Management team in the Customer Support Room (CSR) at JSC in conjunction with the Payload Operations Control Center (POCC) at JSC. Additionally, AMS personnel will be monitoring these parameters from a User Room in the Space Station Processing Facility (SSPF) at KSC. The Ground path for these critical parameters is being worked with JSC and KSC personnel; and will require redundancy to ensure good communications during this critical period. The data will be available via 1553 Bus A, Bus B, or the RS-422 link.

T0 operations include 120 Vdc power routed to the Power Distribution System (PDS) and a separate 28 Vdc power feed to a Vent Pump designed to allow venting of the SFHe

Tank for boil-off during ground operations until T-9 minutes. Following installation, roughly 650 W of power are required for vent pump operation, operation of the four cryocoolers and for critical monitoring functions. Monitoring capability is supplied via the 1553 Bus through the T0 umbilical interface as well as the high-rate data system (RS-422 protocol) through the T0 umbilical interface to Ground Support Equipment (GSE).

During brief periods, a maximum of 2000 W may be required for calibration and contingency troubleshooting of experiment avionics. Again, GSE allows ground controllers to access this data.

All non-essential power systems will be deactivated at T-30 minutes to minimize the current across the T0 connection. The SFHE vent valve will be closed, and the vent pump will be deactivated at this time. These activities are controlled via AMS GSE listed above; as well as KSC ground personnel remote commanding of the power supply for the vent pump to "off." Only systems required for power distribution and monitoring of the SFHe tank will remain active after this point.

6.2 ASCENT

The AMS-02 experiment requires momentary power during ascent for operation of the SFHe nominal vent valve. This valve must be opened during powered flight once the pressure in the Payload Bay drops below the pressure of the SFHe Tank. The primary means of opening this valve is a barometric switch selected to open at a pressure below that of the SFHe Tank (present estimates are approximately 15 millibars or roughly 3 minutes into the flight, but final definition will be made using the flight hardware). The barometric switch allows 28 Vdc power, supplied from a Standard Switch Panel (SSP), to be applied to a solenoid that operates the vent valve to perform this function. The current is limited by the SSP to less than 5A**.** AMS-02 SFHe Tank Valve Control Electronics receives 28 Vdc ascent power from the two powered maintained switches (S16 and S18) on 5A circuit breaker CB4 at the standard switch panel (SSP 2A) through connector J7 on Interface Panel A. Switch S16 is designated as the primary and S18 as the back-up 28 Vdc power feed, as shown in Table 6.2. Figure 6.2 illustrates the SSP layout. As a backup, a time-tagged command in the Backup Flight System (BFS) General Purpose Computer shall issue the same command to open the vent valve at a time following the expected opening by the barometric switch (liftoff plus approximately 3 minutes). Potential ignition sources shall be compliant with NSTS/ISS 18978B, Letter NS2/81-M082.

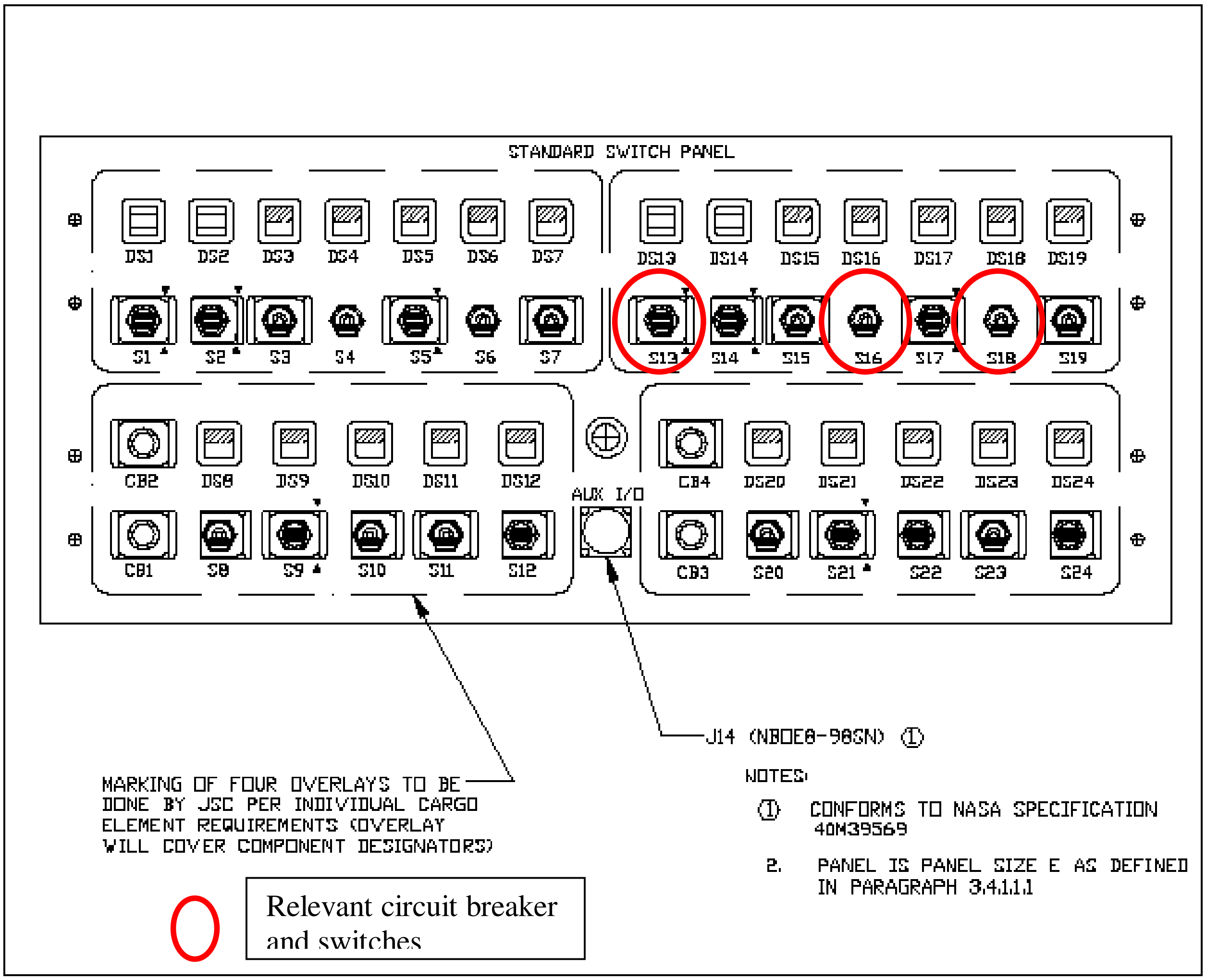

Figure 6.2-1 Standard Switch Panel Layout

TABLE 6.2-1 STANDARD SWITCH PANEL CONFIGURATION

ITEM	DEVICE TYPE	AMS-02 FUNCTION
CB4	Circuit breaker, 5 Ampere IN – Closed OUT - Open	IN – Applies orbiter pwr to switches S16 and S18 (Pre-launch/Ascent Configuration). OUT – Removes orbiter pwr from switches S16 and S18 (performed sometime after Post Insertion)
S16	Toggle switch, 2 positions (Maintained – Maintained) ON – Up Position OFF – Down Position	ON – Applies 28 VDC to AMS-02 Control Electronics Assy (Pre-launch/Ascent Configuration). OFF – Removes 28 VDC from AMS-02 Control Electronics Assy (performed on-orbit sometime after Post Insertion)
S18	Toggle switch, 2 positions (Maintained – Maintained) ON – Up Position OFF – Down Position	ON – Applies 28 VDC to AMS-02 Control Electronics Assy (Pre-launch/Ascent Configuration). OFF – Removes 28 VDC from AMS-02 Control Electronics Assy (performed on-orbit sometime after Post Insertion)

* A return of AMS in the Cargo Bay due to an Orbiter contingency; AMS would request reconfiguration of the switches to the pre-launch configuration during De-orbit Prep activities; not a safety issue, but is an AMS-02 turnaround concern.

The requirement for the opening of the vent valve during ascent stems from a device used as a phase separator for the SFHe; referred to as a "porous plug", this device allows vapors to be vented while containing the liquid within the tank. When the valve is opened, no liquid must be in contact with the porous plug, which is designed specifically to be located in the direction of the acceleration vector during ascent. G-forces during powered flight will ensure only vapors are against the plug at vent opening. If liquid were against the plug at this time it is theorized that the plug could act as a pump to remove the liquid from the tank. Not a safety issue due the rate of pumping that would occur, but a serious impact to mission success as the SFHe is required for operation of the magnet.

6.3 ASCENT ABORT OR AMS RETURN OPERATIONS

In the event of an abort that occurs following the vent valve opening, the barometric switch will automatically close the vent valve as pressure begins to increase in the payload bay (PLB). Failure to close this valve would result in air being drawn into the tank resulting in a freeze plug; this would not lead to a safety issue, as burst disks have been installed in the SFHe Tank; and no hazard is presented by operation of these burst disks except during the period of time described above. However, operation of these burst disks would have a severe negative impact on payload turnaround time for a re-flight opportunity.

Power is applied post-landing to monitor the SFHe tank pressure and re-open the vent valve when the tank pressure exceeds one atmosphere (presently estimated to occur between 10 hours and 2 days after touchdown). Again, failure to apply power and re-open the vent valve would have a negative impact on payload refurbishment, as burst disks would need to be replaced, but is not a safety issue.

6.4 ON-ORBIT OPERATIONS

6.4.1 STS On-Orbit Operations

Once on-orbit, following Post-Insertion activities, payload activation activities are expected to begin at approximately MET 00/02:30. At this time, a middeck locker stowed, STS provided, Payload General Support Computer (PGSC) will be un-stowed, set-up, and activated on the Orbiter Aft Flight Deck (AFD). Setup includes the removal of a cable between two connectors on a Payload Data Interface Panel (PDIP) located on the AFD, and attachment of a payload provided cable to the PDIP to interface with the PGSC. The new cable will route that data to the PGSC (via a DIGI board interface) for recording. This laptop in conjunction with the DIGI board and payload cable is referred to as the AMS-02 Digital Data Recording System (DDRS-02); and will be used to record all high rate data generated by AMS-02 during checkout activities. Concurrent to these activities (or prior to), the Orbiter Interface Unit (OIU) should be powered up and checked out in preparation for communication with the AMS payload.

Next, two ISS provided Assembly Power Control Units (APCUs) are activated by the crew (SSP controlled); and then front-end data interface electronics are activated to initiate the downlink of housekeeping data; then the Cryocoolers on the AMS-02 are activated. Shortly after this, the AMS-02 detectors and other subsystems are activated and checked out. During avionics checkout, RS-422 data is recorded on the hard-drive of the PGSC continuously, and RS-422 from another feed-thru from the PDIP will be down-linked via the Ku-Band as coverage and scheduling permit. No magnet charging can be performed while AMS-02 is located in the Orbiter PLB, as power distribution wiring does not accommodate power to the charging circuit. A maximum of 2 kW is required during these Orbiter operations; however, as AMS-02 heat rejection capabilities in the PLB are quite limited (primary radiators face the Orbiter sidewalls), these operations are limited by thermal constraints (dependent on attitude). All checkout activities are controlled by ground command or pre-programmed into the PGSC; crew intervention is not required. Checkout time is estimated at 40 hours with significant command uplink required.

On MET Day 3, the STS is expected to dock with the ISS. AMS-02 activities will continue as required for checkout and thermal conditioning. At the earliest opportunity, expected to be MET Day 4, the AMS-02 transfer to ISS should occur. Just prior to transfer, AMS-02 is powered down, the APCUs are deactivated and the DDRS-02 stowed. The Shuttle Remote Manipulator System (SRMS) is used to grapple the experiment via the Flight Releasable Grapple Fixture (FRGF) (Figure 6.4.1-1, Frames 1 & 2); the Remotely Operated Electrical Umbilical (ROEU) is disconnected; the Payload Retention Latch Assemblies (PRLAs) and Active Keel Latches are opened; and the SRMS is used to remove AMS-02 from the PLB.

The SRMS then moves the AMS-02 to a position (Figure 6.4.1-1, Frames 3 & 4) for the SSRMS to grapple the Power and Video Grapple Fixture (PVGF) located on the opposing side of the AMS from the FRGF.

6.4.1.1 EVA Operations on STS (Contingency Only)

The AMS experiment must be compatible with a Contingency EVA operation for removal of the FRGF in the event that the SRMS in unable to release the grapple fixture. Discussions are underway to determine what additional hardware, if any, will be required to support this activity either: a) in a "free-floating configuration while the AMS is grappled by both the SRMS and the SSRMS; or b) with AMS "re-berthed" in the Payload Bay. There is forward work with JSC EVA Operations personnel regarding this activity; including assessment of safety.

Another potential Contingency EVA that could be performed on the AMS experiment involves STS provided Government Furnished Equipment (GFE). This task is a standard contingency EVA planned for the contingency release of the ROEU from the (Payload Disconnect Assembly (PDA) in the Payload Bay, in the event that the drive mechanism for the ROEU active half fails to operate. The planning for this operation is clearly performed by the EVA group at JSC. The access requirement was determined to be acceptable since the EVA could be performed from the Orbiter sill; however, no formal documentation of this acceptance has been received, and the project is prepared to supply any AMS models required to close this issue if necessary. Discussions are underway with JSC EVA personnel and EVA Safety personnel to determine what additional hardware, if any, will be required to support these EVAs, as well as what simulation requirements will be, up to and potentially including further Neutral Buoyancy Laboratory (NBL) testing. Procedures for this contingency operation will be provided by JSC EVA personnel.

Finally, the AMS must be compatible with the EVA Contingency task for manually opening the Payload Retention Latch Assemblies (PRLAs). This is also a task involving GSE that will be planned and developed by JSC EVA personnel. This task would only be performed in the event that the drive mechanism for the PRLAs failed. This is also considered standard work by the EVA group. Sill translation activities are a part of all of these Orbiter Contingency EVAs; and AMS must be compatible with that activity.

In summary, AMS must be compatible with STS EVAs that involve: translation down the Orbiter sill; EVA release and re-mate of the ROEU; release of the FRGF; and release of the PRLAs.

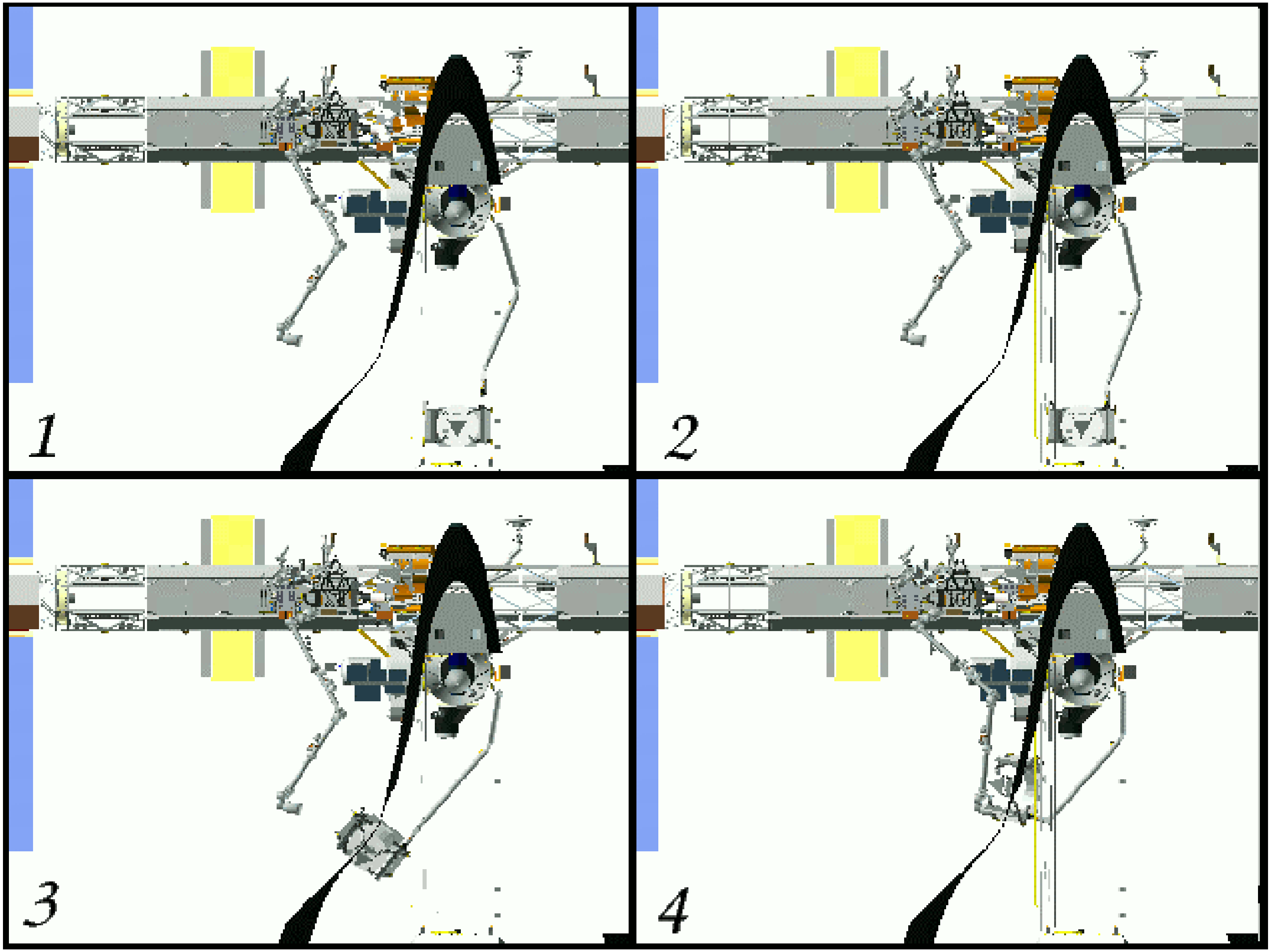

Figure 6.4.1-1 Robotic Transfer of the AMS-02 from the Orbiter Payload Bay to the ISS Integrated Truss Segment S3 (1 of 2)

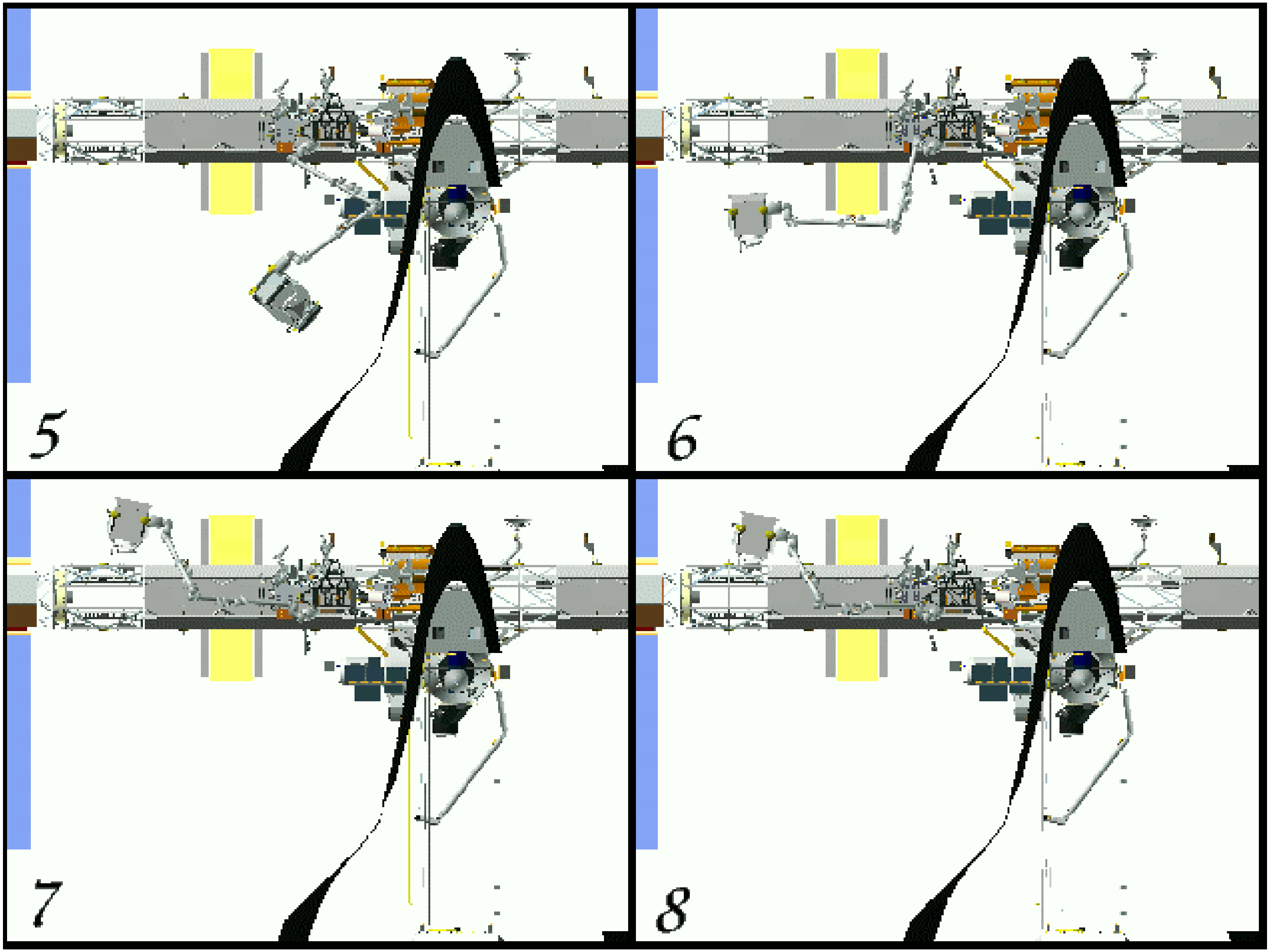

Figure 6.4.1-1 Robotic Transfer of the AMS-02 from the Orbiter Payload Bay to the ISS Integrated Truss Segment S3 (2 of 2)

6.4.2 ISS On-Orbit Operations

Once the grapple is verified with the SSRMS, the SRMS releases the FRGF (Figure 6.4.1-1, Frame 5). At this time, power is applied to the Electronic Berthing Camera System (EBCS) avionics via the SSRMS through the PVGF. The EBCS is ISS provided hardware used as an aid for docking the experiment to the Active Payload Attach System (PAS). The EBCS provides a video image of the docking to the crewmember controlling the SSRMS and utilizes an EBCS target on the truss to facilitate final approach and payload capture in the PAS. The EBCS provides feed-thru power of up to 1800 W for use by the payload. AMS-02 contains thermostatically controlled heaters that may utilize some or all of this power to maintain the payload temperature within design limits. The amount of power required is dependant on environmental conditions during transfer and the length of time the payload spends on the SSRMS.

To complete the transfer, the SSRMS moves the AMS-02 directly above the S3 Upper Inboard attach site so that the Passive PAS on the payload is correctly oriented with the Active PAS on the truss (Figure 6.4.1-1, Frames 6 & 7). As the AMS-02 is lowered toward the capture mechanism on the truss, the EBCS is used to verify closure distance and orientation for final mechanical mating. Once the guide pins on the payload are positioned in the guide vanes of the active PAS, the Capture Latch Assembly (CLA) on the PAS is driven to grapple the capture bar on the AMS Passive PAS to a minimum load (in the –Z direction) of 4900 lbs and a maximum load (in the –Z direction) of 6430 lbs (Figure 6.4.1-1, Frame 8). When proper mechanical mating is verified, the power from the SSRMS to EBCS and AMS heaters is deactivated. The Umbilical Mechanism Assembly (UMA) Active half (located on the truss) is driven into the UMA Passive half (located on AMS). Following verification of mating, power is supplied from the ISS to AMS-02 via the UMA. Once power supply and data links from the Payload are verified by AMS-02 ground personnel, the PVGF is released from the SSRMS and the SSRMS is moved away from the payload.

Following installation of the AMS-02 on the truss, an abbreviated avionics checkout will be conducted. Once the avionics have been checked out, all unnecessary equipment (including all detector subsystems) will be powered down and magnet charging operations will be initiated. Magnet charging requires 1850 W directly from the Cryomagnet Current Source (CCS) within the Cryomagnet Avionics Box (CAB) not including other power within the CAB or losses within the power distribution system, or the required monitoring electronics. For this reason, all unnecessary power devices must be deactivated to remain within power budget allocations. Magnet charging is a complex activity, requiring extensive ground commanding and feedback including operations to: open semiconductor switches; close mechanical disconnects within the magnet; cool bus bars; warm up persistent switches; and operate various cryomagnet valves. Approximately one and a half hours are required to fully charge the magnet. Once fully charged, the magnet is disconnected from the charger and the detectors are again powered. At this point the recording of science data begins. Due to the complexity of the experiment, and the numerous critical subsystems that must operate nominally to achieve mission success, AMS-02 must operate for a period of time to verify that all critical systems are functioning correctly.

AMS-02 will operate continuously on the ISS for a minimum of 3-years, requiring 2 kW average power, and generating high-rate data at an average of 2 Mbps over its lifetime. AMS-02 also utilizes the ISS 1553 bus for low-rate telemetry (health and status) command/data. All of this data is down-linked via the ISS Ku-Band.

Due to limitations in Ku-Band coverage, and the relatively small overlap between S-Band and Ku-Band data; AMS-02 has requested the downlink of 10 Bps of “Critical Health” data via the ISS S-band. This data would be used to provide a greater insight into AMS health throughout the orbit. The entire data stream, which is substantially larger than 10 Bytes, would require numerous cycles to be down-linked.

In the event of a major contingency; the AMS could be required to be returned on the same shuttle flight. If this were required, the AMS-02 would be powered off; the SSRMS would grapple the PVGF; the UMA would be disconnected, and the CLAs would be driven to release the grapple bar. The SSRMS would then maneuver AMS to a position where the SRMS can grapple the FRGF; the SSRMS would release the PVGF; and the SRMS would be used to return AMS to the Payload Bay. At this point the ROEU would be driven to re-mate with the PDA; and power up activities would begin again. Power/data transfer would be deactivated during De-orbit Prep activities per the standard Payload deactivation section of this document.

Minimum safe return configuration of the AMS-02 requires that all PRLAs be fully closed on the AMS-02 trunnions and the Keel Latch closed on the Keel pin. The ROEU does not need to be engaged to affect a safety return.

6.4.2.1 EVA Operations on ISS (Contingency Only)

If an Extravehicular Activity (EVA) is required for any AMS-02 contingency operation on the ISS, power from the UMA will be deactivated at the Type II Remote Power Control Modules (RPCM) upstream of the UMA prior to commencement of the EVA. In addition to this (if required) the UMA Active half can be disconnected from the UMA passive have as a secondary method of assuring fault tolerance. This is not highly desirable as it inherently creates the risk of a failure to re-mate.

The AMS-02 is designed with redundant front-end data interface hardware. In the event that 1553 or Fiber communications are disrupted due to problems with AMS-02 front end data hardware, an EVA may be performed to switch the connectors from the primary to the redundant electronics hardware. These connectors are EVA compatible and are located on the EVA Connector Panel located on the lower end of the Unique Support Structure very close to the Passive UMA (Figures 6.4.2.1-1 and 6.4.2.1-2).

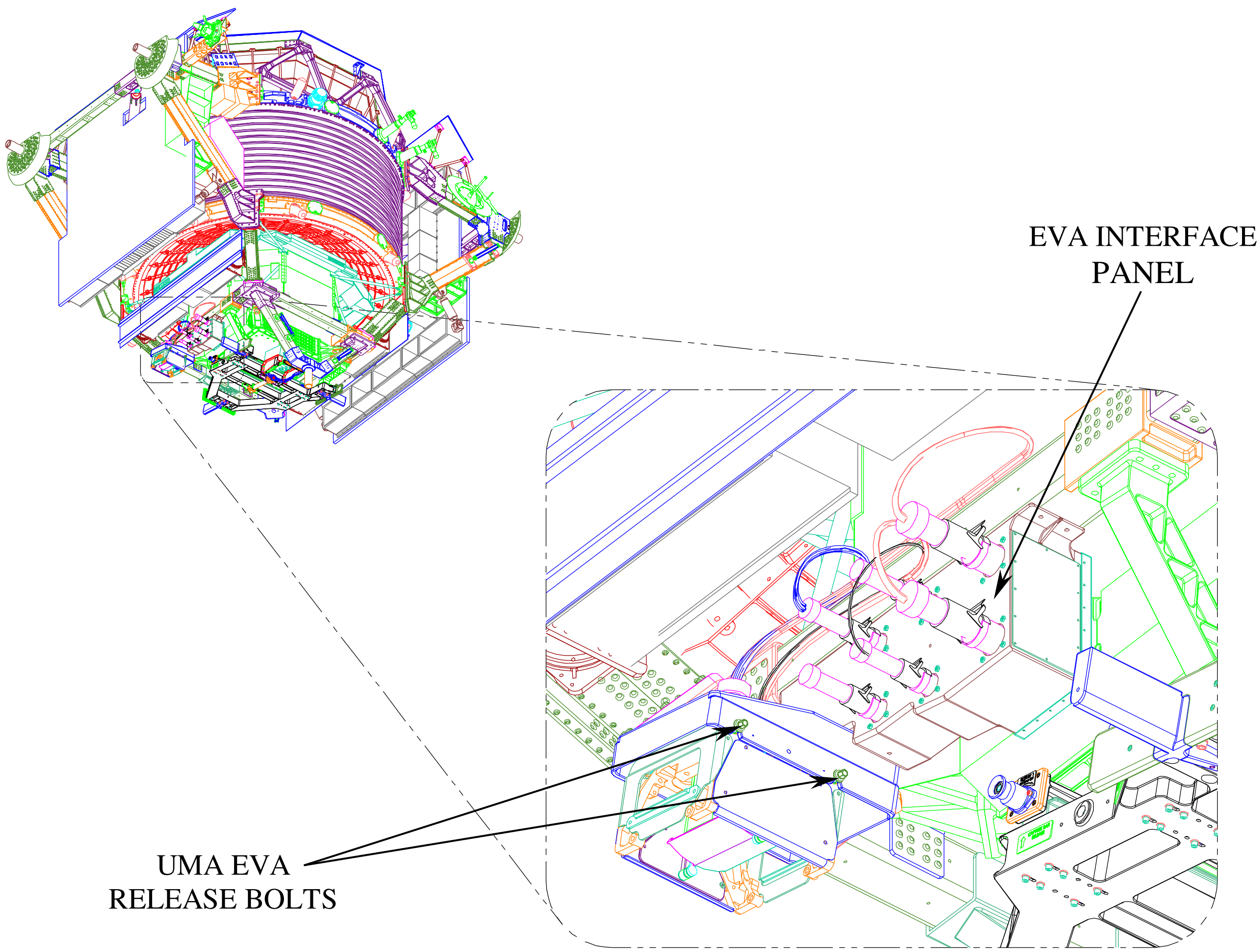

Figure 6.4.2.1-1 AMS-02 UMA (Passive Half) and EVA Interface Panel

AMS-02 was designed such that ISS Power Bus A is the primary bus for magnet charging. AMS-02 will define Launch Commit Criteria requiring that ISS Power Bus A is operable prior to launch. In the event that a station contingency renders Power Bus A inactive at a time when the magnet must be charged, the connectors for Power Bus A and Power Bus B can be interchanged at the EVA Interface Panel by a suited crewmember during a contingency EVA to power the magnet charging circuit.

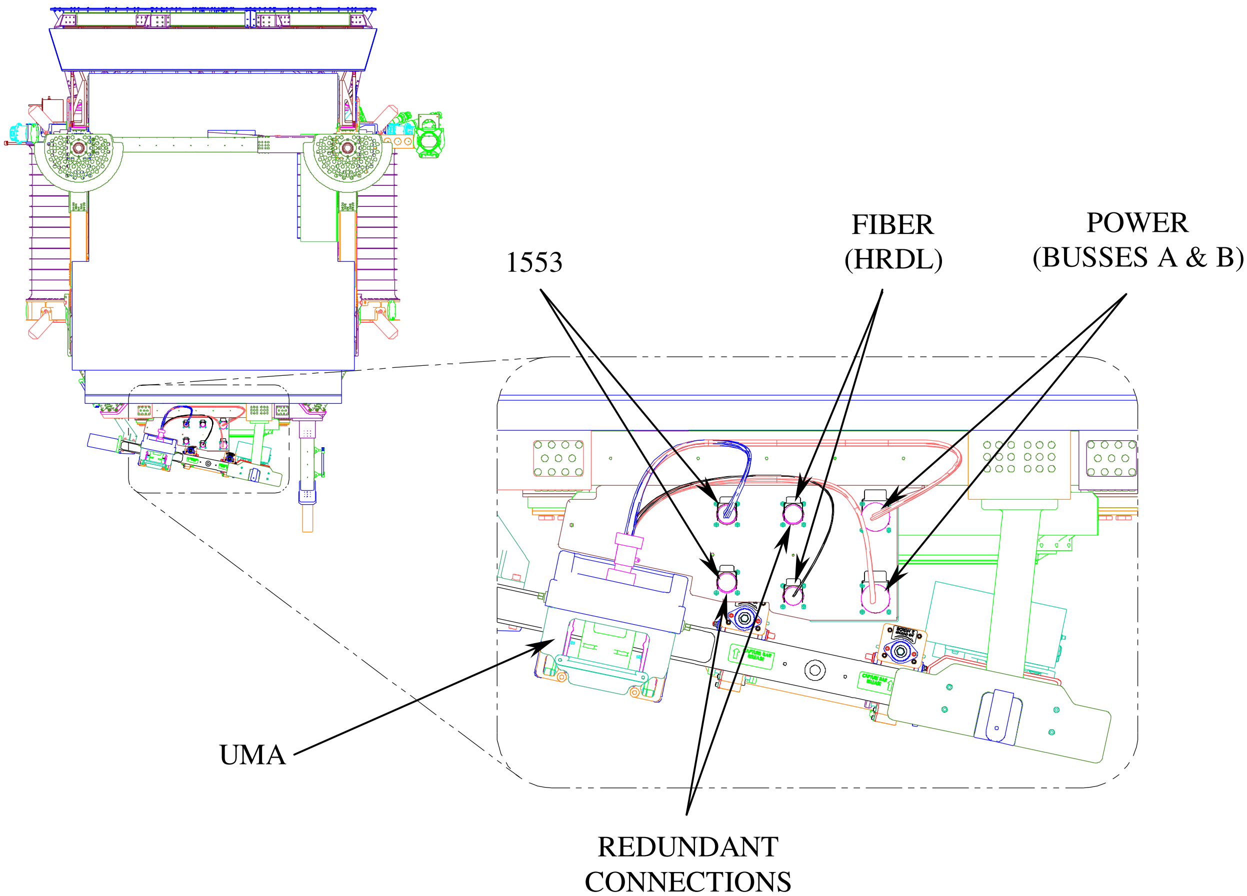

Figure 6.4.2.1-2 AMS-02 Power and Data Connectors on the EVA Interface Panel

Other AMS-02 Contingency EVA Operations include:

- UMA Removal (as required by SSP-57003) (Reference Figure 6.4.2.1-1)
- AMS-02 Passive PAS Capture Bar Removal/Replacement (Reference Figures 5.17-4, 6.4.2.1-3, 6.4.2.1-4, and 6.4.2.1-5)
- FRGF/PVGF contingency release operations (Reference Figures 6.4.2.1-6, 6.4.2.1-7, 6.4.2.1-8, and 6.4.2.1-9)

All the contingency activities and translation paths for AMS-02 on ISS EVAs, ISS Truss EVAs, and alternate Payload Attach Site EVAs were demonstrated using Worksite Analysis tools and in the NBL using a full scale AMS-02 volumetric mockup with high-fidelity EVA interfaces. Successful completion of these tests is documented in Crew Consensus Report (CCR) CB-02-129. Figures 6.4.2.1-16 illustrates an EVA translation path from the EVA Worksite Analysis tool. Figures 6.4.2.1-17 and 6.4.2.1-18 are scenes from the NBL testing performed in November 2002.

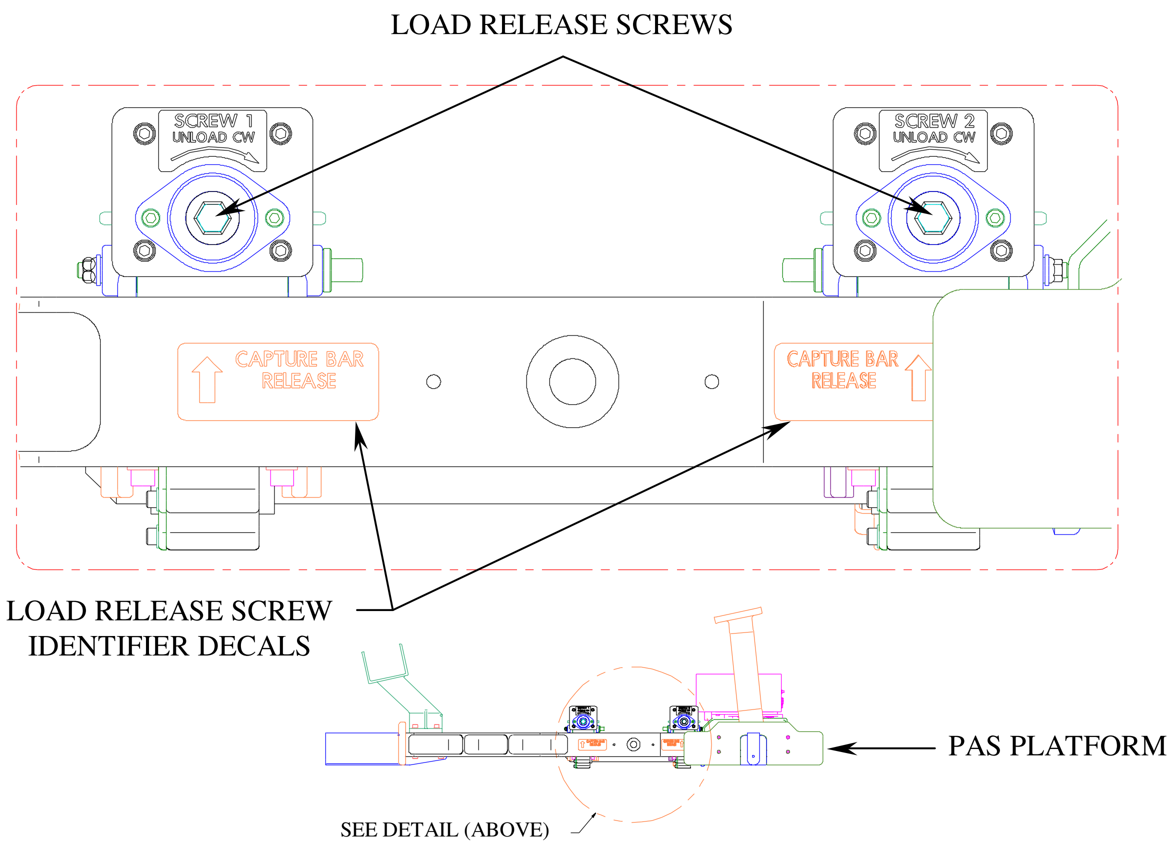

Figure 6.4.2.1-3 AMS-02 Contingency Capture Bar Release (1 of 2)

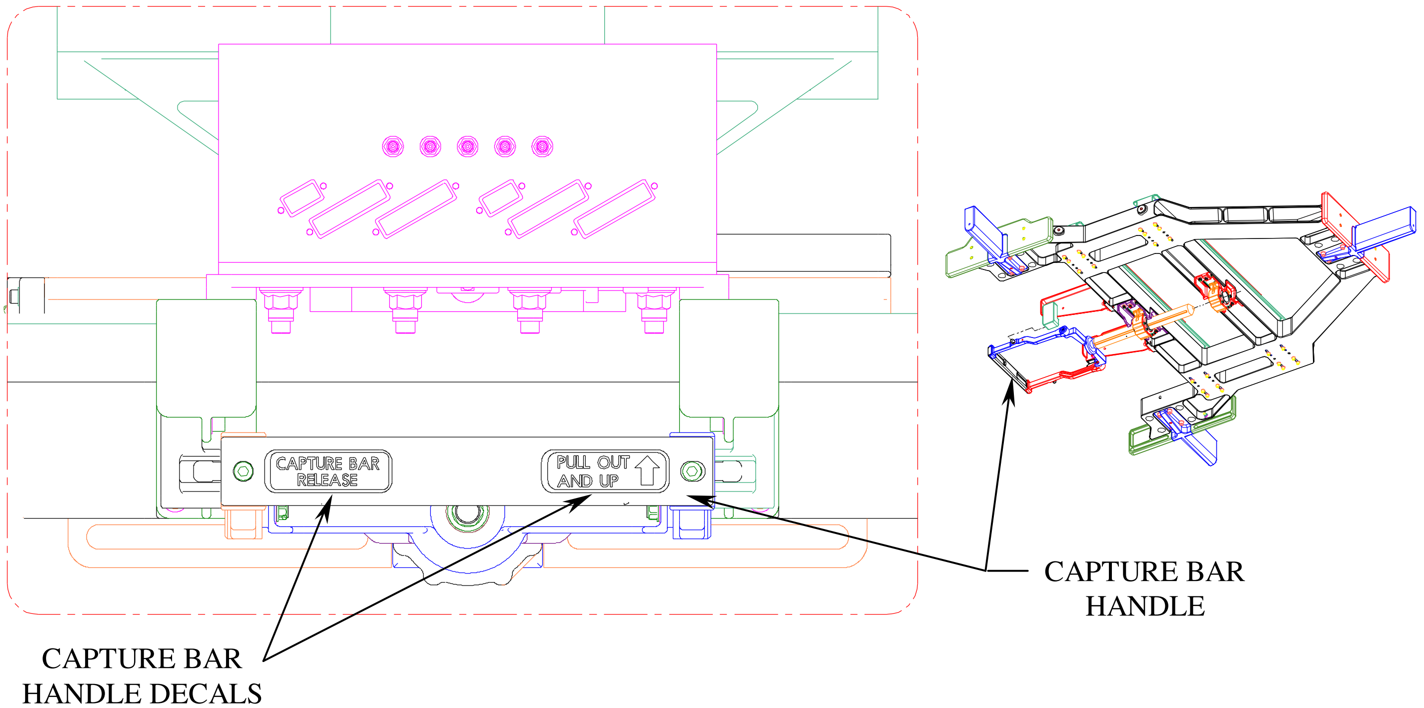

Figure 6.4.2.1-4 AMS-02 Contingency Capture Bar Release (2 of 2)

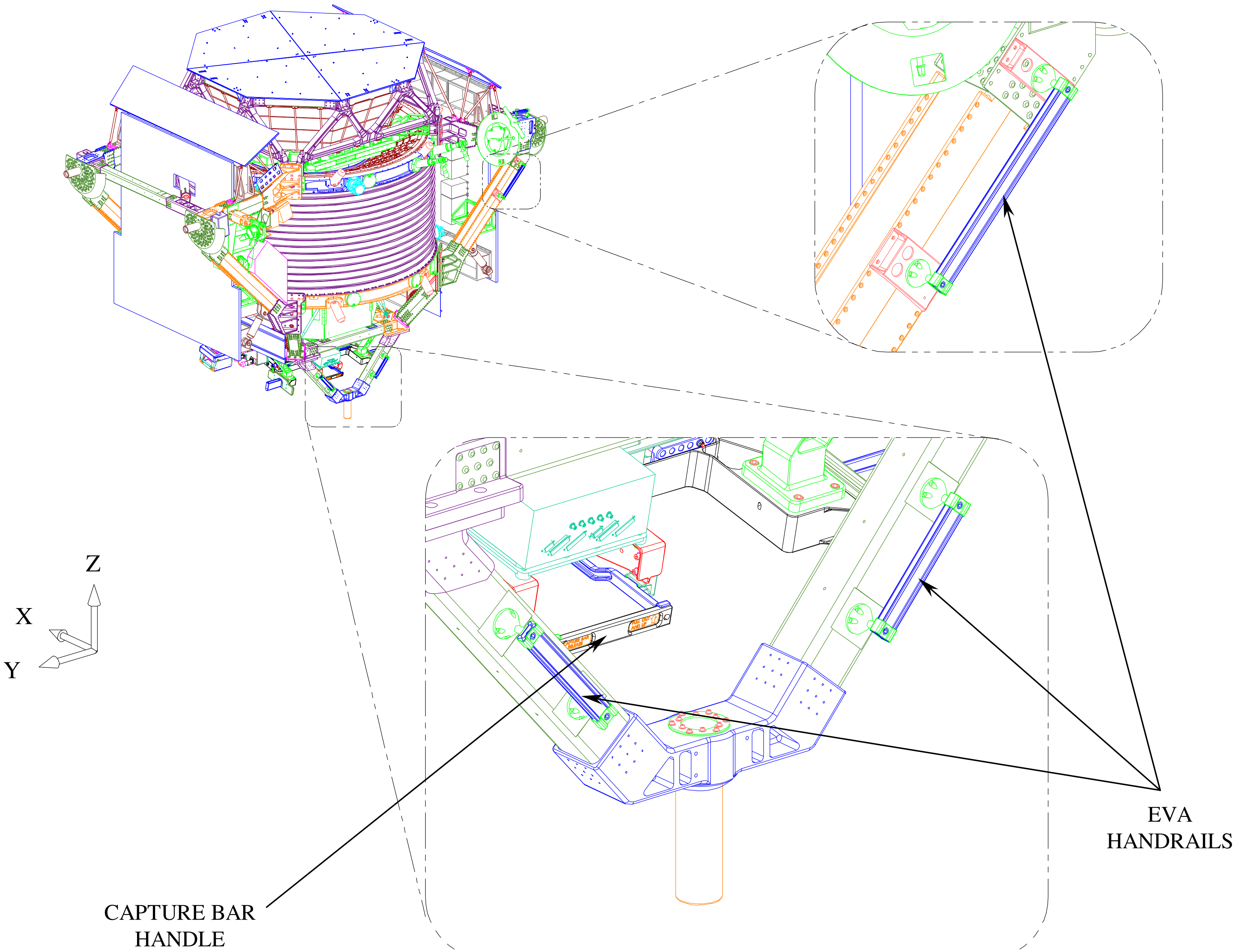

Figure 6.4.2.1-5 EVA Handrails in the Vicinity of the PAS Capture Bar Handle

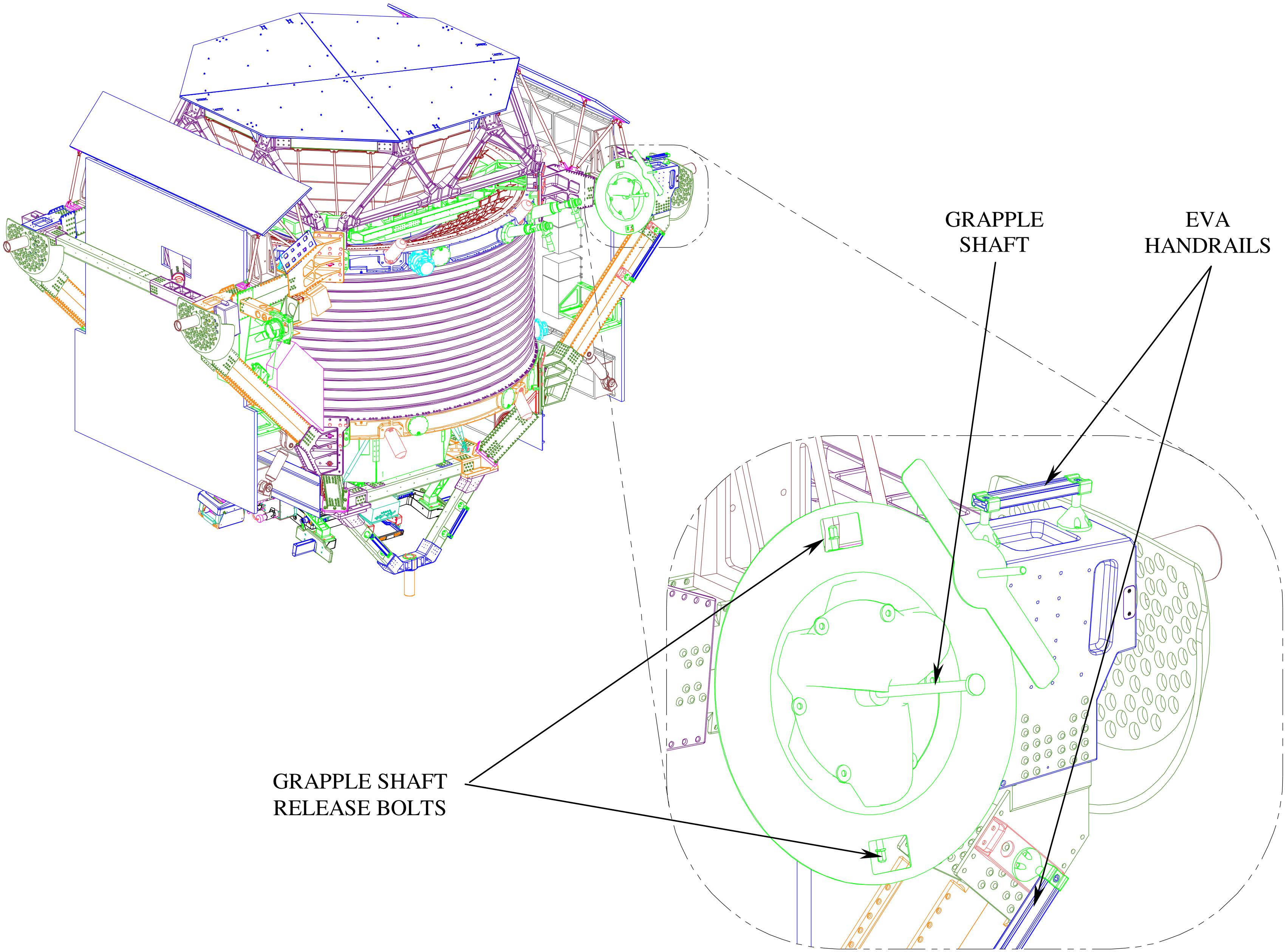

Figure 6.4.2.1-6 FRGF Grapple Shaft Contingency Release Mechanism

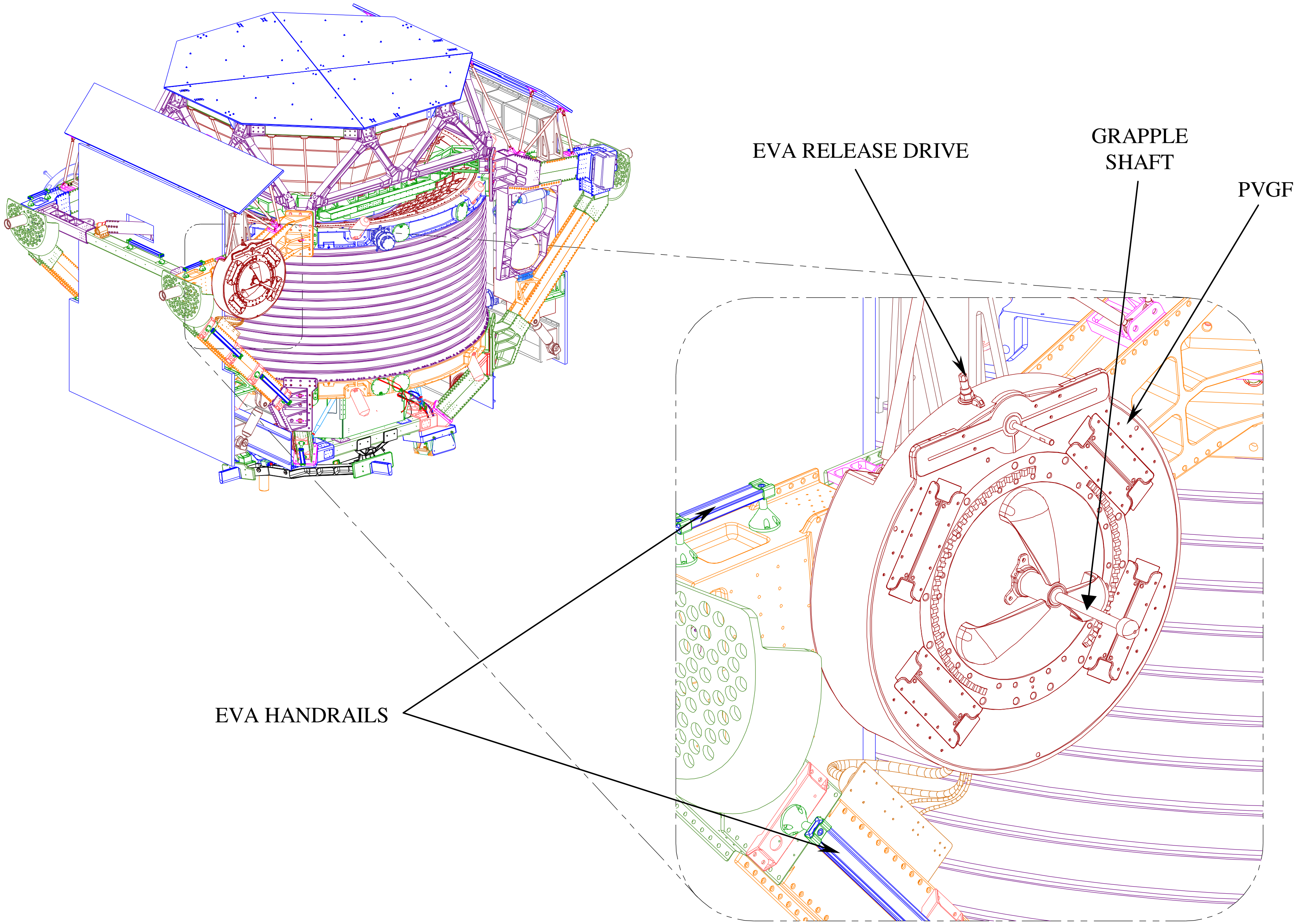

Figure 6.4.2.1-7 PVGF Grapple Shaft Contingency Release Mechanism

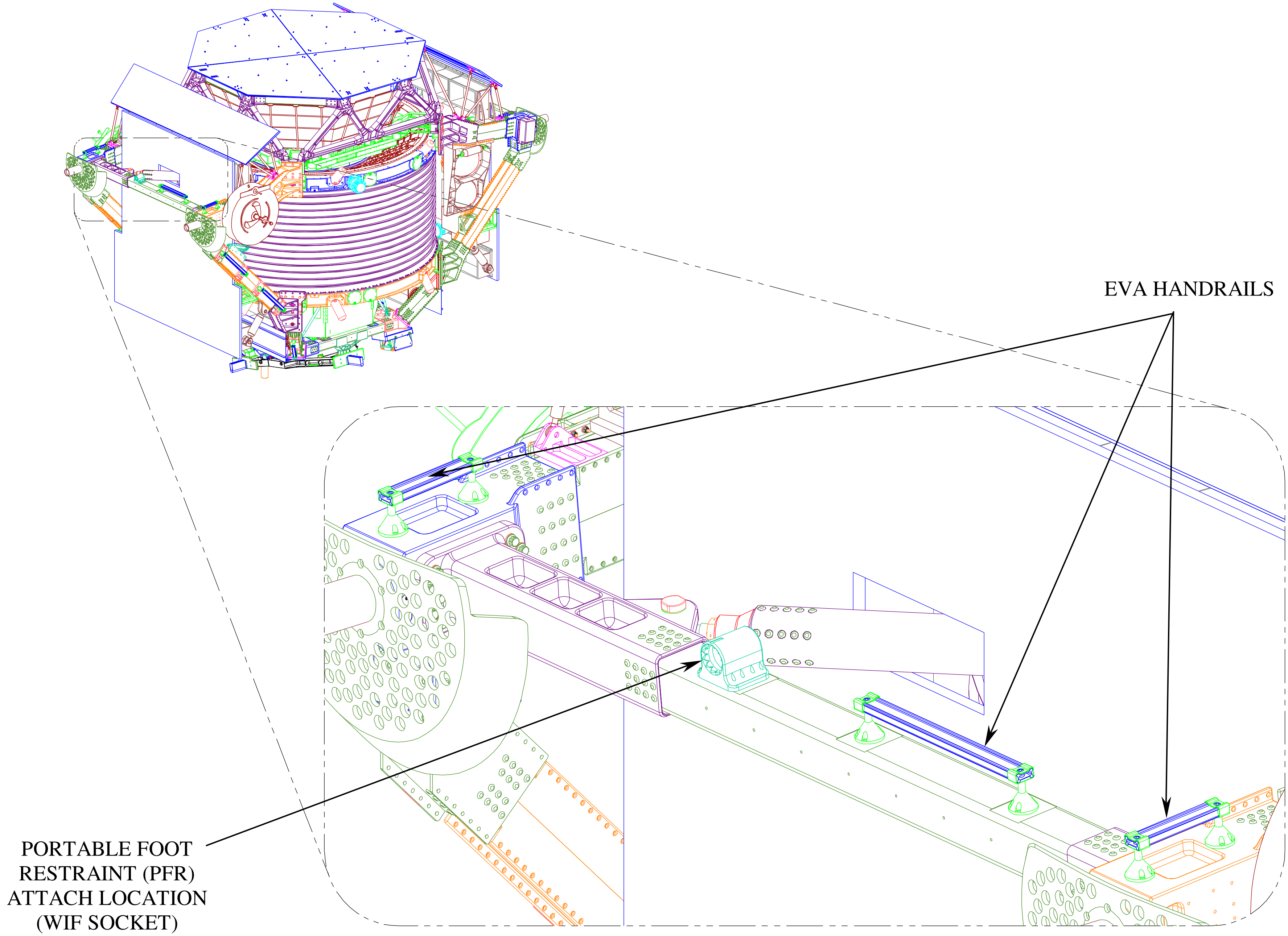

Figure 6.4.2.1-8 EVA Handrails and Worksite Interface Fixture (WIF)

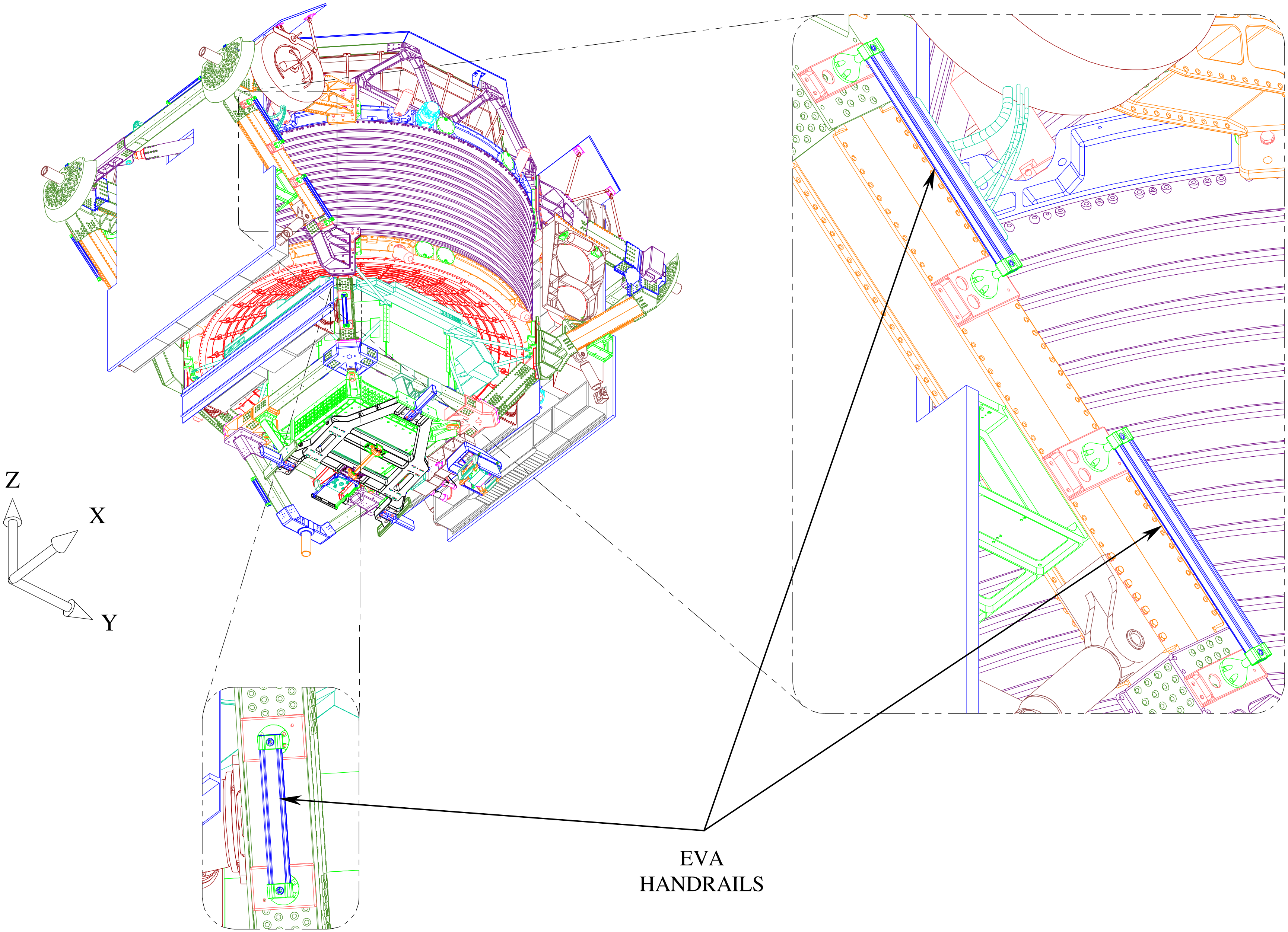

Figure 6.4.2.1-9 EVA Handrails in the Vicinity of the PVGF

The AMS-02 Collaboration has also designed a "foldable" mounting bracket for the ROEU Payload Disconnect Assembly (PDA). This was requested by OZ in response to a desire to decrease the AMS exceedance to the Standard Payload Envelope at the attach site in this particular location. This EVA is also considered a contingency and should only be executed if required prior to the arrival of another attached payload at the S3 Upper Outboard site. If implemented, this EVA would be performed on the AMS experiment while stationed on the S3 Truss. Details of the particular EVA are still in work, and the required worksite analysis or NBL verification of the EVA is still not defined. However, provisions have been made to add a handrail in the area that is expected to be compatible with this operation. Continued work is required with the EVA group at JSC to determine the final requirements. Figures 6.4.2.1-10 through 6.4.2.1-15 are included as representations of the design for this foldable PDA. Figures 6.4.2.1-10, 6.4.2.1-12 and 6.4.2.1-13 demonstrate the nominal configuration, while Figures 6.4.2.1-11, 6.4.2.1-14 and 6.4.2.1-15 illustrate the "folded" position of the hardware. The pip pins identified in the figures are removed but retained by a tether; the arm is folded down, and the pip pins are replaced, locking the arm into the stowed position. The folding operation is manual, and it is expected that little force will be required to fold the arm; however, torque measurements shall be made of the folding operation to ensure compatibility with EVA crewmember requirements. No electrical connections would be broken during this EVA; the magnet would be powered down for this EVA; and the experiment would be powered down to ensure no potential hazards regarding hot-pins. Additionally diode protection is built-in as a secondary protection against hot-pins.

It should be noted that a Manipulator Analysis, Graphics, and Integrated Kinematics (MAGIK) analysis was performed using the AMS model and an SSRMS with a standard payload envelope to determine if there were any contact issues. This analysis included the standard "stacked" tolerances for the arm and still did not reveal an impact concern.

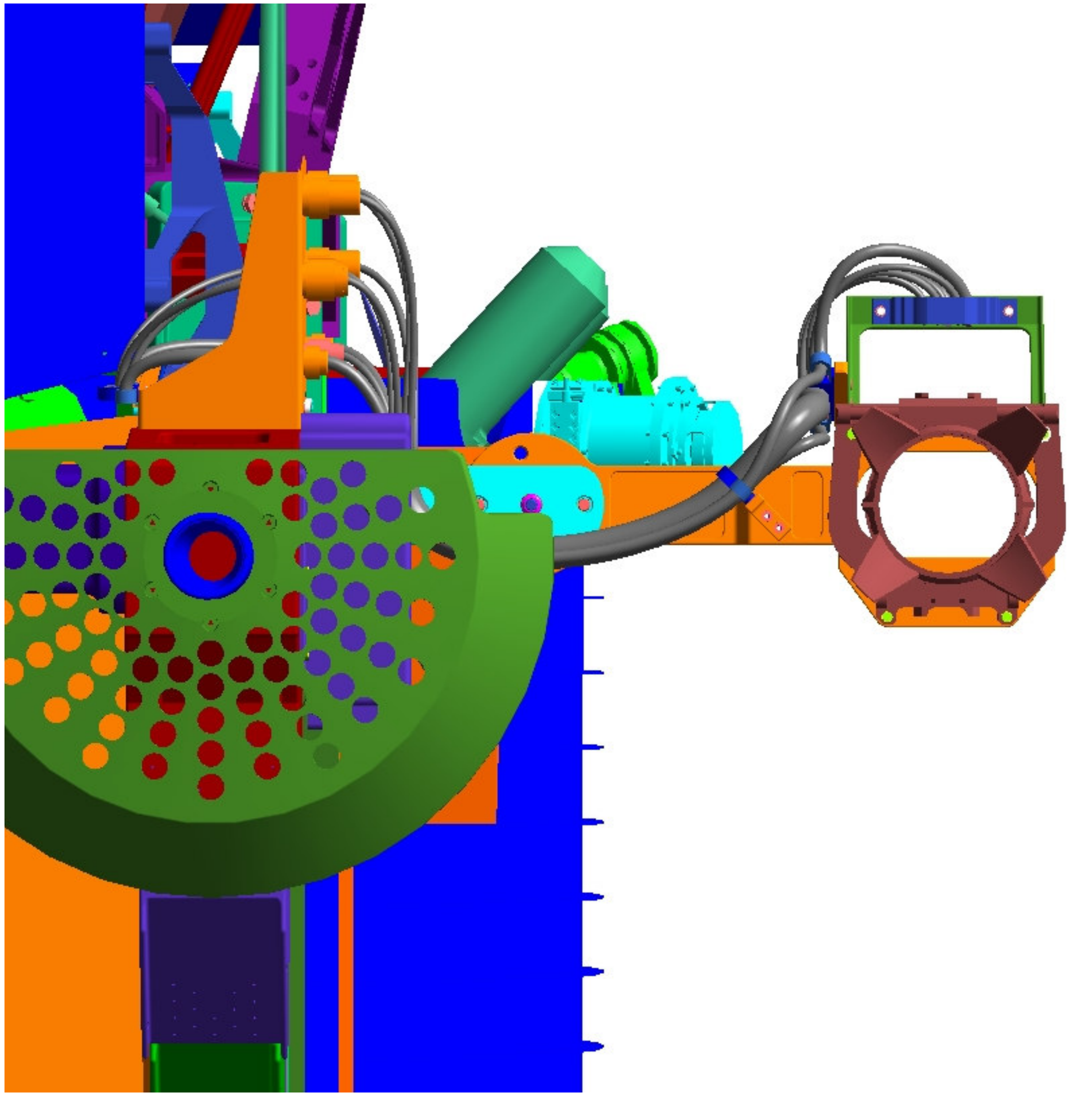

Figure 6.4.2.1-10 ROEU PDA in Nominal Configuration (View from Starboard Side)

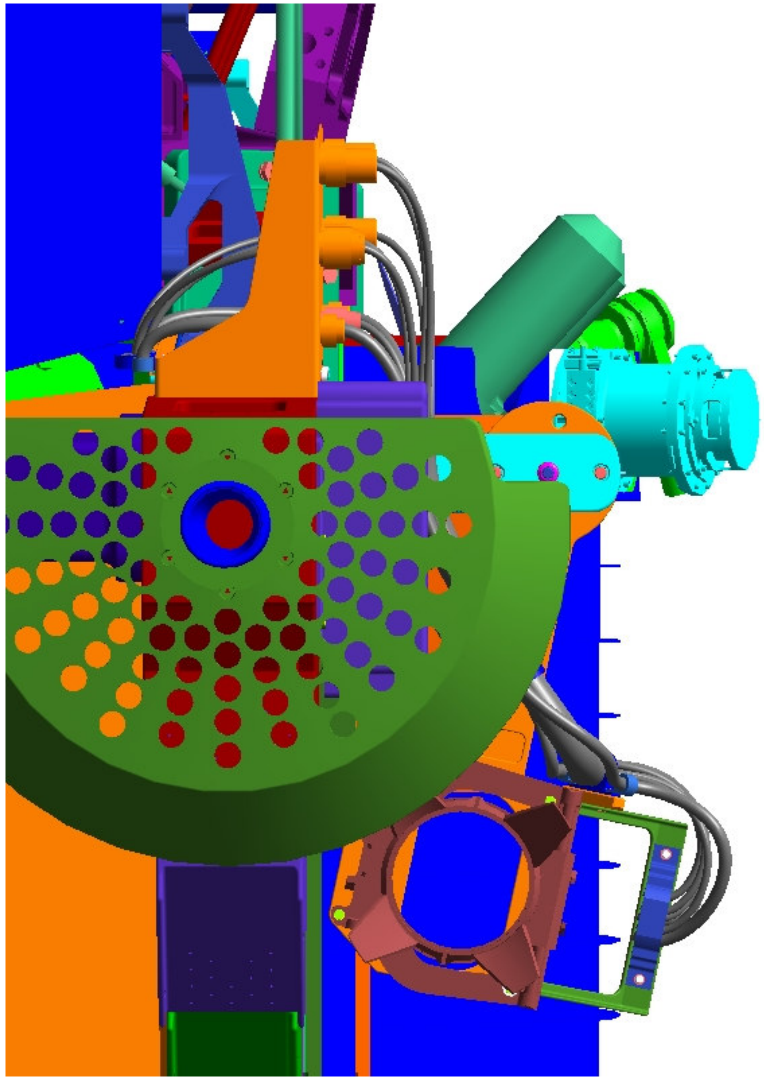

Figure 6.4.2.1-11 ROEU PDA in Folded Configuration (View from Starboard Side)

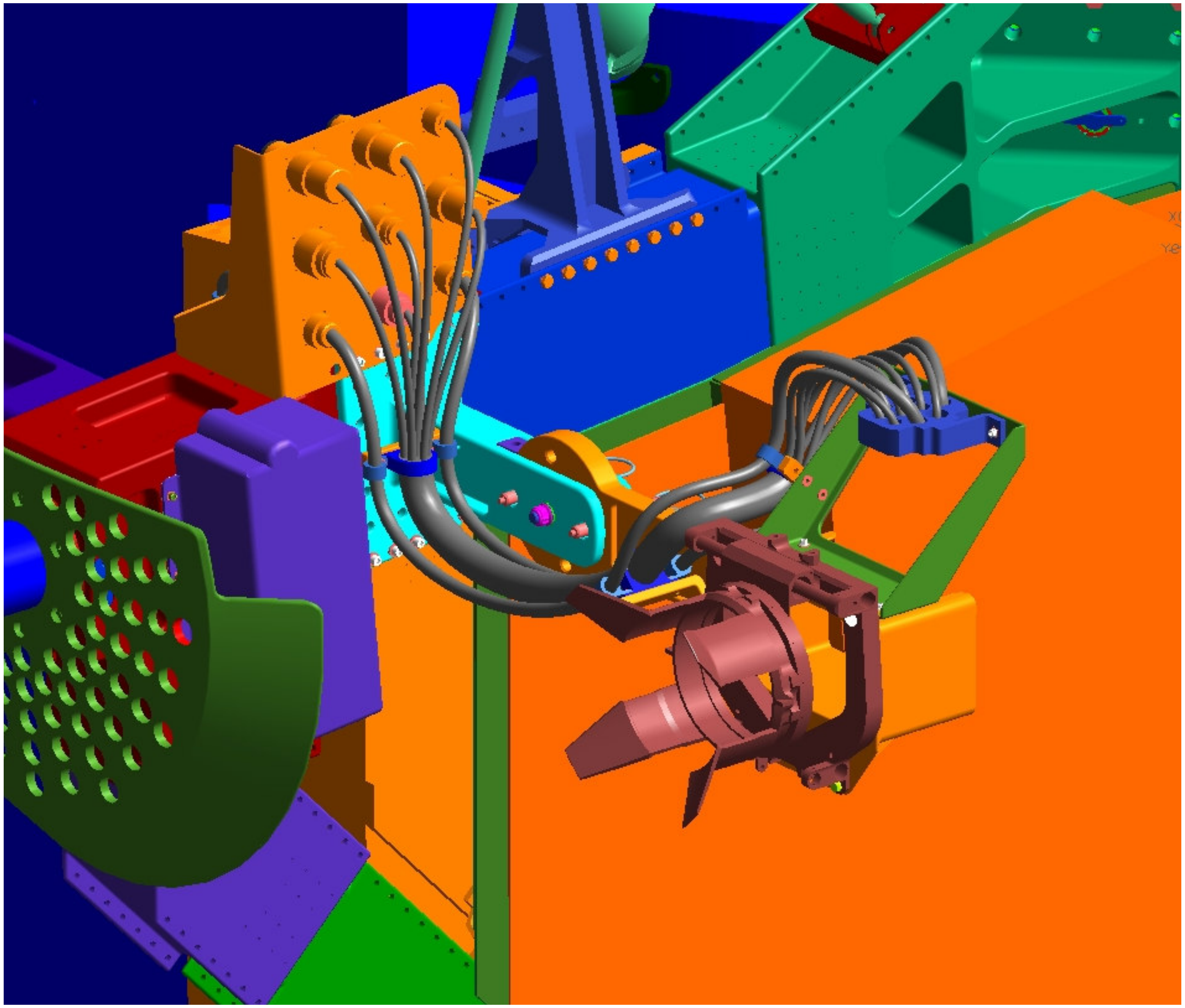

Figure 6.4.2.1-12 ROEU in Nominal Configuration (Iso View from Starboard Side)

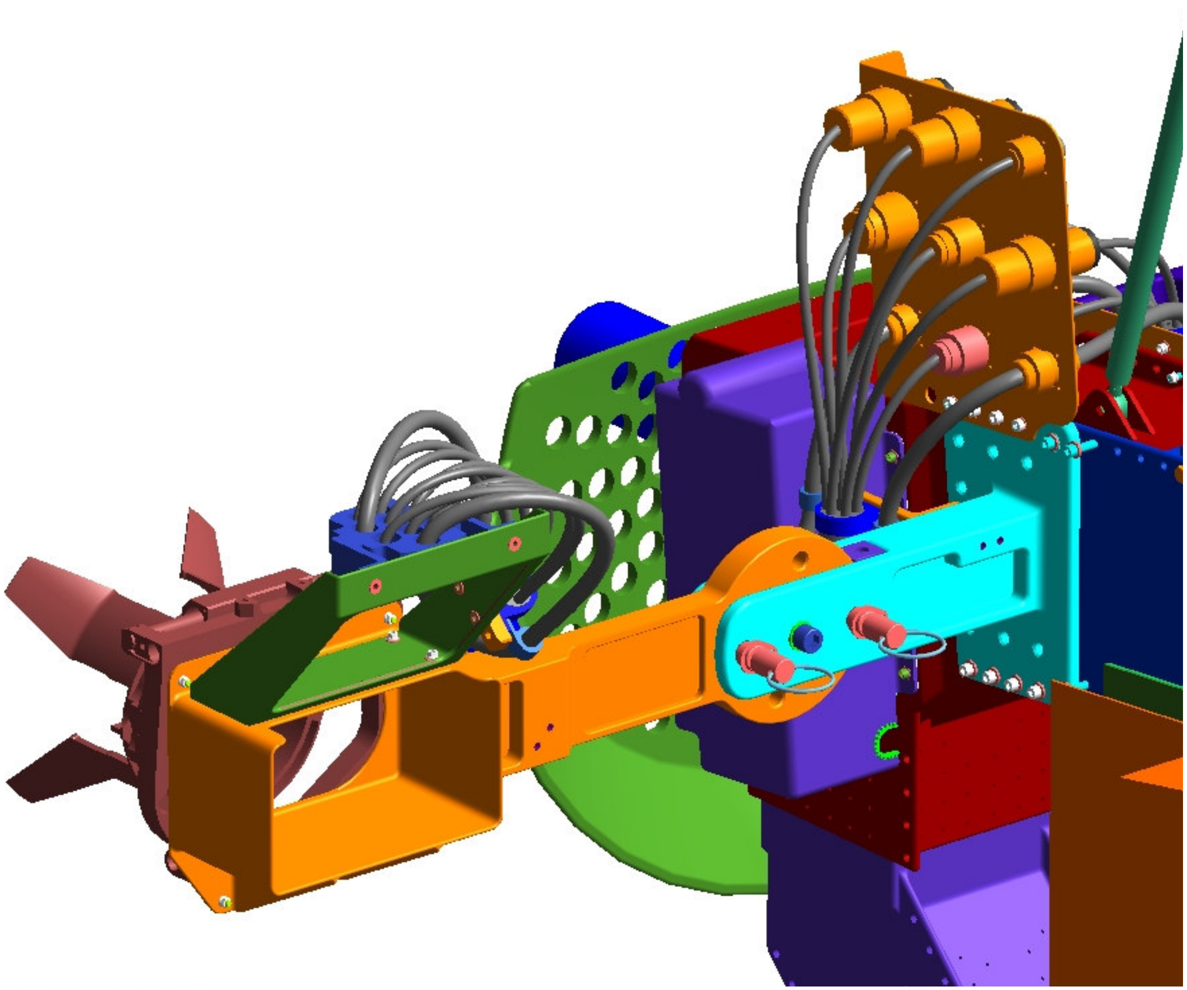

Figure 6.4.2.1-13 ROEU in Nominal Configuration (Iso View from Port Side)

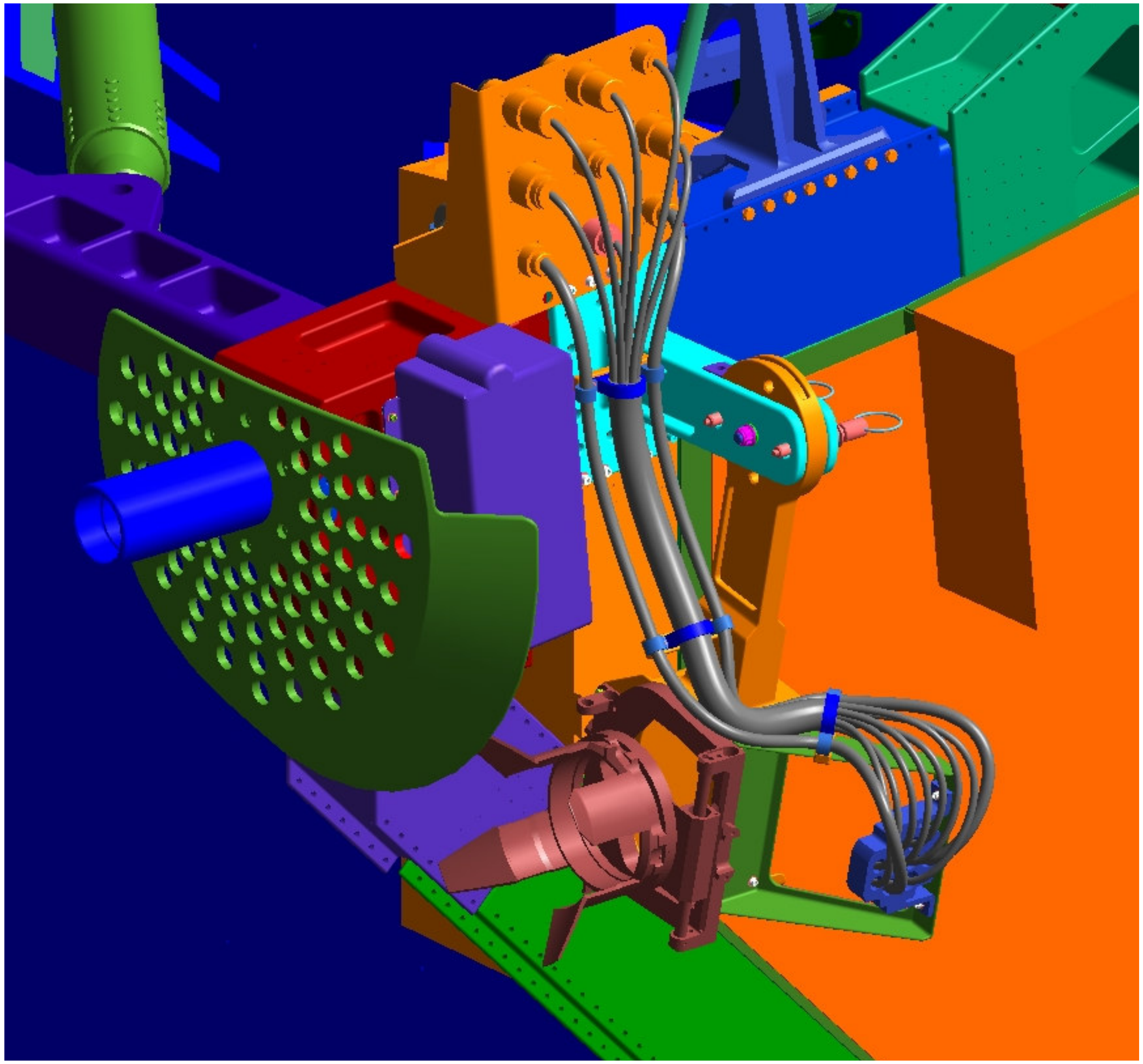

Figure 6.4.2.1-14 ROEU PDA in Folded Configuration (Iso View from Starboard Side)

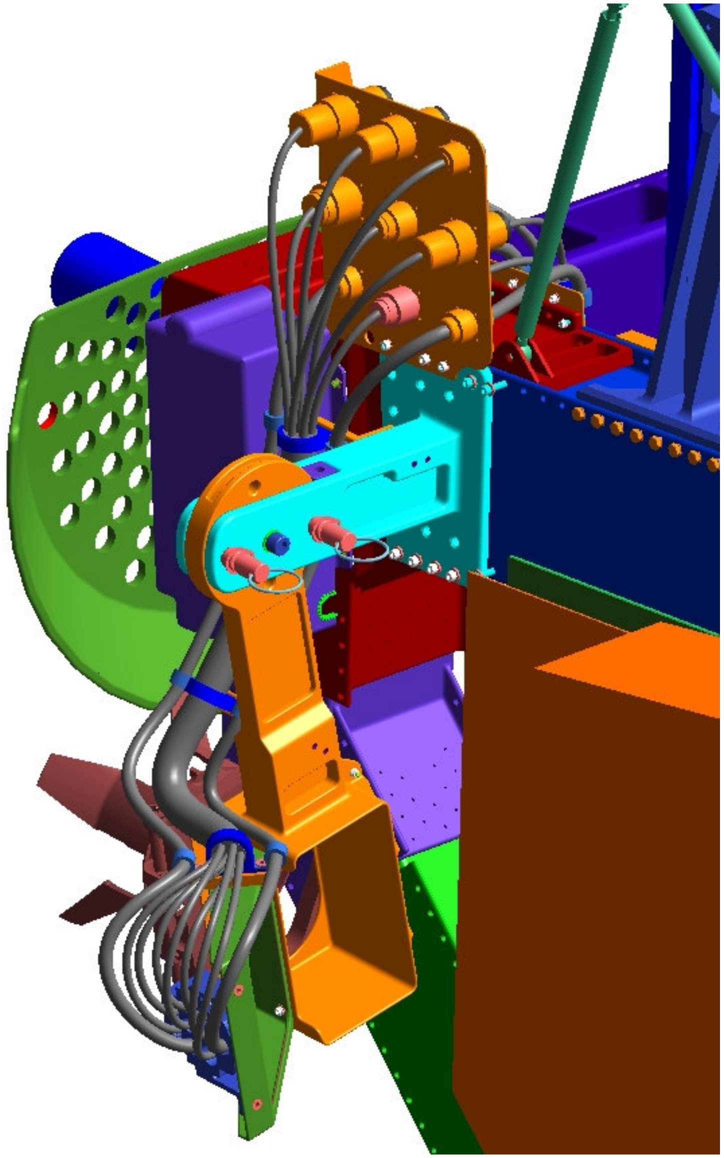

Figure 6.4.2.1-15 ROEU PDA in Folded Configuration (Iso View from Port Side)

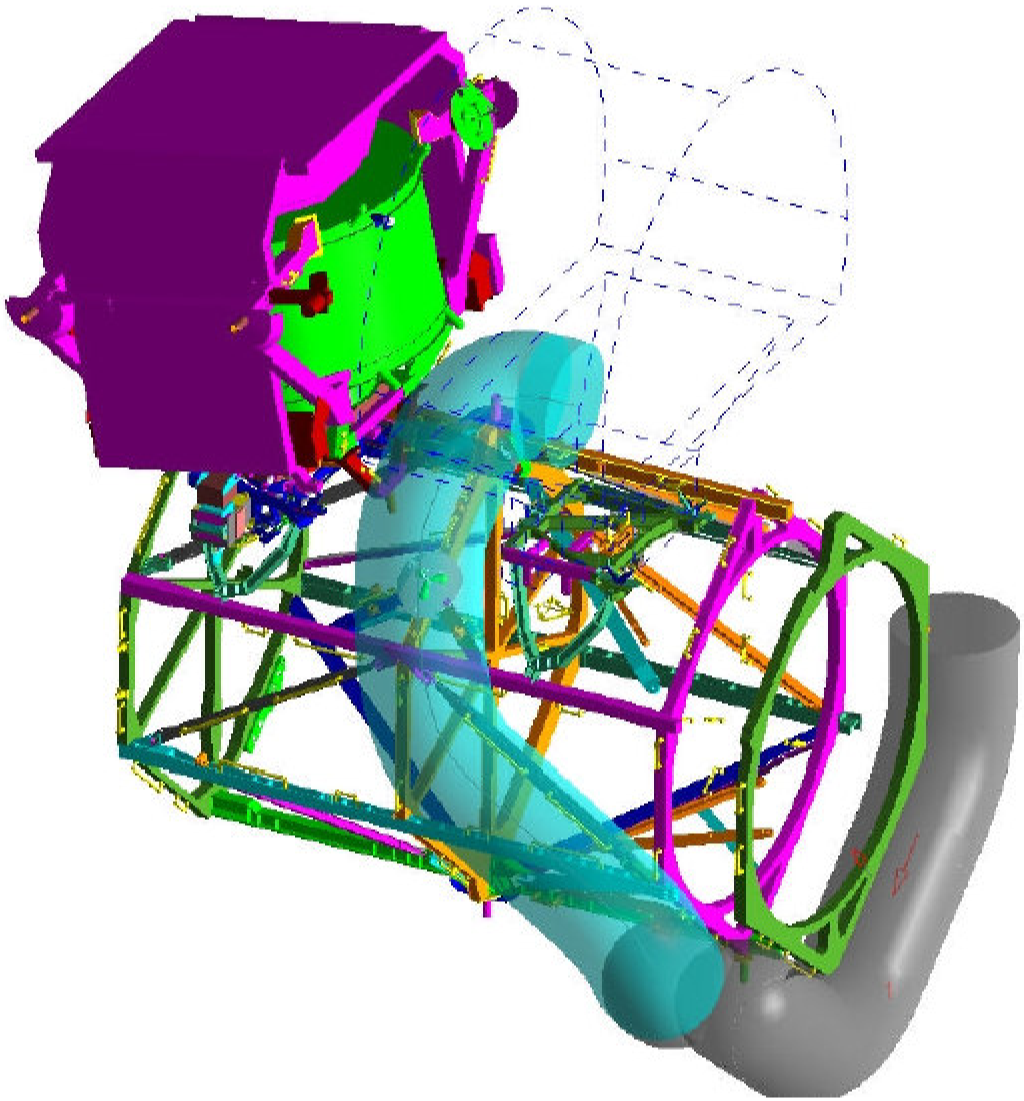

Figure 6.4.2.1-16 EVA Translation Path from Worksite Analysis

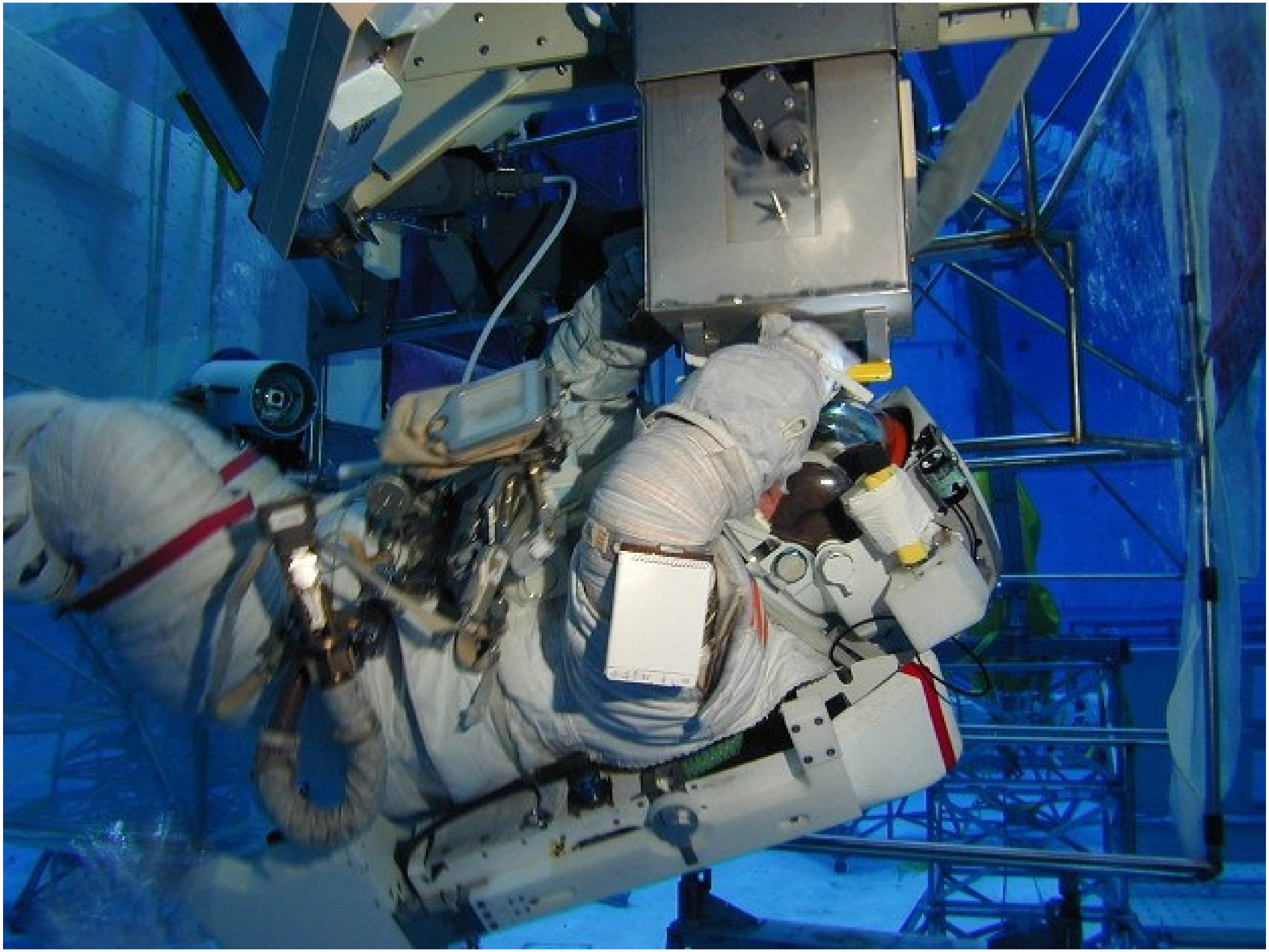

Figure 6.4.2.1-17 EVA Crewmember in NBL Testing (UMA Release Task)

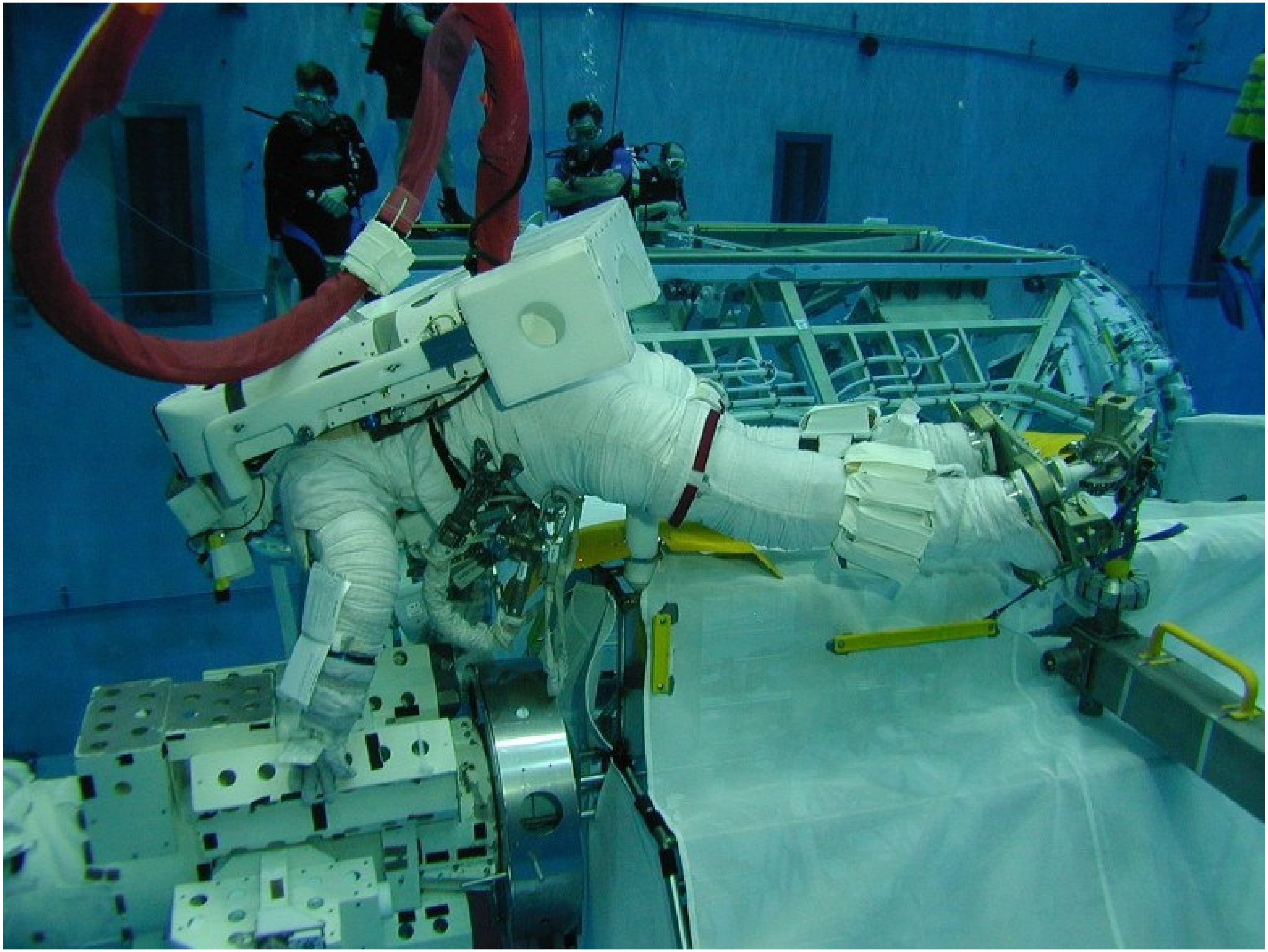

Figure 6.4.2.1-18 EVA Crewmember in NBL Testing (PVGF Release Task)