Interface Definition for Nanoracks Airlock

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Nanoracks

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List of Revisions

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1 Introduction

1.1 Purpose

This Interface Definition Document (IDD) provides the minimum requirements for compatibility of a payload to interface with the Nanoracks Airlock (NRAL). This IDD also defines the requirements to the International Space Station (ISS) flight safety program when using the NRAL. This IDD also defines the various environments applicable to the payload design process. All payloads will need to conform to additional ISS requirements (SSP 57000 for internal and SSP 57003 for external) that may not be covered in this IDD. Nanoracks can help payloads navigate these requirements as necessary. Nanoracks verifies compliance on behalf of payload developers based on incremental data requests. An initial payload Interface Control Agreement (ICA) will be developed based on the available payload data. Subsequent iterations will follow that will fully define all payload applicable requirements, services, and interfaces.

1.2 Scope

The physical, functional, and environmental design requirements associated with payload safety and interface compatibility are included herein. The requirements defined in this document apply to on-orbit phases of the pressurized and unpressurized payload operation. On-orbit requirements apply to all the payloads in the International Space Station (ISS).

1.3 Use

This document levies design interface and verification requirements on payload developers. These requirements are allocated to a payload through the unique payload ICA. The unique payload ICA defines and controls the design of the interfaces between Nanoracks and the Payload, including unique interfaces. This document acts as a guideline to establish commonality with the respect to analytical approaches, models, test methods and tools, technical data and definitions for integrated analysis.

1.4 Exceptions

The Unique Payload ICA documents the payload implementation of the IDD requirements. The Unique ICA is used to determine if the hardware design remains within the interface design parameters defined by this document. Limits of the ICA are established in a conservative manner to minimize individual payload and mixed cargo analyses.

Exception is the general term used to identify any payload-proposed departure from specified requirements or interfaces. Any exception to requirements, capabilities, or services defined in this IDD shall be documented in Section 5.0 of the derived ICA and evaluated to ensure that the stated condition is controlled. Section 5.0 will document the specific requirement excepted, the exception number, the exception title, and the approval status.

2 Acronyms, Definitions and Applicable Documents

Table 2-1: Acronyms

Acronym	Definition
ACBM	Active Common Berthing Mechanism
C&DH	Command & Data Handling
CMC	Cargo Missions Contract
CTB	Cargo Transfer Bag
DHS	Data Handling System
ECM	Electronic Control Module
EPS	Electrical Power System
EVA	Extra Vehicular Activities
EVR	Extra Vehicular Robotics
EWC	External Wireless Communication
FSE	Flight Support Equipment
FTP	File Transfer Protocol
GFE	Government Furnished Equipment
GOLD-2	General-Purpose Oceaneering Latching Device-2
HFIT	Human Factors Interface Test
H&S	Health & Status
ICA	Interface Control Agreement
IDD	Interface Definition Document
IMV	Intermodular Ventilation
IP	Internet Protocol
ISS	International Space Station
IVA	Intravehicular Activities
JEM	Japanese Experiment Module
JOTI	JEM ORU Transfer Interface
JSL	Joint Station LAN
Ku-IP	Ku-Band Internet Protocol
MCC-H	Mission Control Center – Houston
MIUL	Material Identification Usage List
MMOD	Micrometeoroid Orbital Debris
MRDL	Medium Rate Data Link
NRAL	Nanoracks Airlock

Acronym	Definition
ORU	Orbital Replacement Unit
PCBM	Passive Common Berthing Mechanism
POA	Payload ORU Adapter
POIF	Payload Operation Integration Function
PIU	Payload Interface Unit
PVGF	Power and Video Grapple Fixture
SDGF	Standard Dexterous Grapple Fixture
SPDM	Special Purpose Dexterous Manipulator
SSRMS	Space Station Remote Manipulator System
USB	Universal Serial Bus
VDC	Volts Direct Current
W	Watts
WAP	Wireless Access Point

Table 2-2: Applicable Documents

Doc No.	Rev	Title
SSP 57000	S	Pressurized Payloads Interface Requirements Document
SSP 57003	L	External Payload Interface Requirements Document
SSP 52005	F	Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures
SSP 30233	H	Space Station Requirements for Materials and Processes
SSP 30240	H	Space Station Grounding Requirements
SSP 30245	P	Space Station Electrical Bonding Requirements
NASA-STD-8719.14A		NASA Technical Standard Process for Limiting Orbital Debris
JSC 20793	C	Crewed Space Vehicle Battery Safety Requirements
MSFC-SPEC-522	B	Design Criteria for Controlling Stress Corrosion Cracking
GOLD02-SP005	D	General-Purpose Oceaneering Latching Device (GOLD-2) Interface Control Document (ICD)
NR-AIRLOCK-R0017	A	Airlock Payload Concept of Operations

3 Nanoracks Airlock Overview

This section is an overview of the Nanoracks Airlock. It describes the various system interfaces and the operational elements of the payload lifecycle.

3.1 NRAL Physical Descriptions

The NRAL is an airlock, as well as a payload platform, (ref. Figure 3.1-1) capable of accommodating internal and external payloads. The Airlock provides a more efficient egress from and to the station for payloads, Orbital Replacement Units (ORU's), trash and potentially many other uses. The Airlock uses a bell jar design and attaches to the Node 3 Port berthing ring. The Airlock is maneuvered and installed/removed by the Space Station Remote Manipulator System (SSRMS). Astronauts would prepare and install payloads via Intravehicular Activities (IVA) and then ground control manages depressurization, EVR and deployment activities. When a deployment or other use is complete, the Airlock is returned to Node 3 for the next usage cycle.

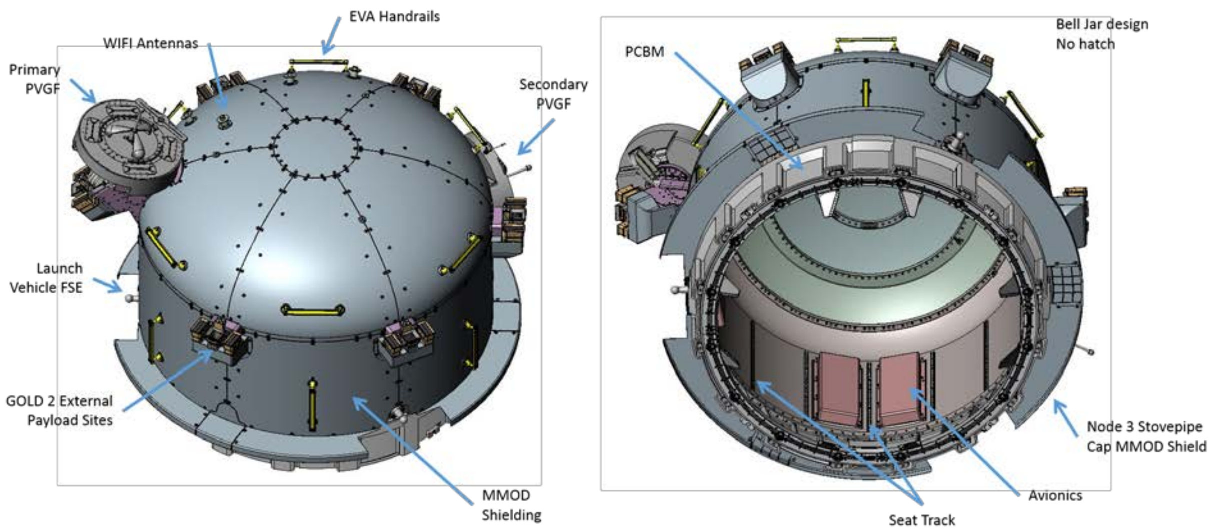


Figure 3.1-1: Nanoracks Airlock

3.1.1 Airlock Primary Structure

The primary structure is the main load bearing elements of the structure and consists of the following:

- The Passive Common Birthing Mechanism (PCBM) is a standard, flight-proven piece of hardware that will interface to the ISS Active Common Berthing Mechanism (ACBM) on Node 3.
- The pressure shell provides the habitable environment and is a unique piece of hardware that will be designed, analyzed, and tested for the Airlock environment. The pressure shell will be a three-piece bolted structure.
- The Launch Vehicle Flight Support Equipment (FSE) is provided as Government Furnished Equipment (GFE) by SpaceX. It is installed by SpaceX at their facility in Florida prior to installation into the Dragon trunk.
- The Power and Video Grapple Fixture (PVGF) will also be GFE and provide the interface to the International Space Station (ISS) SSRMS. The PVGF support structure will be unique hardware designed, analyzed, and built for the Airlock environment

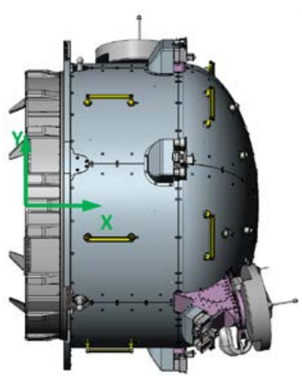
3.1.2 Airlock Secondary Structure

The secondary structures consists of those elements that are not considered in the primary load path of the payload. These structures consist of the following:

- Payload Support Structure (e.g. internal seat track and external payload connectors)
- Micrometeoroid Orbital Debris (MMOD) shielding
- WIFI antenna structures
- Extra Vehicular Activities (EVA) handrails and mounts (GFE)
- Miscellaneous connector panels and bracketry

3.1.3 Airlock Coordinate System

The coordinate system of the Airlock is a right-handed system shown in Figure 3.1.3-1. Its origin is the geometric center of the mating surface of the PCBM to the ACBM. The X-Axis runs through the length of the Airlock, the Y-Axis points ISS Zenith and the Z-Axis points ISS Forward.



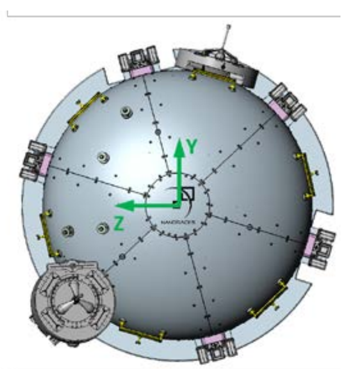


Figure 3.1.3-1: Airlock Coordinate System

3.1.3.1 External Payload Locations

External payloads are mounted to the GOLD-2 connectors. The individual payload locations are described in **Figure 3.1.3.1-1**.

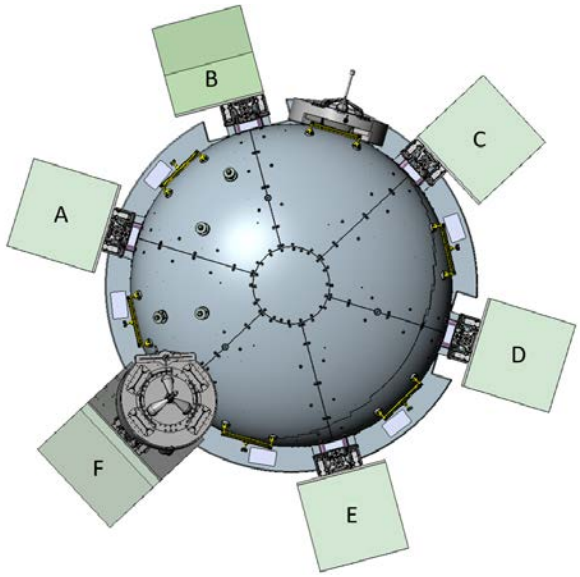


Figure 3.1.3.1-1: External Payload Location Code

3.1.4 Airlock General Dimensions

The airlock general dimensions are shown in **Figure 3.1.4-1**. More detailed dimensions can be found in NR-AIRLOCK-D0010 Launch Configuration, Airlock Assembly drawing. A CAD model resides on NASA/JSC Systems Engineering & Integration Office 3D CAD Models website, and can also be provided upon request.

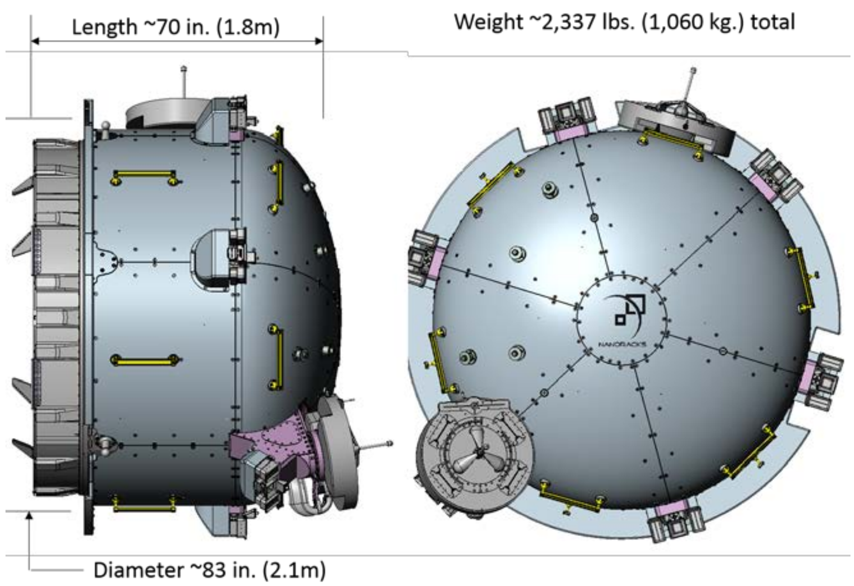


Figure 3.1.4-1: Airlock Envelope Dimensions

3.1.5 Airlock Avionics System

The Airlock avionics (**Figure 3.1.5-1**) consists of a Command & Data Handling System (C&DH), Electrical Power System (EPS), video system and thermal control system. The Command and Data Handling Unit (CDHU) consists for the Airlock computer, Network Switch and Network Attached Storage. It interfaces to the ISS Joint Station LAN (JSL) via a hardline while berthed to Node 3 and via a WIFI when deployed. The WIFI is via a NASA furnished Wireless Access Point device located in the Payload Interface Unit 2 (PIU2). The Electrical Power System consists of a Power Distribution Unit (PDU) which provides power isolation from the various Space Station power sources, filtering and current protection. The PDU receives power via a hardline either from Node 3 when berthed or via either PVGF when deployed. Each ISS power interface contains two channels of power for redundancy purposes. After PDU conditioning, the power is distributed out to the various Airlock systems and payloads. Payload power control is via Payload Interface Unit 1 (PIU1) which contains several power controllers to allow operators to power ON/OFF payloads as necessary. The Airlock contains Internet Protocol (IP) cameras that interface to the Airlock C&DH system via a Camera Electronics Unit (CEU). The CEU can accommodate up to 4 video cameras and cameras can be positioned are various places around the interior of the Airlock to support payload operations. The Airlock thermal control system consisting of several pressure shell heaters which are thermostatically controlled and temperature sensors for monitoring performance of the heaters. The heaters are powered via the Heater Power Unit (HPU) which contains power controllers to allow operators to power ON/OFF the heaters as necessary. Smoke detection is via the Node 3 IMV detectors. The Node 3 hatch may be open or closed.

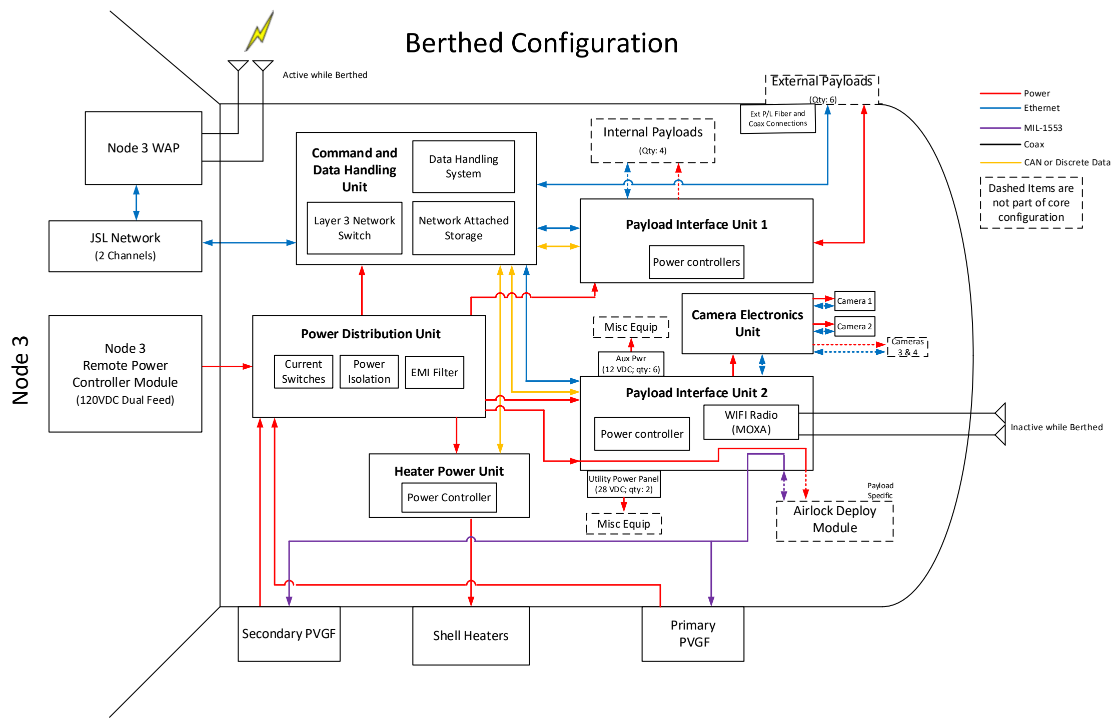


Figure 3.1.5-1: Airlock Avionics Block Diagram

4 Airlock Payload Overview

The Airlock Payload Support System has been developed to provide the interface between the Airlock and future payloads for both inside of Airlock as well as external payload sites. The following sections provide an overview of these payload support systems.

4.1 Internal Payloads

The Airlock internal payloads interface with the seat track on the dome or cylinder as well as threaded fastener interfaces located on the pressure shell structural rings. Figure 4.1-1 shows general dimension envelopes for internal payloads. These envelopes do not account for Avionics boxes, cables or other vestibule hardware. CAD versions of the envelopes as well as the Airlock internal interfaces is available upon request. Payload power is 120 Volts DC (VDC), 350 Watts (W) nominal and data is Ethernet protocol.

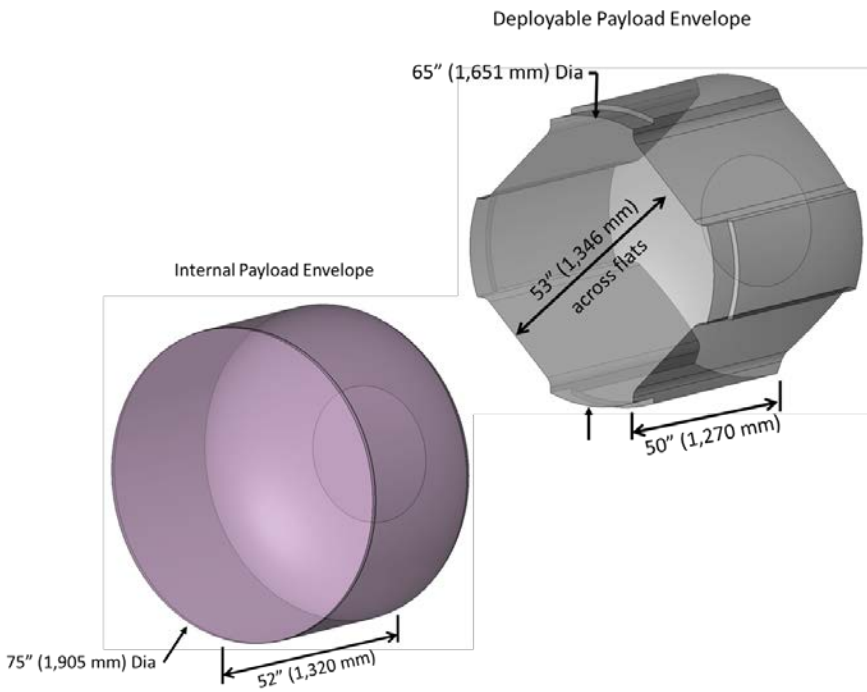


Figure 4.1-1: Generic Internal Volumes

The max deployable payload size is 44.2" x 44.2" x 50", 709 lbs based on Nanoracks Airlock (NRAL) volume and ISS jettison policy (Ref Nanoracks report NR-AIRLOCK-R0006).

4.2 External Payloads

There are six external payload sites available (**Figure 4.2-1**). Oceaneering General-Purpose Oceaneering Latching Device (GOLD-2) connectors (**Figure 4.2-2**) provide electrical, mechanical and robotic interfaces. Nominal payload envelope is 24 in. x 24 in. x 28 in. and 500 lbs. One payload site has specific volume limitations described later. Payload power is 120 VDC, 350 W nominal and data is Ethernet protocol. There are redundant power and data interfaces.

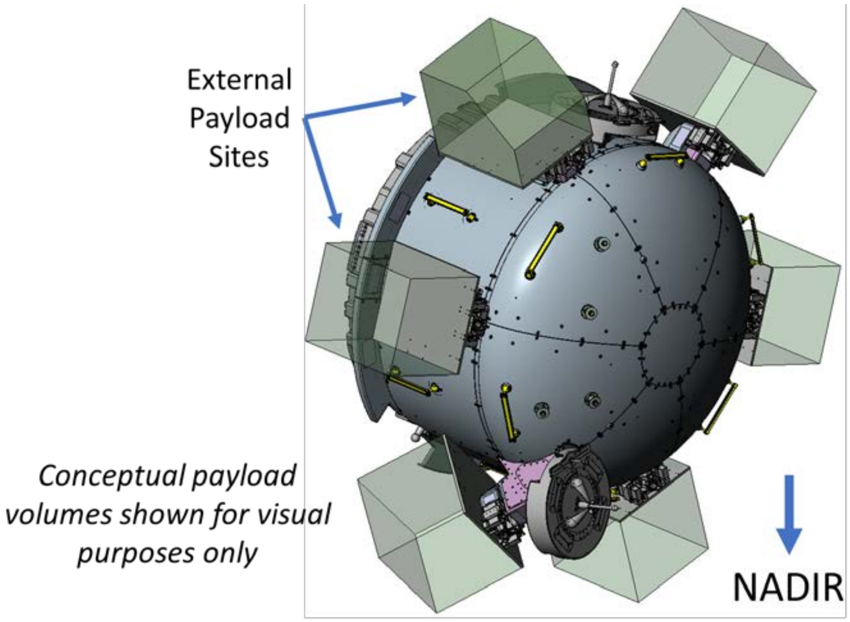


Figure 4.2-1: External Payload Volumes

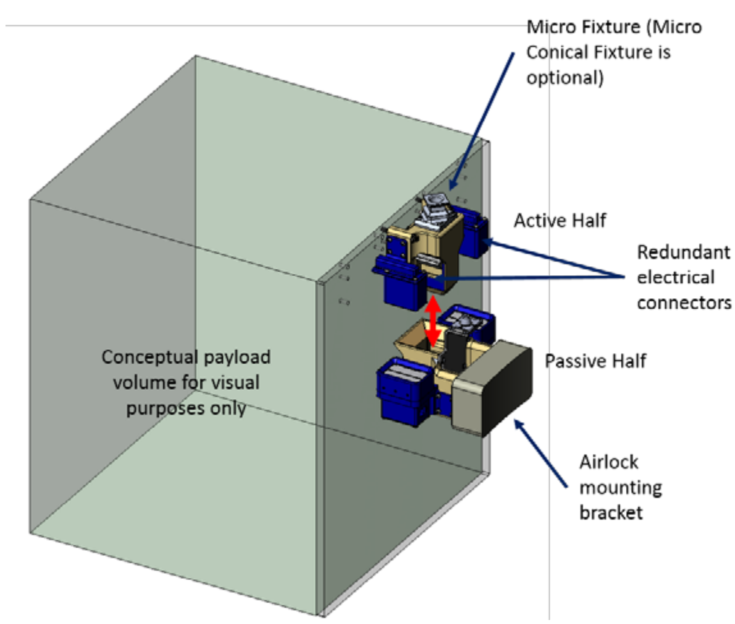


Figure 4.2-2: Oceaneering GOLD 2 Connector

4.3 Hatch

For payloads being launched inside of the ISS cargo vehicles, the launch vehicle hatch has additional considerations with respect to payload sizes. All payloads must fit through the dimensions one of the hatches as shown in **Figures 4.3-1 through 4.3-4**.

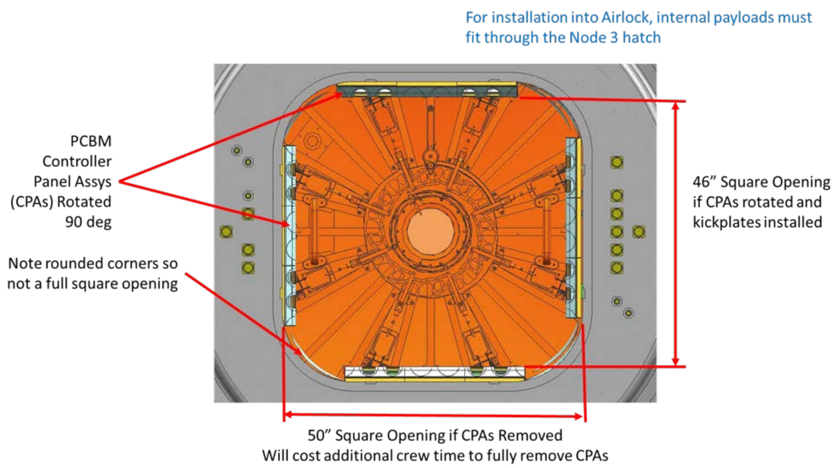


Figure 4.3-1: Node 3 Hatch Opening

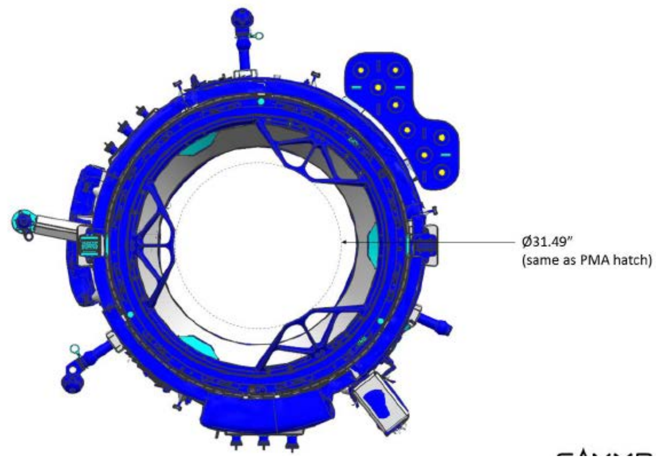


Figure 4.3-2: IDA Hatch Opening

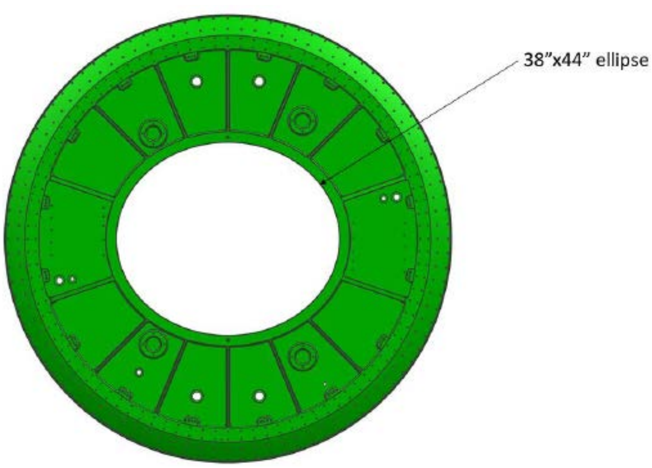


Figure 4.3-3: DreamChaser Hatch Opening

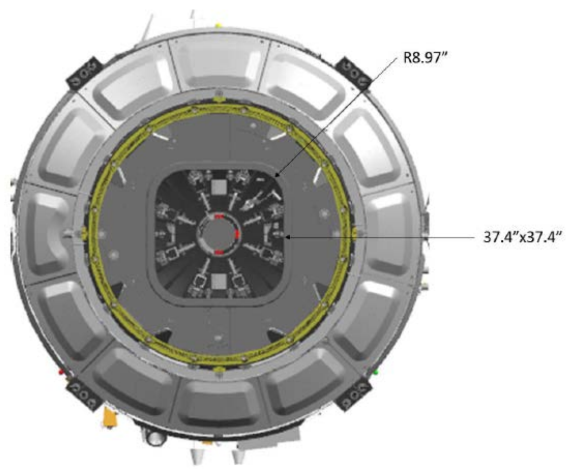


Figure 4.3-4: Cygnus Hatch Opening

4.4 Stowage Constraints

Cargo Transfer Bags (CTBs) are Nomex stowage bags that are the typical packing means for payloads inside of the ISS Cargo Vehicles. **Table 4.4-1** describes the different sizes of bags and their weight and dimensional capabilities.

Table 4.4-1: Cargo Transfer Bags

CTB	Empty Bag Wt. (lbs.)	Internal Dimensions (LXWXH)(in.)			Max Load including Bag Wt. (lbs.)
		L	W	H	
0.5 CTB	1.25	16.50	9.50	9.0	30
1.0 CTB	1.96	19.50	16.50	9.50	60
2.0 CTB	2.63	19.50	16.50	19.50	120
3.0 CTB	3.46	29.25	16.50	19.50	180
4.0 CTB	4.13	35.05	19.75	20.75	200
6.0 CTB	5.77	35.05	32.00	20.75	300
8.0 CTB	6.51	39.75	35.05	20.75	400
10.0 CTB	8.00	51.75	35.05	20.75	500
13.5 CTB	13.60	67.00	32.25	19.25	600

A few items to note with regards to CTBs:

- Not all cargo vehicles can accommodate all different sizes of bags
- Bag sizes 2.0 and below offer the most flexibility with regards to manifesting. Larger bags are available but can be more difficult to find room on a particular flight
- If the payload doesn't fit in a CTB, custom foam can be generated but will require coordination with NASA.

4.5 Airlock Payload Operations Overview

The launch, on-orbit installation and operation of a payload in the Airlock, or deployment of a payload (e.g. micro-satellite) from the Airlock, is documented in the payload Interface Control Agreement (ICA). The Airlock Payload Concept of Operations document, NR-AIRLOCK-R0017 provides guidelines regarding the operations of payloads within the Airlock and will be used in conjunction with the IDD. The payload representative will be notified of the status of its hardware and will be notified to ensure his support for flight operations.

4.5.1 Schedule

Table 4.5.1-1 is a standard template schedule. The detailed payload schedule will be coordinated through the individual ICA between Nanoracks and the Payload provider.

Table 4.5.1-1: Milestone Schedule

Milestone/Activity	Launch-minus Dates (Months)
Contract Signing	L – 12
ICA Start	L – 11.5
Payload Deliveries: Functional Description, Interface Drawings, Material Identification Usage List (MIUL), Budget Report	L – 10
Payload service provider starts ISS safety process	L – 10
Payload delivery: Crew IVA Operations inputs	L – 10
Payload delivery: Thermal Model or equivalent data	L – 9
Payload delivery: Structural Model or equivalent data	L – 9
Payload delivery: Mass Properties Report	L – 9
Payload delivery: Avionics requirements, power, grounding, bonding, or equivalent data	L – 9
Payload manifested on a flight	L – 9
Payload delivery: Flight operations description	L - 6
Payload delivery: On-Orbit payload commanding inputs	L – 6
Payload - handover to Airlock service provider	L - 3
Payload Environmental tests and Functional test within Airlock test bed	L - 6 to L – 1
Payload Environmental tests (JSL, Acoustics, vibration, etc.)	L – 6 to L – 1
Payload Certification for flight and handover to launch authority	L-1
Launch	L-0
Payload installation into Airlock	L+1
Payload operation	L+1 to L+TBD based on payload developer
Payload return to payload provider	If requested by payload developer

5 Payload Interface Requirements

The requirements contained in this section will be complied with in order to certify a payload for integration into or onto the NRAL. This section addresses the following disciplines for external and internal payloads: Structural, Electrical, Command and Data Handling.

5.1 Internal Payloads

Internal payloads are defined as payloads installed into the airlock volume IVA by the crew members. They utilize the internal seat track and threaded fastener locations for mounting. They are designed to operate inside the airlock, deploy from the airlock or be brought in through the airlock. Internal payloads can also be brought into the ISS from an external location and handled by the Crew IVA.

5.1.1 Internal Payload Envelope

The maximum payload envelope is defined below for internal payloads. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.

5.1.1.1 Deployable Payloads

The maximum payload envelope for deployable payloads shall not exceed the dimensions defined in Figure 5.1.1.1-1. Note that depending on the type of deployable payload, additional envelop restrictions could become applicable based upon NASA Robotics operational assessments. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.

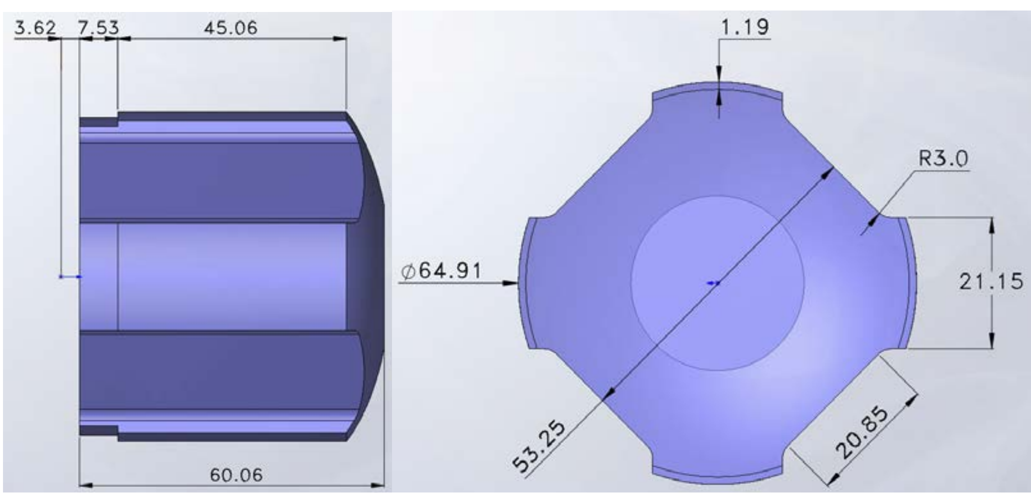


Figure 5.1.1.1-1: Maximum Payload Envelope for Internal Deployable Payloads

5.1.1.2 Non-Deployable Payloads

The maximum payload envelope for static payloads shall not exceed the dimensions defined in Figure 5.1.1.2-1. Note that depending on the type of deployable payload, additional envelop restrictions could become applicable. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.

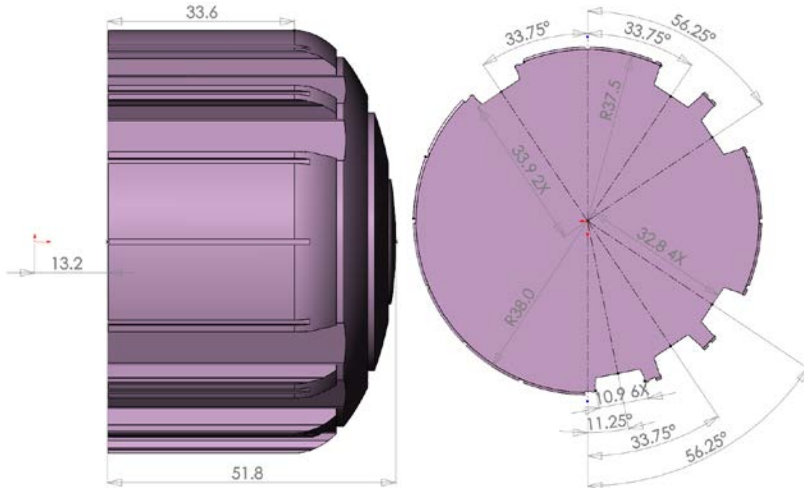


Figure 5.1.1.2-1: Maximum Payload Envelope for Internal Non-Deployed Payloads

5.1.1.3 SSRMS/SPDM Payloads

Payloads that require the SSRMS to remove from or install into the airlock shall meet a 12 inch clearance for extraction or insertion from any other structure. Payloads that require the SPDM to remove from or install into the airlock shall meet a 6 inch clearance for extraction or insertion from any other structure. Any deviation from these requirements may be allowed and will require additional analysis and need to be documented in the Payload ICA and approved by Nanoracks.

5.1.2 Internal Payload Mass Properties

The maximum weight for internal payloads shall not exceed 1500 lbs. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.

5.1.3 Internal Payload Seat Track Interfaces

All the seat track on the internal airlock surfaces is per SSP 57000 N.3.1.1.5-1.

5.1.3.1 Dome Seat Track

Any payload that interfaces with the dome seat track shall utilize the location coding and meet the dimensions referenced in the figures below. The location coding for the internal Dome seat track is per **Figure 5.1.3.1-1**. The coordinate location for the dome seat track is defined in **Figure 5.1.3.1-2**. The seat track dimensions are defined in **Figure 5.1.3.1-3**.

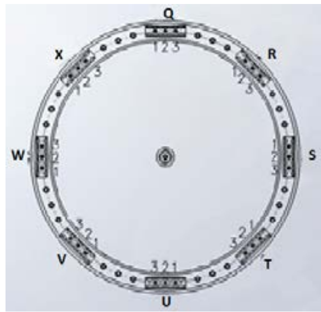


Figure 5.1.3.1-1: Dome Seat Track Location Coding

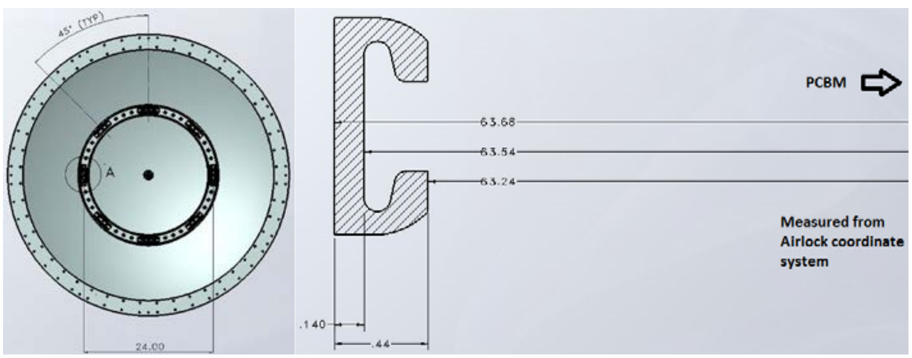


Figure 5.1.3.1-2: Dome Seat Track Dimensions

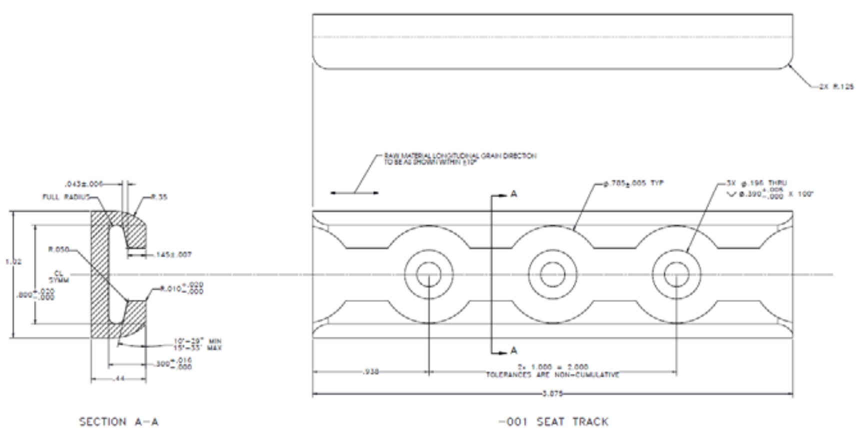


Figure 5.1.3.1-3: Dome Seat Track Dimensions

5.1.3.2 Cylinder Seat Track

Any payload that interfaces with the cylinder seat track shall utilize the location coding and meet the dimensions referenced in the figures below. The location coding and coordinate location for the cylinder seat track is per **Figure 5.1.3.2-1** and **Figure 5.1.3.2-2**.

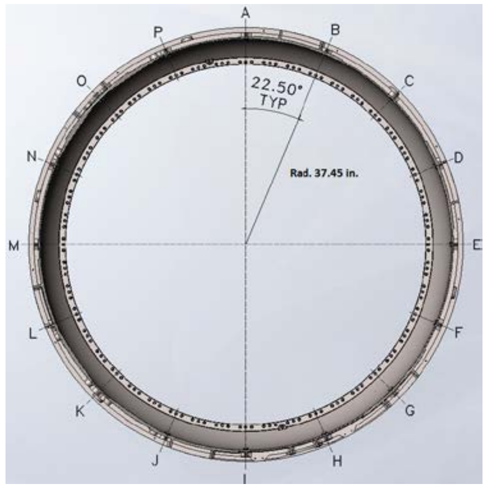


Figure 5.1.3.2-1: Cylinder Seat Track Location Coding and Coordinate Location

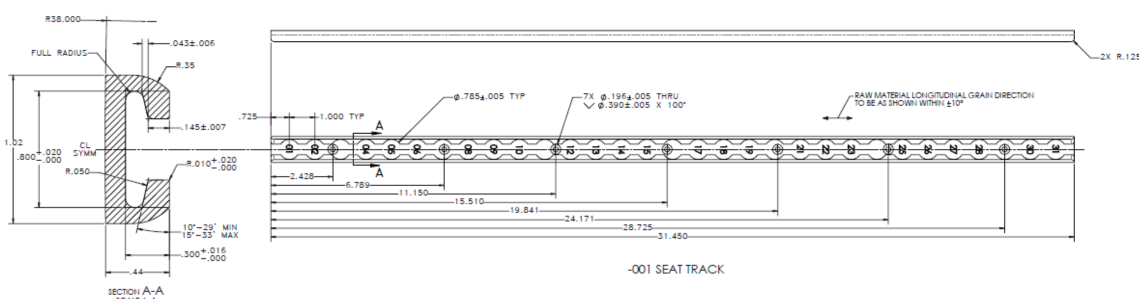


Figure 5.1.3.2-2: Cylinder Seat Track Location Coding and Coordinate Location

5.1.3.3 Dome Seat Track Loads

Payloads attaching to the dome seat tracks shall be within the limit loads as shown in **Table 5.1.3.3-1**. Limit loads can be applied at any one of the three locations on the seat track segments as shown in **Figure 5.1.3.3-1.** The seat track coordinate directions are shown in **Figure 5.1.3.3-2**

Table 5.1.3.3-1: Dome Seat Track Limit Loads

Limit Loads	Anywhere on Track	
Fx	550	lbf
Fy	395	lbf
Fz	650	lbf
F_RSS	920	lbf
Mx	160	lbf-in
My	160	lbf-in
Mz	195	lbf-in
M_RSS	299	lbf-in

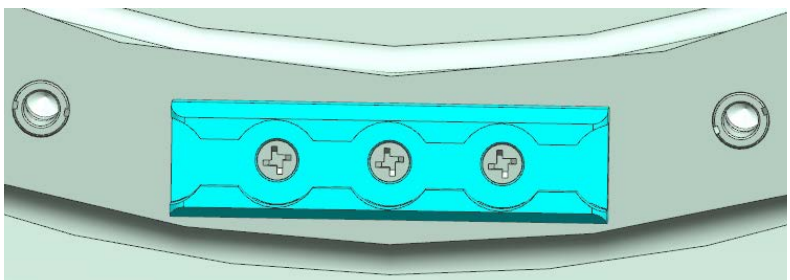


Figure 5.1.3.3-1: Dome Seat Track Locations

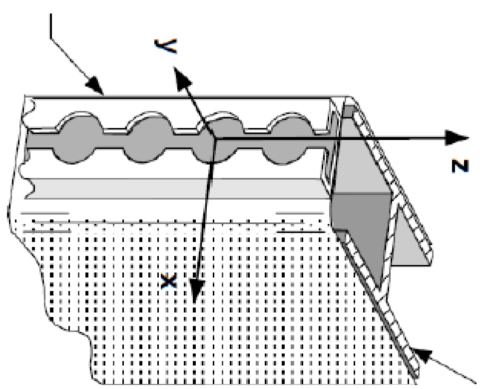


Figure 5.1.3.3-2: Dome Seat Track Coordinates

5.1.3.4 Cylinder Seat Track Loads

Payloads attaching to the cylinder seat tracks shall be within the limit loads as shown in **Table 5.1.3.4-1**. Limit loads can be applied at any of the seat track locations, with the exception that the free edge of the track locations have a reduced loads limit as shown in **Figure 5.1.3.4-1.** The seat track coordinate directions are shown in **Figure 5.1.3.4-2**

Table 5.1.3.4-1: Cylinder Seat Track Limit Loads

Limit Loads	Away From Edge	On Free Edge	
Fx	375	300	lbf
Fy	365	255	lbf
Fz	375	300	lbf
F_RSS	644	495	lbf
Mx	1245	195	lbf-in
My	195	195	lbf-in
Mz	195	195	lbf-in
M_RSS	1275	338	lbf-in

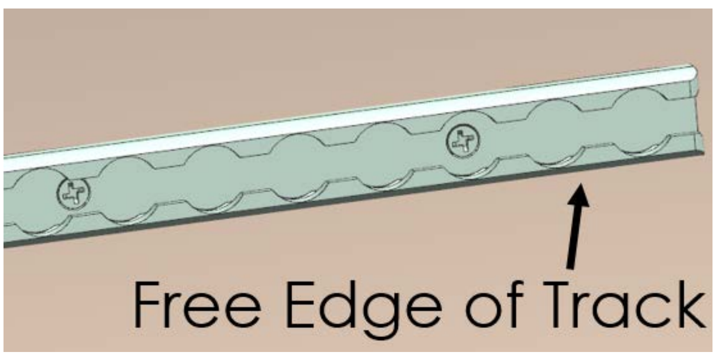


Figure 5.1.3.4-1: Cylinder Seat Track Locations

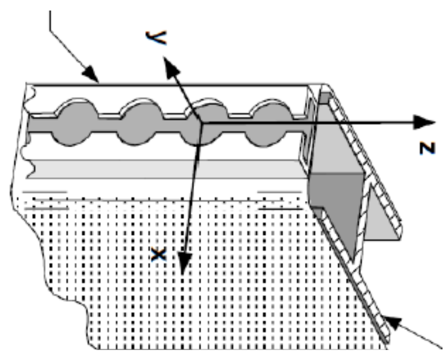


Figure 5.1.3.4-2: Cylinder Seat Track Coordinates

5.1.4 Internal Payload Threaded Fastener interface

There are four different locations of threaded fasteners on the inside of the Airlock. **Figure 5.1.4-1** shows the planar location of these fasteners with respect to the X axis of the Airlock coordinate system.

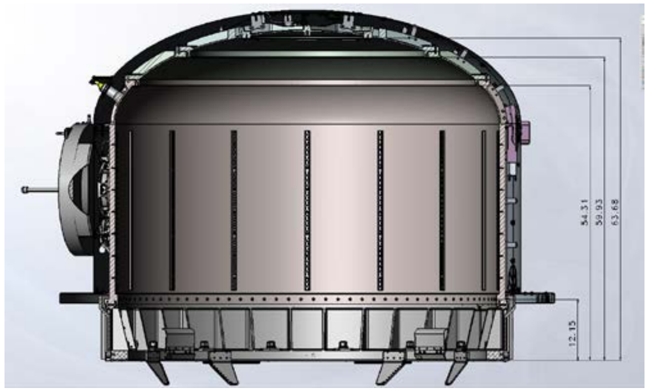


Figure 5.1.4-1: Threaded Fastener Planar Locations (in.)

5.1.4.1 X(63.68) threaded fasteners

All payloads that interface with the X(63.68) fasteners shall meet the location coding, dimensions and threaded fastener requirements listed below. The location coding for the X(63.68) plane threaded fasteners is per **Figure 5.1.4.1-1**. The coordinate location for the X(63.68) plane threaded fasteners is defined in **Figure 5.1.4.1-2**. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.

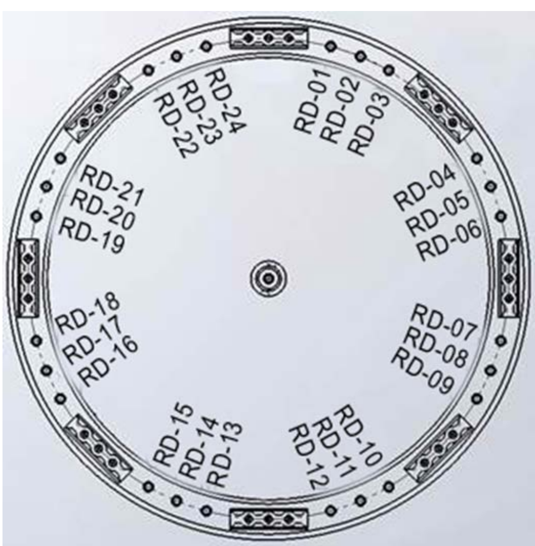


Figure 5.1.4.1-1: X(63.68) Threaded Fastener Location Coding

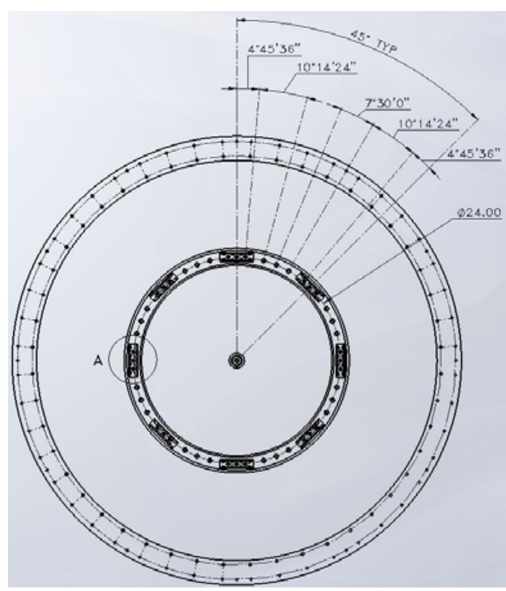


Figure 5.1.4.1-2: X(63.68) Threaded Fastener

5.1.4.2 X(59.93) threaded fasteners

All payloads that interface with the X(59.93) fasteners shall meet the location coding, dimensions and threaded fastener requirements listed below. The location coding and coordinate location for the X(59.93) plane threaded fasteners is per **Figure 5.1.4.2-1**. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.

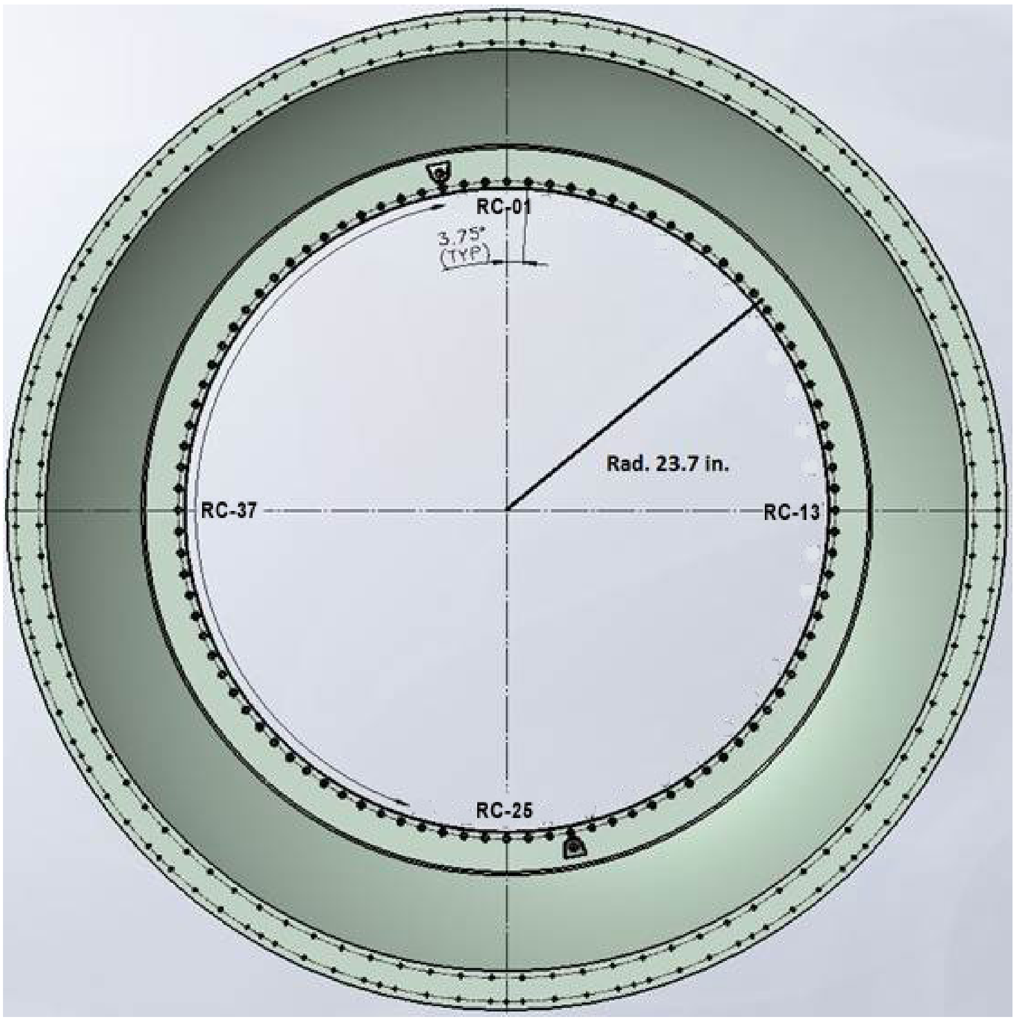


Figure 5.1.4.2-1: X(59.93) Threaded Fastener Coordinate Location and Dimensions

5.1.4.3 X(54.31) threaded fasteners

All payloads that interface with the X(54.31) fasteners shall meet the location coding, dimensions and threaded fastener requirements listed below. The location coding and coordinate location for the X(54.31) plane threaded fasteners is per **Figure 5.1.4.3-1**. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.

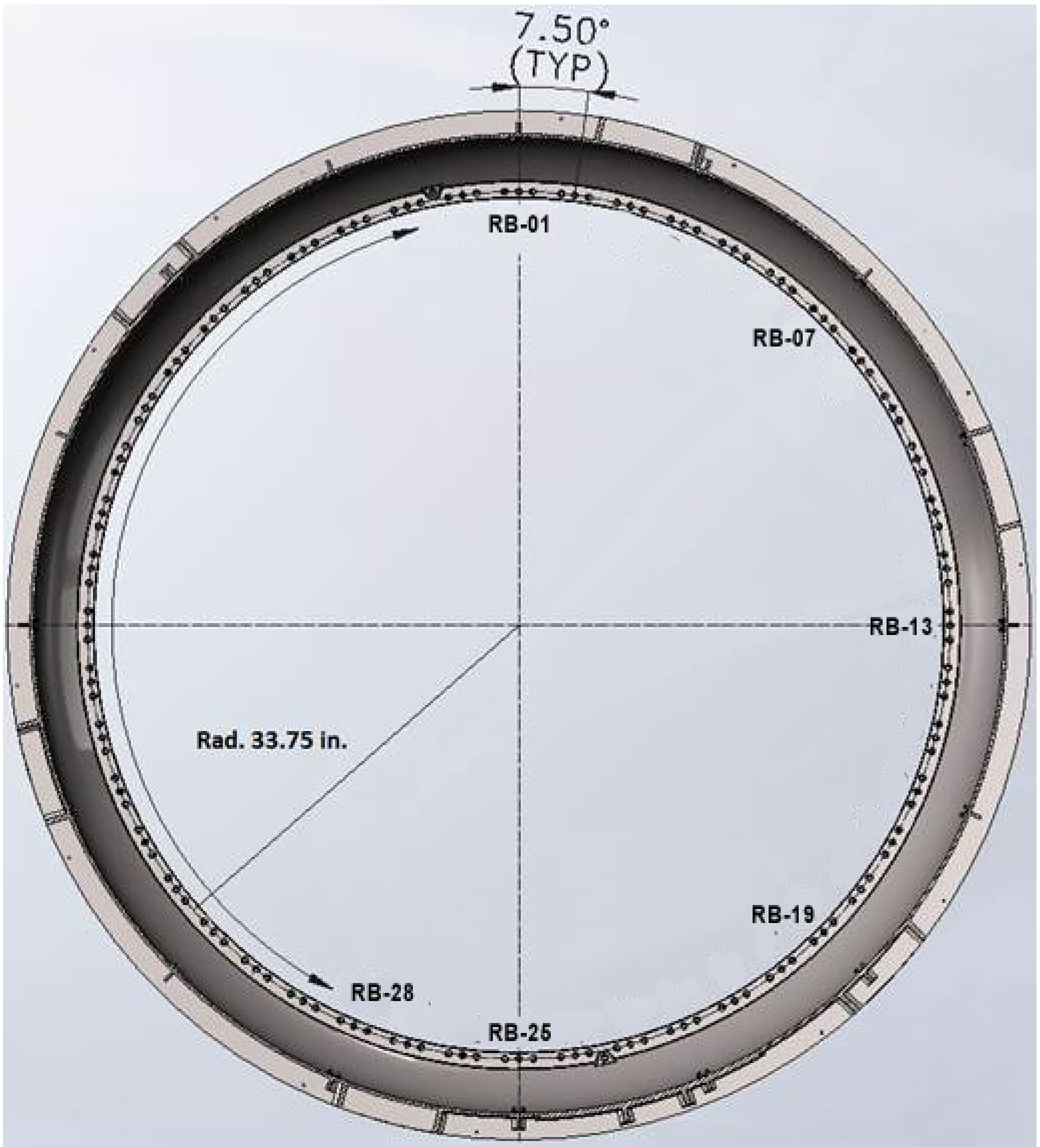


Figure 5.1.4.3-1: X(54.31) Threaded Fastener Location Coding and Coordinate Location

5.1.4.4 X(12.15) threaded fasteners

All payloads that interface with the X(12.15) fasteners shall meet the dimensions and threaded fastener requirements listed below. Any internal payloads that need to utilize the X(12.15) threaded hole locations will work with Nanoracks to determine which locations are available for use. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.

5.1.4.5 Endcap Threaded Fastener

All payloads that interface with the endcap threaded fastener shall meet the threaded fastener requirements listed below. There is a single axial insert located at the center of the endcap. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.

5.1.4.6 Threaded Fastener Loads

All payloads that interface with the threaded fasteners shall not exceed the capabilities of the MS51831CA203L insert in 2219-T851 as stated in **Table 5.1.4.6-1**.

Table 5.1.4.6-1: Threaded Fastener Limits

Capabilities of Insert in 2219-T851		
Axial	**3913**	lbf
RSS Shear	**15452**	lbf

5.1.5 Internal Payload Bonding and Grounding

All payloads shall, at a minimum, be bonded to the Airlock structure either via the seat track or the structural rings of the Airlock per SSP 30245 Class S. Higher class bonds are capable and will be documented in the payload unique ICA. For the seat track, the seat track is nickel plated such that faying surfaces between the payload support structure and the seat track can be electrically conductive. For the threaded fasteners, the local area around each insert is chem film coated to allow the faying surfaces between the payload and the rings can be electrically conductive.

5.1.6 Internal Payload Power Interfaces

Electrical services are available via 4 payload interface connectors for internal payloads. The connectors are located on the Payload Interface Unit 1 (PIU1). For each payload interface connector on PIU1, there are two power interfaces and a data interface to the payload. Each connector is identical on PIU1 for operational flexibility and redundancy. Each connector has the following type connections:

- Payload Operational Power: Switchable 120 VDC power, nominal 350 W and maximum of 700 W; 2 feeds
- Data: Ethernet, Gigabit
- Bridge Detect: Loop back circuit that verifies a good mate has occurred at the PIU1 connector

Details about the maximum available power and data rates will be defined and documented in the Airlock payload-specific ICA.

12 and 28 VDC Utility Power Panel Interface

In addition to nominal payload power interfaces, 12 and 28 VDC utility power outlets on PIU2 may be available for payload use. Because these interfaces are not typically used for payload power, payload use of any utility power outlet should be evaluated with Nanoracks on a case-by-case basis. Further information is available in the tables below.

Figure 5.1.6-1: 12 and 28 VDC Power Interfaces on PIU2

Table 5.1.6-1: 12 & 28 VDC Utiility Power Properties

	12 VDC Utility Power	28 VDC Utility Power
Location	Top of PIU2	Front of PIU2
Quantity	6 (identical)	2 (identical)
Voltage	12 VDC	28 VDC
Max Current	4 A total across all six connectors	10 A each, with 10 A circuit breaker installed
Power Indication	Voltage and Current telemetry to Nanoracks Ops team	Voltage and Current telemetry to Nanoracks Ops team and LED indicator for crew
Switching	Controlled by Nanoracks Ops team via command	Controlled by Nanoracks Ops team via command and manual (crew operated) toggle switch
Connectors	J28, J29, J30, J31, J32, J33 D38999/20GB98SN	J5, J6 NB0E14-12SNC – Compatible with MS3470L14-12S, approved for Airlock sorties.
Pinouts		
	C: +12 VDC; 20 AWG	J: +28 VDC; 16 AWG
	D: 12 VDC RTN; 20 AWG	K: 28 VDC RTN; 16 AWG
		L: Chassis; 16 AWG

5.1.6.1 Electromagnetic Compatibility

The Airlock electrical grounding shall be in accordance with SSP 30240, section 3.1.

5.1.6.2 Electrical Grounding

The Payload shall be electrically bonded to the Airlock per SSP 30245, Space Station Electrical Bonding Requirements, paragraphs 3.2 and 3.3.

5.1.6.3 Payload Surface Electrostatic Charging

All Payload metallic hardware elements shall comply with the Class-S bond requirements of SSP 30245, Space Station Electrical Bonding Requirements.

5.1.6.4 Insulated Materials

Hardware consisting of or containing low-conductivity material shall be bonded in accordance with SSP 30245, Section 3.3.4.4.2.

5.1.6.5 Radiation Emissions

The Payload shall not exceed emissions defined in SSP 30237, Space Station Electromagnetic Emission and Susceptibility Requirements

5.1.7 Internal Payload Command and Data Interfaces

The command and data interface to the payloads will be Ethernet protocol and will utilize the same connectors on the PIU1 as the power interface.

5.1.8 Internal Power and Data Connector Interface

The payload shall meet the power and data interface defined in **Table 5.1.8-1**. The payload shall meet the specification of the interface connector provided in **Figure 5.1.8-1**.

Table 5.1.8-1: Internal Payload Power and Data Interface Definition

Designation: PIU1: J7, J8, J9, J10 Interface: Power and Data Connector P/N: D38999/20GJ4SN with socket (female) contacts: M39029/56-351 (20 AWG) and M39029/56-352 (16 AWG) Location: Airlock Internal Payload Unit				
Pin No.	**Signal Name**	**Contact Size**	**Contact P/N:**	**Wire Size**
A	ETH DA+	20	M39029/58-363	24 AWG
B	ETH DA-	20	M39029/58-363	24 AWG
C	Not connected		Sealing plug	
D	ETH DB+	20	M39029/58-363	24 AWG
E	ETH DB-	20	M39029/58-363	24 AWG
a	ETH DC+	20	M39029/58-363	24 AWG
b	ETH DC-	20	M39029/58-363	24 AWG
d	ETH DD+	20	M39029/58-363	24 AWG
e	ETH DD-	20	M39029/58-363	24 AWG
F	Not connected		Sealing plug	
G	Not connected		Sealing Plug	
H	BRIDGE PRIME SIG	20	M39029/58-363	20 AWG
J	BRIDGE PRIME RTN	20	M39029/58-363	20 AWG
K	BRIDGE SEC SIG	20	M39029/58-363	20 AWG
L	BRIDGE SEC RTN	20	M39029/58-363	20 AWG
…	Not connected		Sealing plugs	
y	120VDC PRIME	16	M39029/58-364	16 AWG
z	120VDC RTN PRIME	16	M39029/58-364	16 AWG
AA	CHAS PRIME	16	M39029/58-364	16 AWG
BB	Not connected		Sealing plug	
CC	Not connected		Sealing plug	
DD	CHAS SEC	16	M39029/58-364	16 AWG
EE	120V RTN SEC	16	M39029/58-364	16 AWG
FF	120VDC SEC	16	M39029/58-364	16 AWG
…	Not connected		Sealing plugs	

Each payload that requires power and data interfaces shall provide a harness pigtail with the following connector D38999/26GJ4PN with pin (male) contacts: M39029/58-363 (20 AWG) and M39029/58-364 (16 AWG). The standard exposed length of the cable will be dependent on the payload installation location and documented in the ICA. The power wire size inside Payload shall be at least 16 AWG up to an internal fuse and then may decrease in size based on the that fusing.

The Nanoracks operations team at the Nanoracks ground facility will control and configure the Airlock DHS, payloads, and shared resources (such as data streaming destinations).

The data downlink along this path includes Health and Status monitoring data for the Airlock DHS and all its payloads using the ISS's Medium Rate Data Link (MRDL), some of which are exclusively used by the Airlock DHS itself, and some shared by the payloads.

The Airlock C&DH interface also includes file transfer capabilities directly between the ground and the Airlock DHS (and to/from payloads in a second step).

Payload owners do not have direct access to this command interface. Payloads will get thier H&S telemetry and science data in the form of file downlink and/or data streaming via the BRIDGE.

5.1.9 Airlock Data Handling System (DHS) to Payload Software Interface

This section describes the software interface between the Airlock DHS and the payload. Adherence to the required and optional interfaces described here is essential for the successful and safe operation of Airlock payloads in space. It will ensure that an optimal amount of scientific as well as operational data from a payload can be made available to its owner.

5.1.9.1 Commanding

The Airlock DHS provides the capability to send commands to an internal payload. All Airlock payload commanding shall be performed from the Nanoracks BRIDGE by the Nanoracks Operations team.

5.1.9.2 Health and Status Monitoring

Health and status monitoring of the payloads is unique to each payload based on their requirements and will be defined in the payload unique ICA.

5.1.9.3 File Transfer

Using the Transmit and Receive commands, files can be transferred between a payload and the Airlock DHS. In this case, the Airlock DHS is used as an intermediary, and additional steps will be needed to transfer a file between the DHS and its original source resp. final destination.
Due to the relatively low baud rate of the serial connection and the overhead of the Intel HEX format, the user data transfer rate is limited to about 2 kB/s; therefore, serial file transfer should be limited to small files. Also, consider that while the serial connection is in use by a file transfer, status monitoring for that payload is suspended, which creates a gap in payload monitoring data.

5.2 External Payloads

The Airlock utilizes the Oceaneering Space System's (OSS) GOLD-2 connector (Reference the GOLD-2 ICD, GOLD02-SP005) shown in Figure 5.2-1. The passive half of the connector is mounted to the Airlock and the active half is mounted to the payload. Payloads are responsible for acquiring the active half of the GOLD-2 connector. Any assistance from Nanoracks to aid in the procurement of an active GOLD-2 connector will be documented in the payload ICA. Robotic mating/demating of the payload to the Airlock is done via the SPDM. Payloads have access to power and data through these connectors. Payloads can also utilize a combination of internal volume along with the external volume of the airlock. Figure 5.2-1 shows the external payload location coding. See Appendix A for payloads that utilize the Airlock Payload Transfer FSE to transfer from inside the ISS to the outside of Airlock.

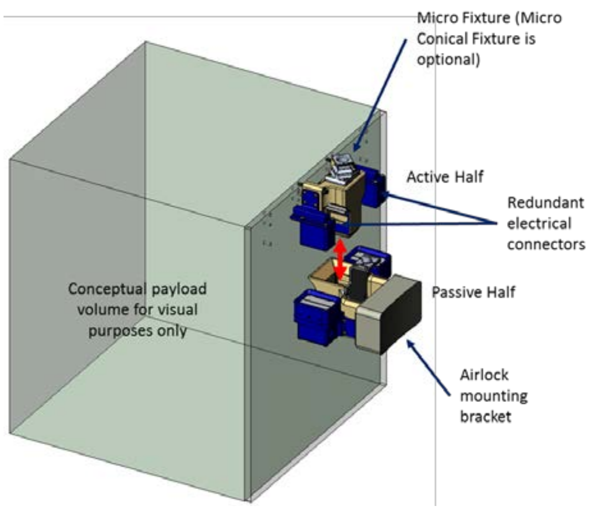


Figure 5.2-1: Oceaneering GOLD-2 Connector

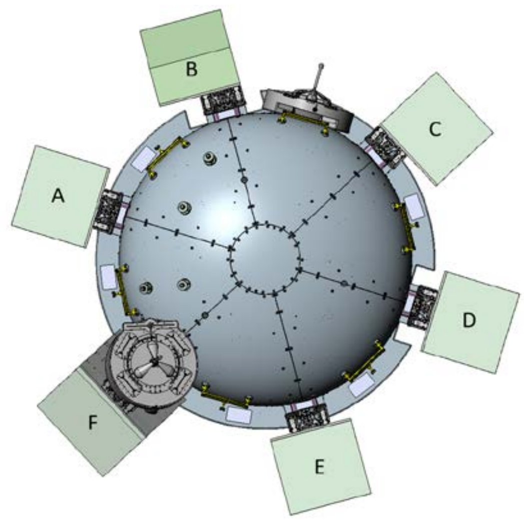


Figure 5.2-2: GOLD-2 Connector Locations

5.2.1 External Payload Envelope

Payloads utilizing the external GOLD-2 interfaces on the external Airlock shall not exceed the payload envelopes defined in **Figures 5.2.1-1** through **5.2.1-4**. The external GOLD-2 locations are defined in **Figure 5.2-2**. Note that the maximum envelopes do not take into consideration any envelope restrictions with respect to the launch vehicle or how it gets from inside the ISS to its external location (i.e. launches in soft stowage). The GOLD-2 may be able to accommodate larger dimensions than those indicated below. Larger payloads may be possible based on the type and locations of other existing payloads. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.

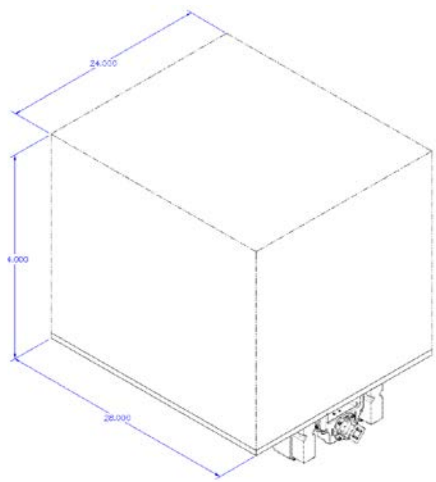


Figure 5.2.1-1: Location A, D and E Payload Envelope

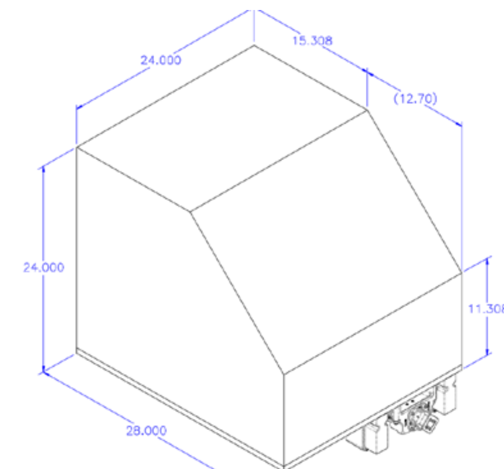


Figure 5.2.1-2: Location B Payload Envelope

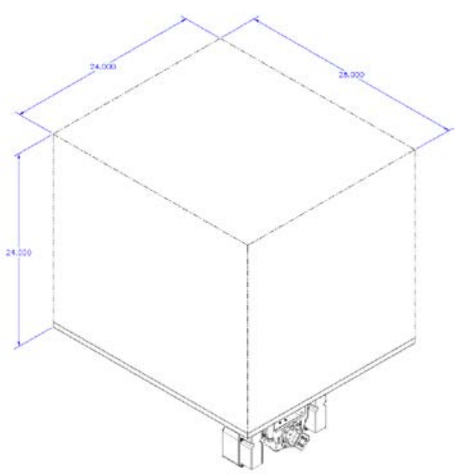


Figure 5.2.1-3: Location C Payload Envelope

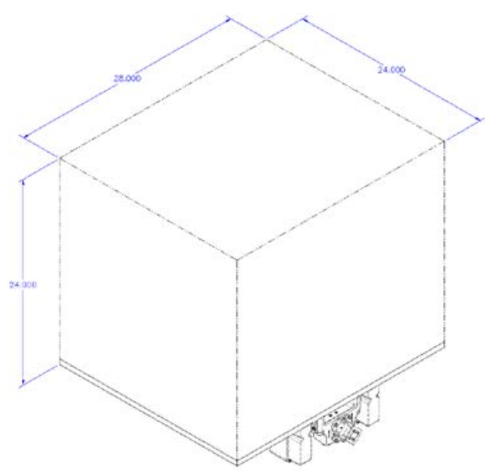


Figure 5.2.1-4: Location F Payload Envelope

5.2.1.1 Active GOLD-2 Installation on Payloads

The installation tolerance of the active side of the GOLD 2 connector is dependent on the final external stowage location on the Airlock and shall meet the tolerances based **Figures 5.2.1.1-1** through **5.2.1.1-4.**

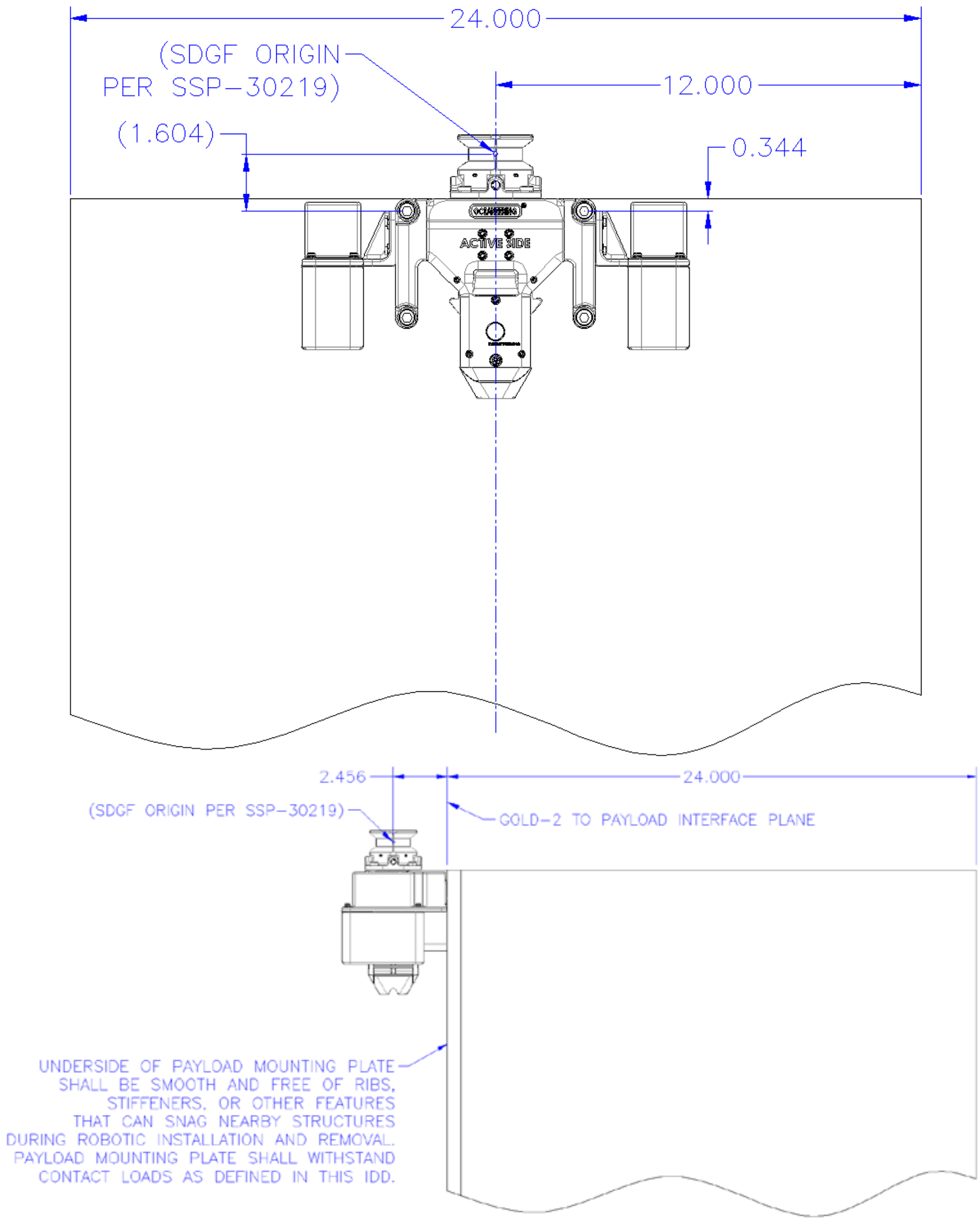


Figure 5.2.1.1-1: Location A, D and E GOLD-2 Installation Tolerance

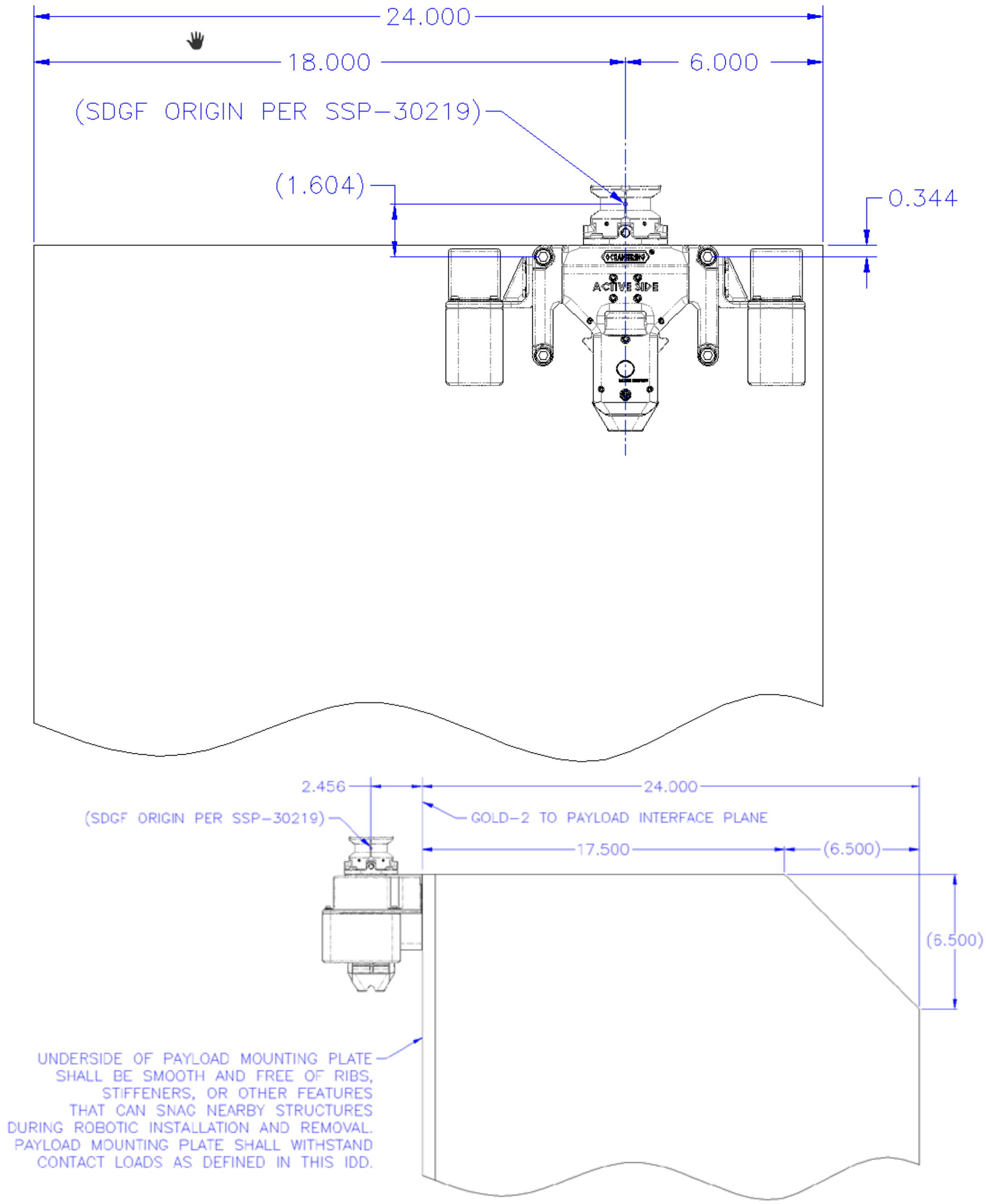


Figure 5.2.1.1-2: Location B GOLD-2 Installation Tolerance

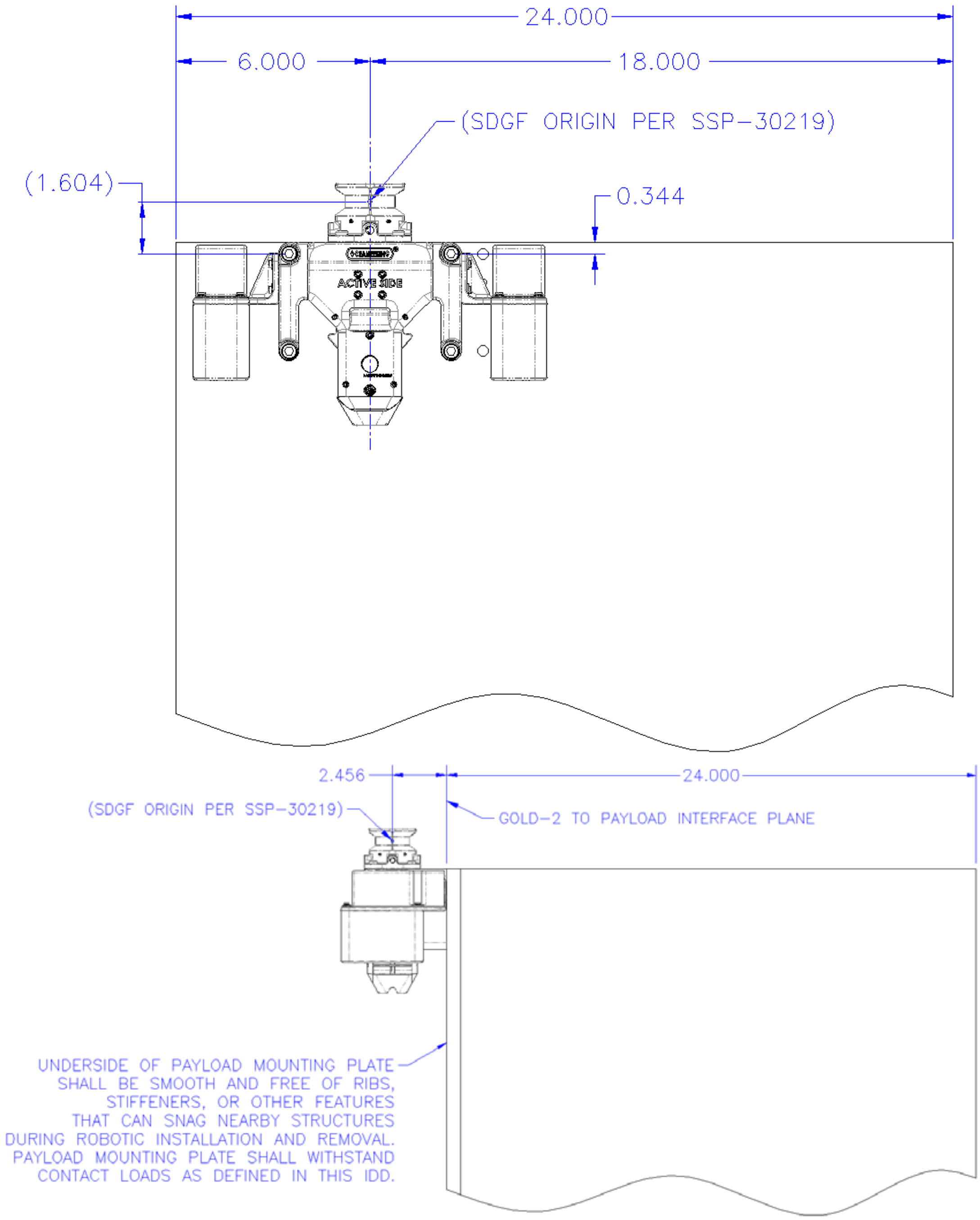


Figure 5.2.1.1-3: Location C GOLD-2 Installation Tolerance

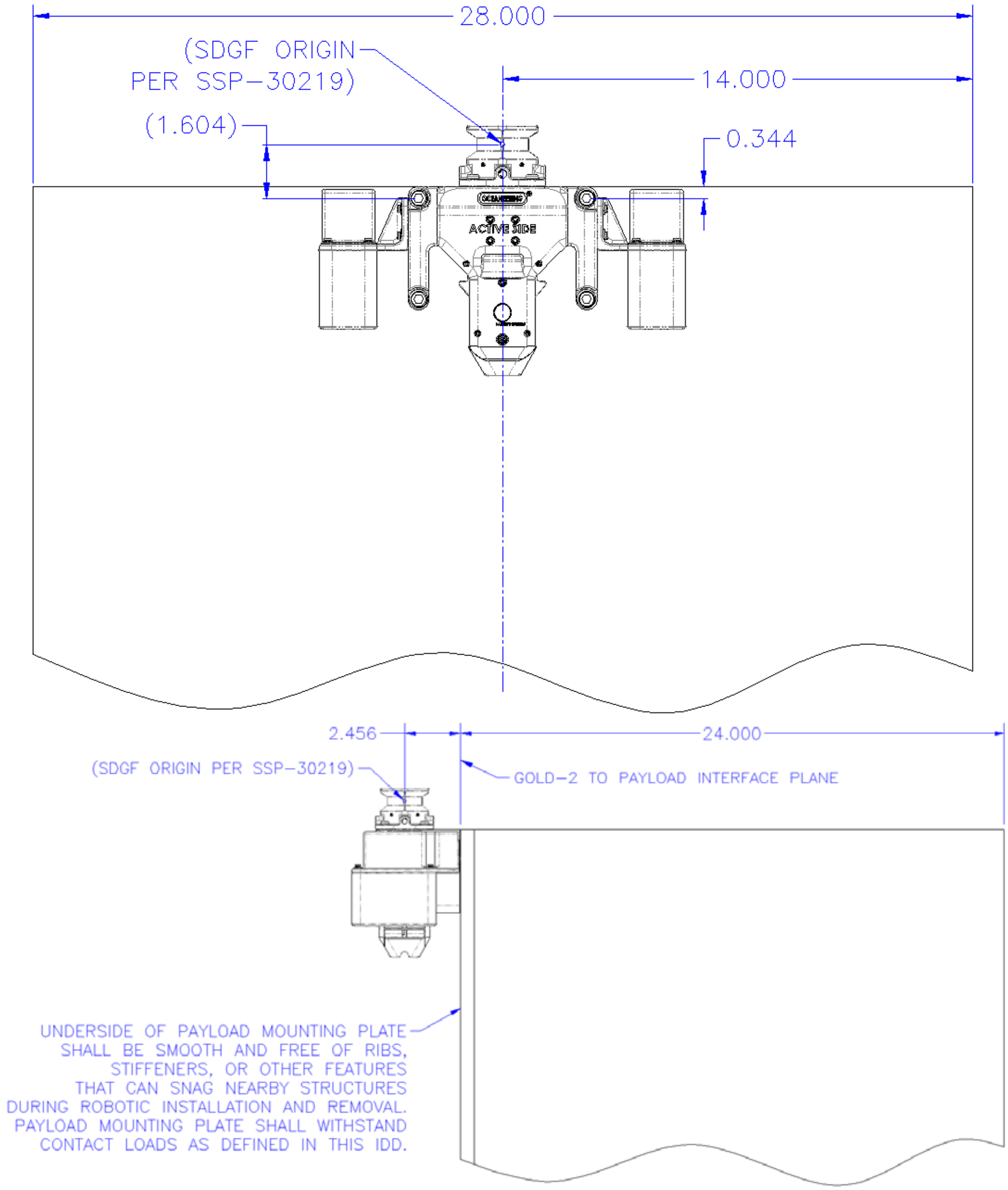


Figure 5.2.1.1-4: Location F GOLD-2 Installation Tolerance

5.2.2 External Payload Mass Properties

The maximum weight of payloads installed on the Airlock GOLD 2 fittings shall not exceed 500 lbs. The maximum c.g., measured from the active GOLD 2 fitting (**Figure 5.2.2-1**) is TBD. Higher weights may be possible and will need to be coordinated with Nanoracks require further analysis.

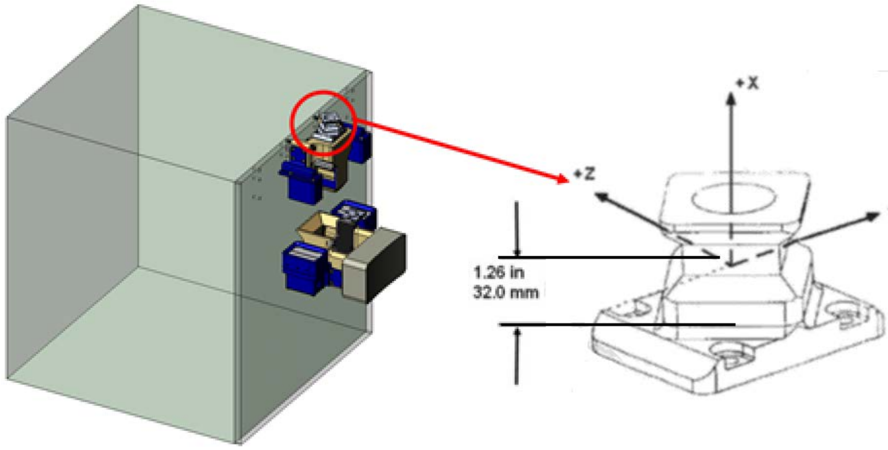


Figure 5.2.2-1: External Payload c.g. Coordinate System

5.2.2.1 Minimum Frequency

Payloads that utilize the SPDM to transfer out of the Airlock shall have minimum frequency that does not exceed 3 Hz. Minimum payload integrated assembly frequency is resolved at the dexterous grasp fixture coordinate frame origin and assumes that the grasp fixture is the only constrained point on the User hardware for all payload configurations (e.g., locked and unlocked).

5.2.2.2 Maximum Moment of Inertia

Payloads that utilize the SPDM to transfer out of the Airlock shall have a maximum Moment of Inertia of 29,663 lbm-ft2. Moments of inertia are expressed with respect to the dexterous grasp fixture coordinate frame and the value applies to all components of the inertia matrix individually for all payload configurations (e.g., locked and unlocked).

5.2.3 External Payload Bonding and Grounding

Bonding and ground of the payload shall be per the GOLD02-SP005 GOLD 2 ICD, Section 4.4.

5.2.4 External Payload Electrical Interfaces

There are two electrical buckets on the GOLD-2 that provide the power and data interfaces to the payload. Each bucket is identical and therefore redundant if redundancy is desired by the payload. Each bucket has the following type connections:

- Payload Operational Power: Switchable 120 VDC power, nominal 350 W and maximum of 700 W.
- Keep Alive Heater (Survival Heater) Power: Switchable 120 VDC power, nominal 150 W and maximum of 350 W
- Data: Ethernet, 10/100 base
- Bridge Detect: Loop back circuit that verifies a good robotic mate has occurred at the GOLD-2
- Temperature: For RTD mounted on the payload if desired

Details about the maximum available power and data rates will be defined and documented in the Airlock payload-specific ICA.

5.2.4.1 GOLD-2 Passive Module and Socket Definition

Figure 5.2.4.2-1 shows the modules that are installed in the passive GOLD-2 located on the Airlock. **Table 5.2.4.1-1** shows the socket definitions for each module. Reference GOLD02-SP005 for more detailed information on each individual module.

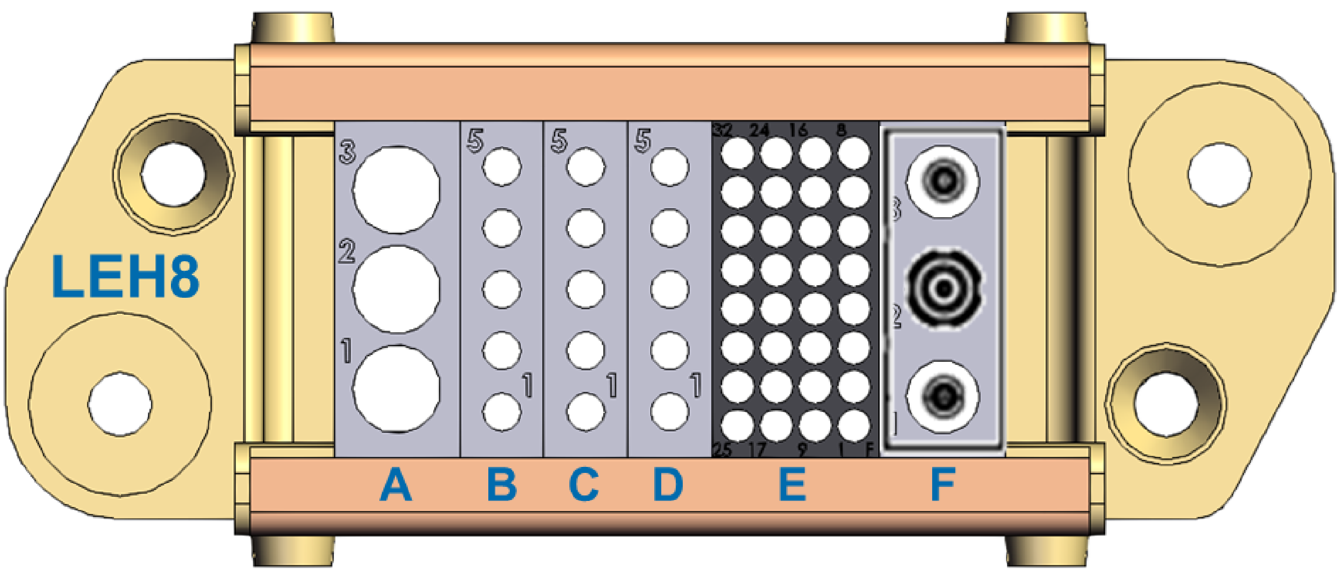


Figure 5.2.4.1-1: GOLD-2 Passive Module

Table 5.2.4.1-1: GOLD-2 Passive Socket Definitions

Module P/N	Module Insert Id	Socket No.	Wire (AWG)	Contact P/N	Description
LSF4	A	1	12 AWG	YSK025-013AH	120 VDC Operational
		2	12 AWG	YSK025-013AH	120 VDC RTN Operational
		3	12 AWG	YSK025-013AH	Chassis
LRF1	B	1	22 AWG	YSK015-013AH	120 VDC Survival Heater
		2	22 AWG	YSK015-013AH	120 VDC RTN Survival Heater
		3	N/A	YSK015-013AH	Not Connected
		4	22 AWG	YSK015-013AH	Temperature
		5	22 AWG	YSK015-013AH	Temperature Return
LRF1	C	1	22 AWG	YSK015-013AH	Bridge Detect/Bucket Mate POS
		2	24AWG	YSK015-013AH	ENET DA+ (TX+)
		3	24AWG	YSK015-013AH	ENET DA- (TX-)
		4	24AWG	YSK015-013AH	ENET DB+ (RX+)
		5	24AWG	YSK015-013AH	ENET DB- (RX-)
LRF1	D	1	22 AWG	YSK015-013AH	Bridge Detect/Bucket Mate RTN
		2	N/A	YSK015-013AH	Not Connected
		3	N/A	YSK015-013AH	Not Connected
		4	N/A	YSK015-013AH	Not Connected
		5	N/A	YSK015-013AH	Not Connected
LWFRTAH	E	1	N/A	Guidepost	Guidepost
		2	N/A	YSK0006-011ANH	Not Connected
		3	N/A	YSK0006-011ANH	Not Connected
		4	N/A	YSK0006-011ANH	Not Connected
		5	N/A	YSK0006-011ANH	Not Connected
		6	N/A	YSK0006-011ANH	Not Connected
		7	N/A	YSK0006-011ANH	Not Connected
		8	N/A	YSK0006-011ANH	Not Connected
		9	N/A	YSK0006-011ANH	Not Connected
		10	N/A	YSK0006-011ANH	Not Connected
		11	N/A	YSK0006-011ANH	Not Connected
		12	N/A	YSK0006-011ANH	Not Connected
		13	N/A	YSK0006-011ANH	Not Connected
		14	N/A	YSK0006-011ANH	Not Connected
		15	N/A	YSK0006-011ANH	Not Connected
		16	N/A	YSK0006-011ANH	Not Connected
		17	N/A	YSK0006-011ANH	Not Connected
		18	N/A	YSK0006-011ANH	Not Connected
		19	N/A	YSK0006-011ANH	Not Connected
		20	N/A	YSK0006-011ANH	Not Connected
		21	N/A	YSK0006-011ANH	Not Connected
		22	N/A	YSK0006-011ANH	Not Connected
		23	N/A	YSK0006-011ANH	Not Connected
		24	N/A	YSK0006-011ANH	Not Connected
		25	N/A	YSK0006-011ANH	Not Connected
		26	N/A	YSK0006-011ANH	Not Connected
		27	N/A	YSK0006-011ANH	Not Connected
		28	N/A	YSK0006-011ANH	Not Connected
		29	N/A	YSK0006-011ANH	Not Connected
		30	N/A	YSK0006-011ANH	Not Connected
		31	N/A	YSK0006-011ANH	Not Connected
		32	N/A	Guidepost	Guidepost

Table 5.2.4.1-2: GOLD-2 Passive Socket Definitions – CONT.

Module P/N	Module Insert Id	Socket No.	Wire (AWG)	Contact P/N	Description
YPC0432	F	1	100/140/172MM	181-001-173	Fiber TX
		2	RG 316	YCX0315-002AH	Coaxial SIG (only antenna)
			RG 316	YCX0315-002AH	Coaxial RTN (only antenna)
		3	100/140/172MM	181-001-173	Fiber RX

Note: The module and contact part numbers are from Smith's Interconnect except for the fiber optic which is from Glenair.

5.2.4.2 GOLD-2 Active Module and Socket Definition

The payload shall have an active GOLD-2 connector with modules and interfaces as shown in **Figure 5.2.4.2-1** and **Table 5.2.4.2-1**. Reference GOLD02-SP005 for more detailed information on each individual module.

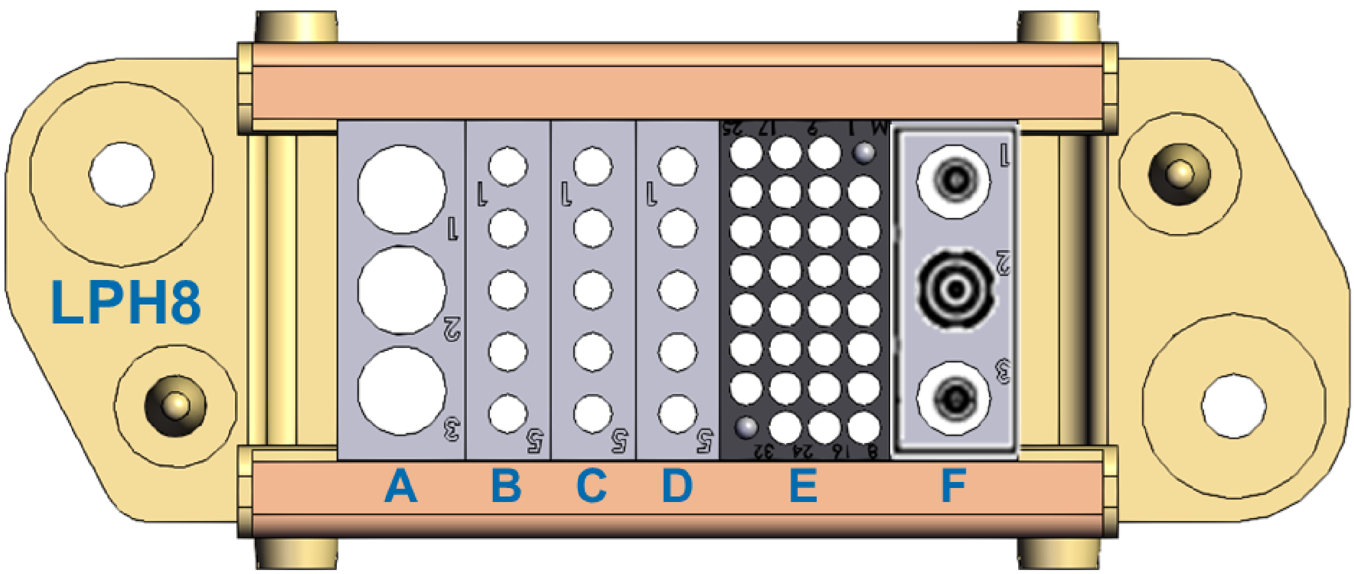


Figure 5.2.4.2-1: GOLD-2 Active Module

Table 5.2.4.2-1: GOLD-2 Active Socket Definitions

Module P/N	Module Insert Id	Socket No.	Wire (AWG)	Contact P/N	Description
LSM4H	A	**1**	12 AWG (Note 1)	YPN025-011RH	120 VDC Operational
		2	12 AWG (Note 1)	YPN025-011RH	120 VDC RTN Operational
		3	12 AWG (Note 1)	YPN025-011RH	Chassis
LRM1H	B	1	22 AWG	YPN015-009RH	120 VDC Survival Heater
		2	22 AWG	YPN015-009RH	120 VDC RTN Survival Heater
		3	N/A	YPN015-009RH	Not Connected
		4	22 AWG	YPN015-009RH	Temperature
		5	22 AWG	YPN015-009RH	Temperature Return
LRM1H	C	1	22 AWG	YPN015-009RH	Bridge Detect/Bucket Mate POS
		2	24 AWG	YPN015-009RH	ENET DA+ (TX+)
		3	24 AWG	YPN015-009RH	ENET DA- (TX-)
		4	24 AWG	YPN015-009RH	ENET DB+ (RX+)
		5	24 AWG	YPN015-009RH	ENET DB- (RX-)
LRM1H	D	1	22 AWG	YPN015-009RH	Bridge Detect/Bucket Mate RTN
		2	N/A	YPN015-009RH	Not Connected
		3	N/A	YPN015-009RH	Not Connected
		4	N/A	YPN015-009RH	Not Connected
		5	N/A	YPN015-009RH	Not Connected
LWMRTH	E	1	N/A	Guidepost	Guidepost
		2	N/A	YPN006-021H	Not Connected
		3	N/A	YPN006-021H	Not Connected
		4	N/A	YPN006-021H	Not Connected
		5	N/A	YPN006-021H	Not Connected
		6	N/A	YPN006-021H	Not Connected
		7	N/A	YPN006-021H	Not Connected
		8	N/A	YPN006-021H	Not Connected
		9	N/A	YPN006-021H	Not Connected
		10	N/A	YPN006-021H	Not Connected
		11	N/A	YPN006-021H	Not Connected
		12	N/A	YPN006-021H	Not Connected
		13	N/A	YPN006-021H	Not Connected
		14	N/A	YPN006-021H	Not Connected
		15	N/A	YPN006-021H	Not Connected
		16	N/A	YPN006-021H	Not Connected
		17	N/A	YPN006-021H	Not Connected
		18	N/A	YPN006-021H	Not Connected
		19	N/A	YPN006-021H	Not Connected
		20	N/A	YPN006-021H	Not Connected
		21	N/A	YPN006-021H	Not Connected
		22	N/A	YPN006-021H	Not Connected
		23	N/A	YPN006-021H	Not Connected
		24	N/A	YPN006-021H	Not Connected
		25	N/A	YPN006-021H	Not Connected
		26	N/A	YPN006-021H	Not Connected
		27	N/A	YPN006-021H	Not Connected
		28	N/A	YPN006-021H	Not Connected
		29	N/A	YPN006-021H	Not Connected
		30	N/A	YPN006-021H	Not Connected
		31	N/A	YPN006-021H	Not Connected
		32	N/A	Guidepost	Guidepost

Table 5.2.4.2-1: GOLD-2 Active Socket Definitions – CONT.

Module P/N	Module Insert Id	Socket No.	Wire (AWG)	Contact P/N	Description
YPC0431	F	1	100/140/172MM	See Note 2	Fiber TX
		2	RG 316	YCX0315-004AH	Coaxial SIG (only antenna)
			RG 316	YCX0315-004AH	Coaxial RTN (only antenna)
		3	100/140/172MM	See Note 2	Fiber RX

Note 1: The operational power wire size from Module A inside the Payload shall be at least 12 AWG up to an internal fuse and then may decrease in size based on the fusing.

Note 2: For payloads that utilized the fiber optic connections of the active GOLD-2 connector, the Glenair Assembly Procedure GAP-015 instructions shall be used for the mating Glenair Size 16, with Style 1 Cable Strain Relief Capture Mechanism (Exterior Sleeve), Fiber Size (core/cladding/coating) µm: 100/140/172, Pin (Male) Terminus proprietary Part Number: 181-002-173 (i.e. MIL-PRF-29504/4 specification Part Number: M29504/04-4087).

Note 3: The GOLD-2 fitting will be fully populated with contacts and no sealing plugs are allowed for the Not Connected interfaces

5.2.5 Electromagnetic Compatibility

The Airlock electrical grounding shall be in accordance with SSP 30240, paragraph 3.1.

5.2.5.1 Electrical Grounding

The Payload shall be electrically bonded to the Airlock per SSP 30245, Space Station Electrical Bonding Requirements, paragraphs 3.2 and 3.3.

5.2.5.2 Payload Surface Electrostatic Charging

All Payload metallic hardware elements shall comply with the Class-S bond requirements of SSP 30245, Space Station Electrical Bonding Requirements.

5.2.5.3 Insulated Materials

Hardware consisting of or containing low-conductivity material shall be bonded in accordance with SSP 30245, Section 3.3.4.4.2.

5.2.5.4 Radiation Emissions

The Payload shall not exceed emissions defined in SSP 30237, Space Station Electromagnetic Emission and Susceptibility Requirements

5.2.6 External Payload Command and Data Interfaces

The command and data interface to the payloads shall be Ethernet protocol and will interface via the GOLD-2 ICD.

The Nanoracks operations team at the Nanoracks ground facility will control and configure the Airlock DHS, payloads, and shared resources (such as data streaming destinations).

The data downlink along this path includes Health and Status monitoring data for the Airlock DHS and all its payloads using the ISS's Medium Rate Data Link (MRDL), some of which are exclusively used by the Airlock DHS itself, and some shared by the payloads.

The Airlock C&DH interface also includes file transfer capabilities directly between the ground and the Airlock DHS (and to/from payloads in a second step.

5.2.7 Airlock DHS to Payload Software Interface

This section describes the software interface between the Airlock DHS and the payload. Adherence to the required and optional interfaces described here is essential for the successful and safe operation of Airlock payloads in space. It will ensure that an optimal amount of scientific as well as operational data from a payload can be made available to its owner.

5.2.7.1 Commanding

The Airlock DHS provides the capability to send commands to an external payload. All Airlock payload commanding is performed from the Nanoracks BRIDGE by the Nanoracks Operations team.

5.2.7.2 Health and Status Monitoring

Health and status monitoring of the payloads is unique to each payload based on their requirements and will be defined in the payload unique ICA.

5.2.7.3 File Transfer

Using the Transmit and Receive commands, files can be transferred between a payload and the Airlock DHS. In this case, the Airlock DHS is used as an intermediary, and additional steps will be needed to transfer a file between the DHS and its original source resp. final destination.

Due to the relatively low baud rate of the serial connection and the overhead of the Intel HEX format, the user data transfer rate is limited to about 2 kB/s; therefore, serial file transfer should be limited to small files. Also, consider that while the serial connection is in use by a file transfer, status monitoring for that payload is suspended, which creates a gap in payload monitoring data.

5.2.8 External Payload Field of View Analysis

The figures in this section provides fields of view of the external payload sites. Two views from each site are provided:

1. Normal: View looking normal from the mounting plane of the GOLD-2
2. Nadir or Zenith: View looking either Nader or Zenith based on the position of the GOLD-2 on the Airlock

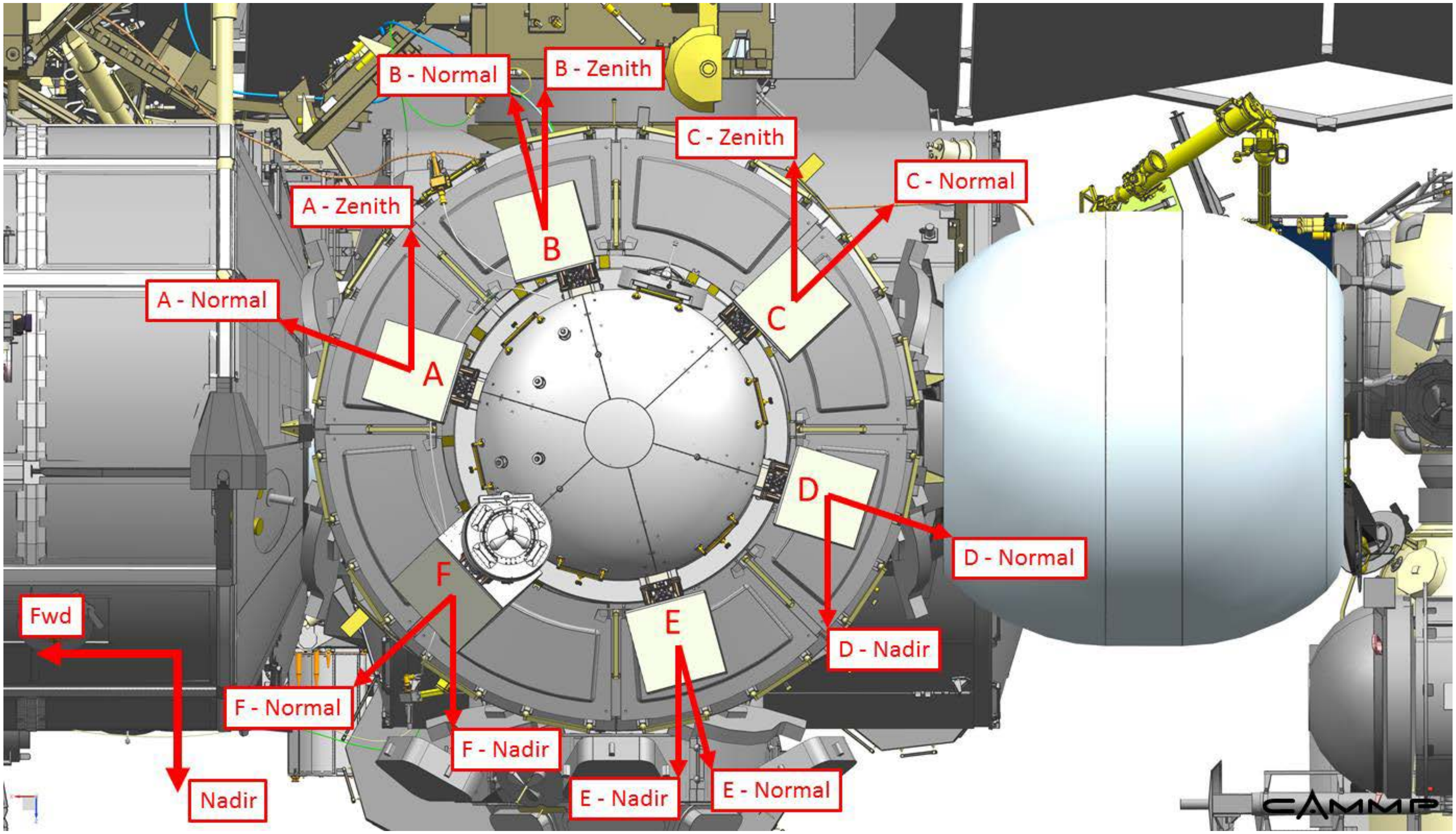


Figure 5.2.8-1: NanoRacks Airlock payload sites A through F and their respective FOV directions

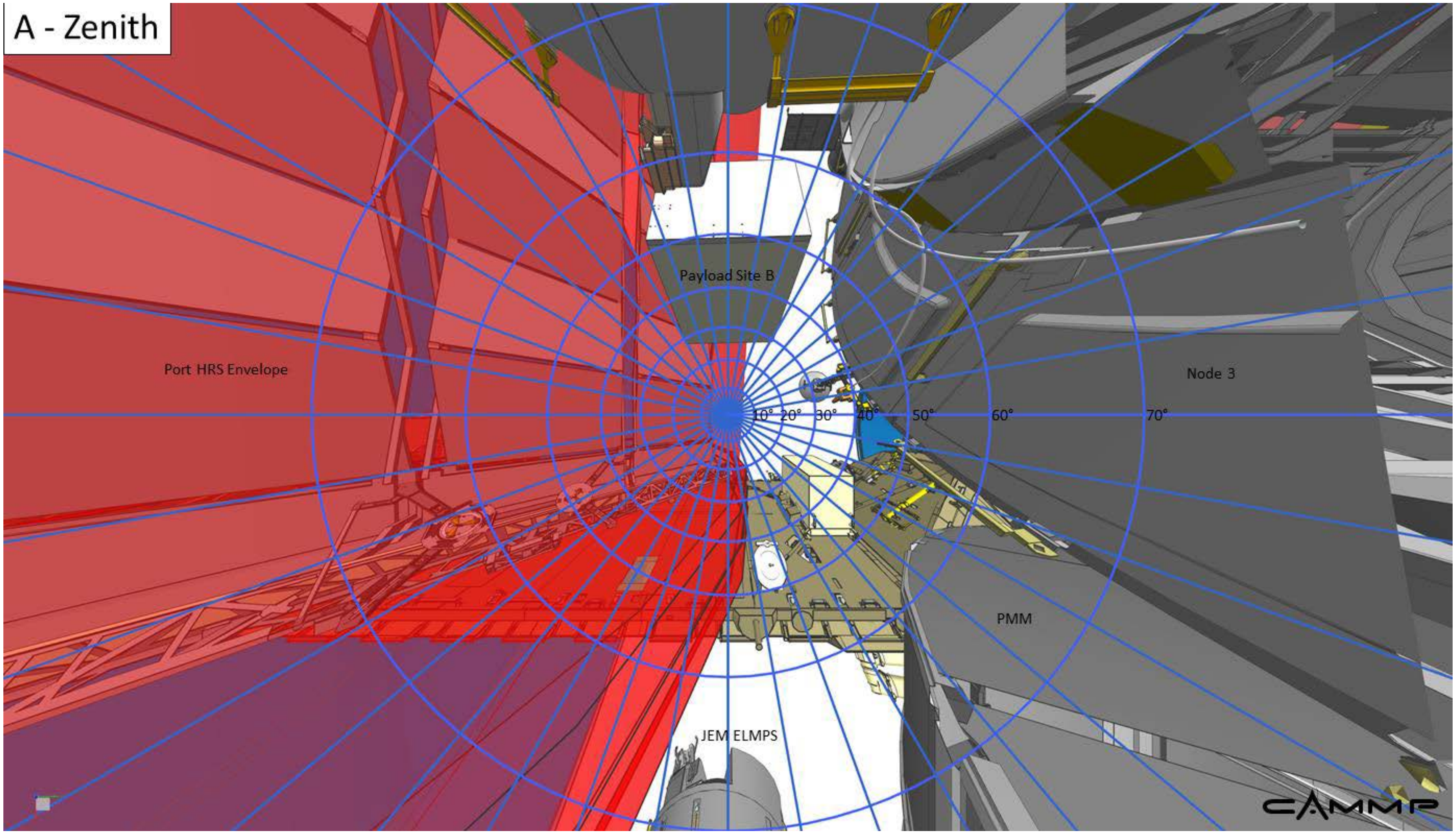


Figure 5.2.8-2: Payload A – Zenith FOV

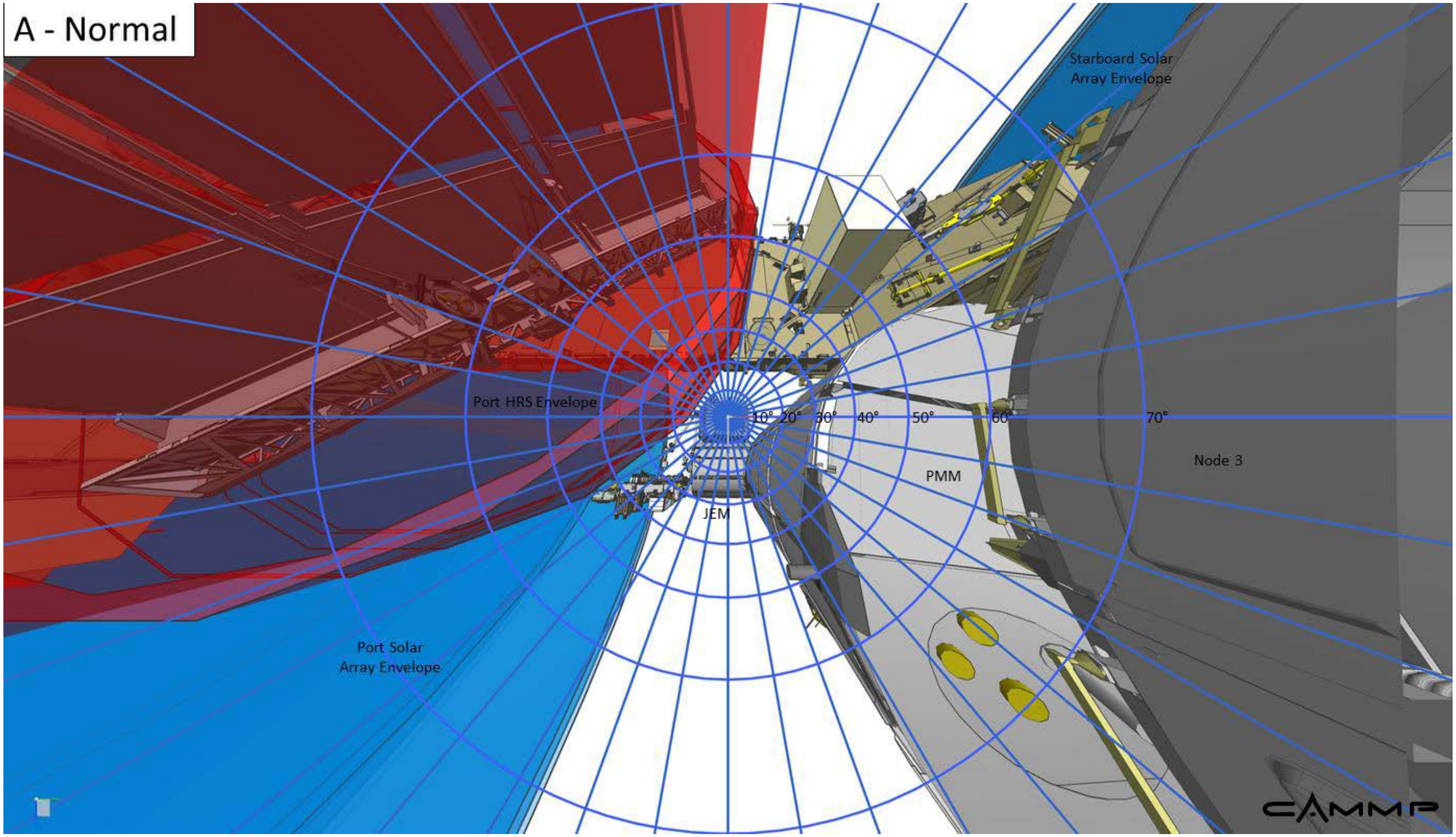


Figure 5.2.8-3: Payload A – Normal FOV

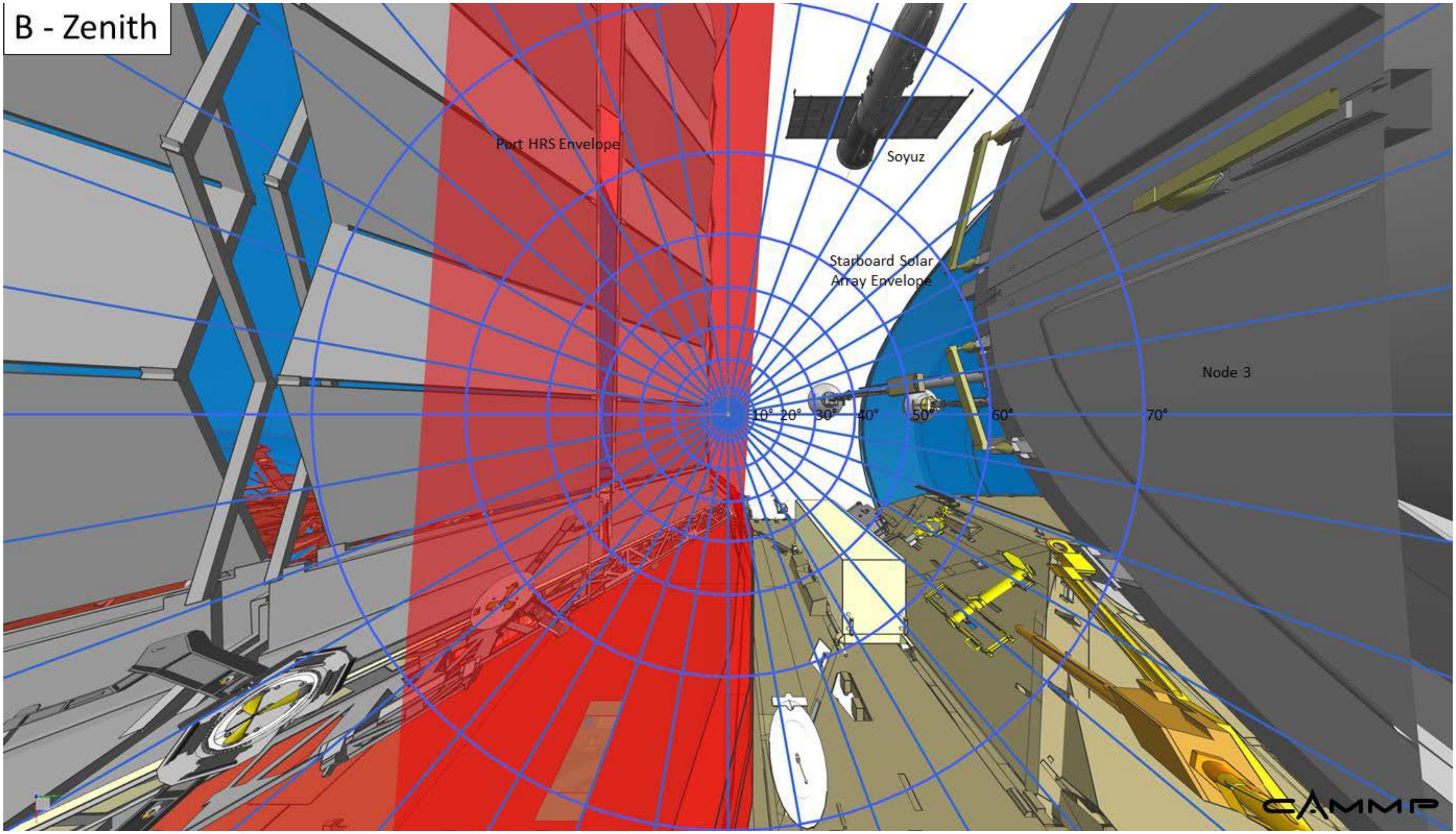


Figure 5.2.8-4: Payload B – Zenith FOV

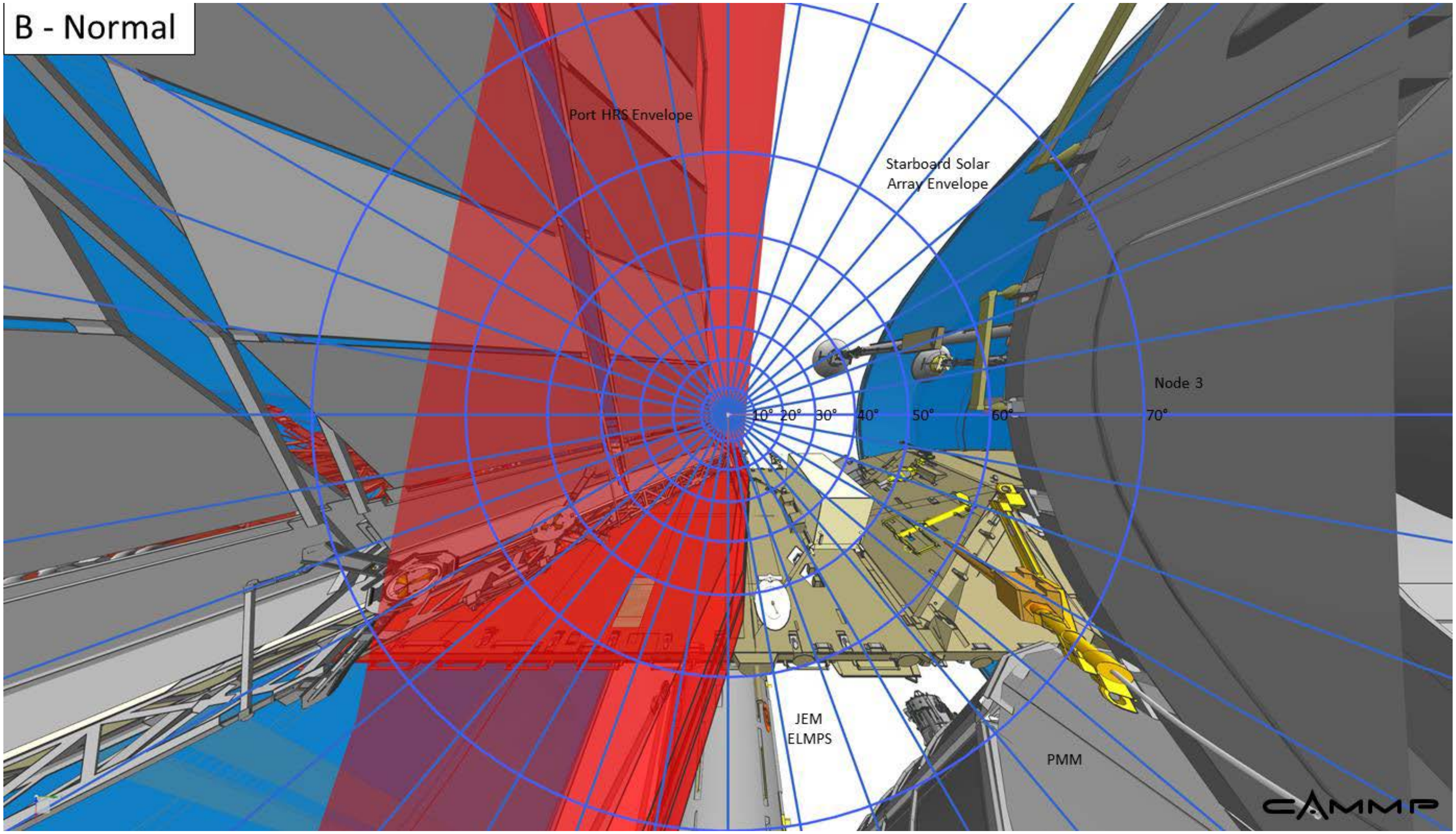


Figure 5.2.8-5: Payload B – Normal FOV

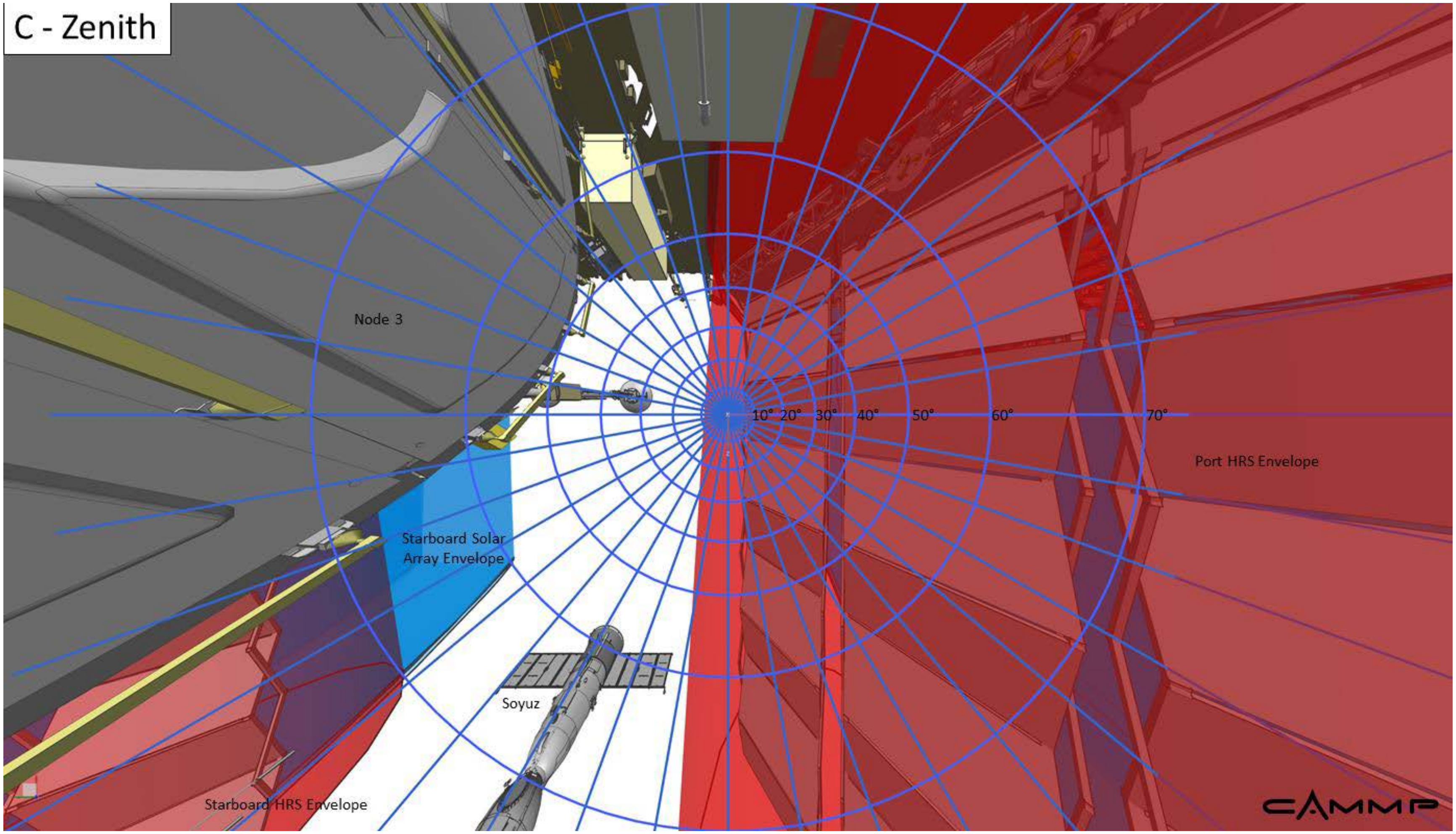


Figure 5.2.8-6: Payload C – Zenith FOV

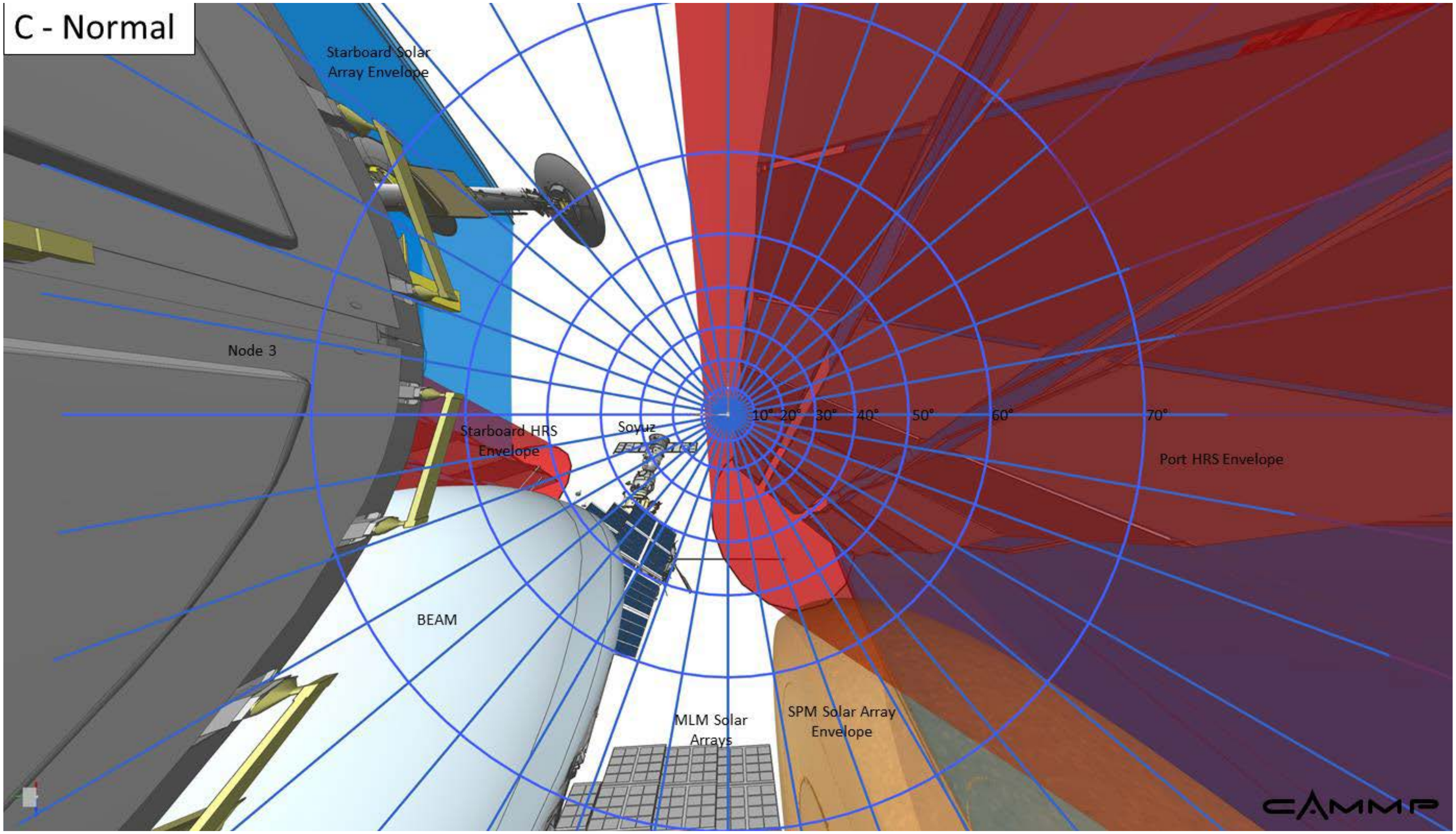


Figure 5.2.8-7: Payload C – Normal FOV

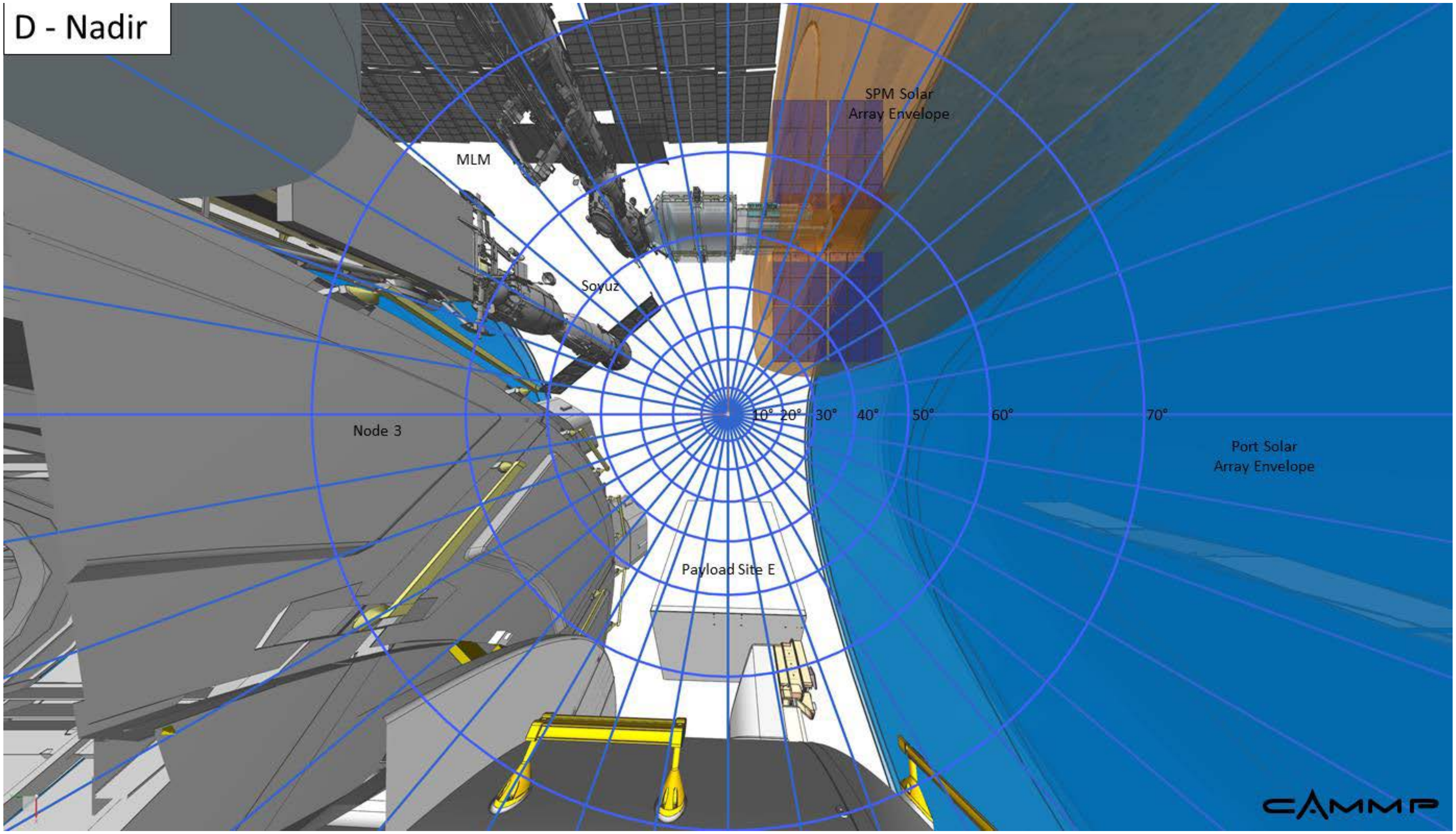


Figure 5.2.8-8: Payload D – Nadir FOV

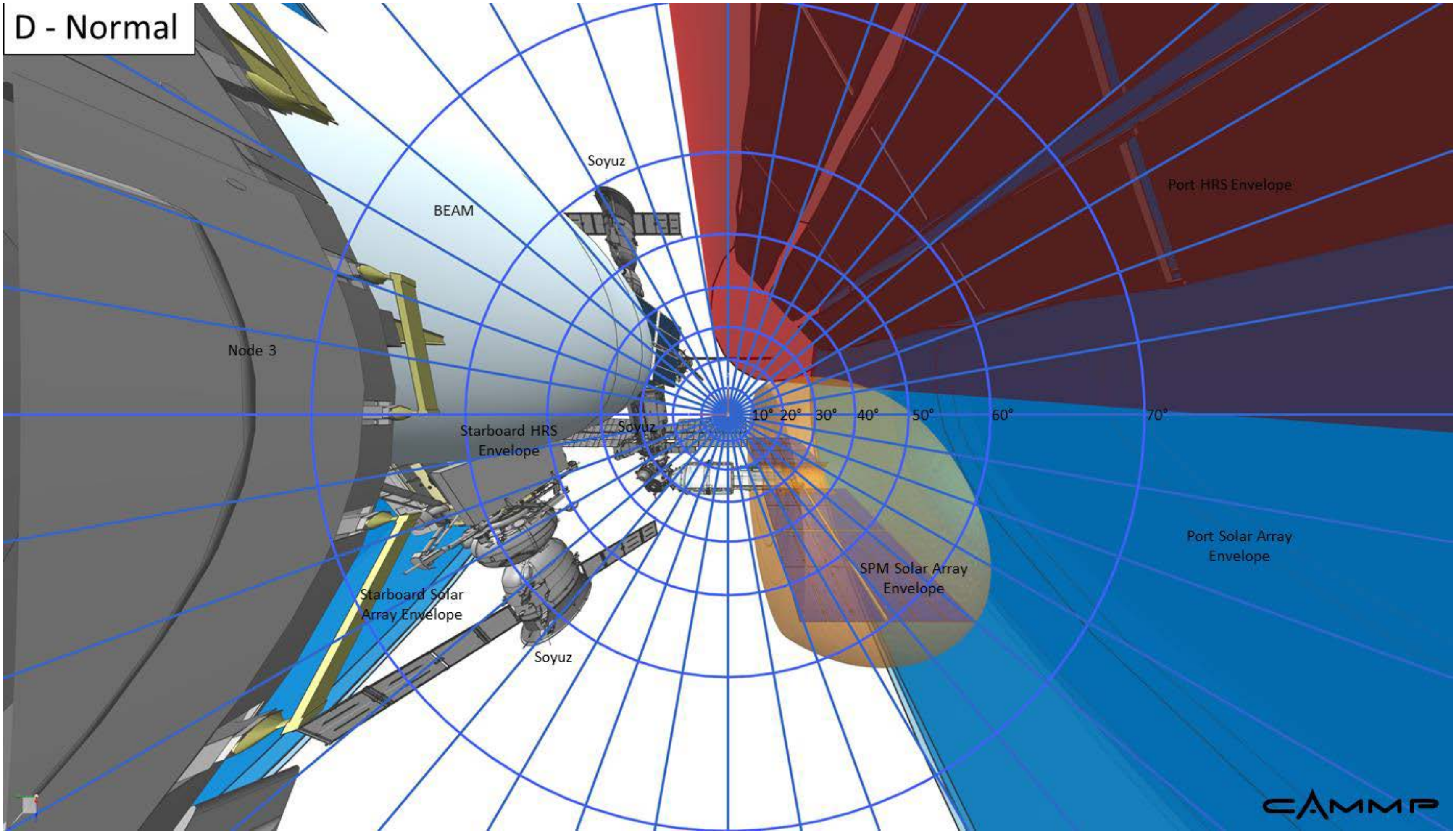


Figure 5.2.8-9: Payload D – Normal FOV

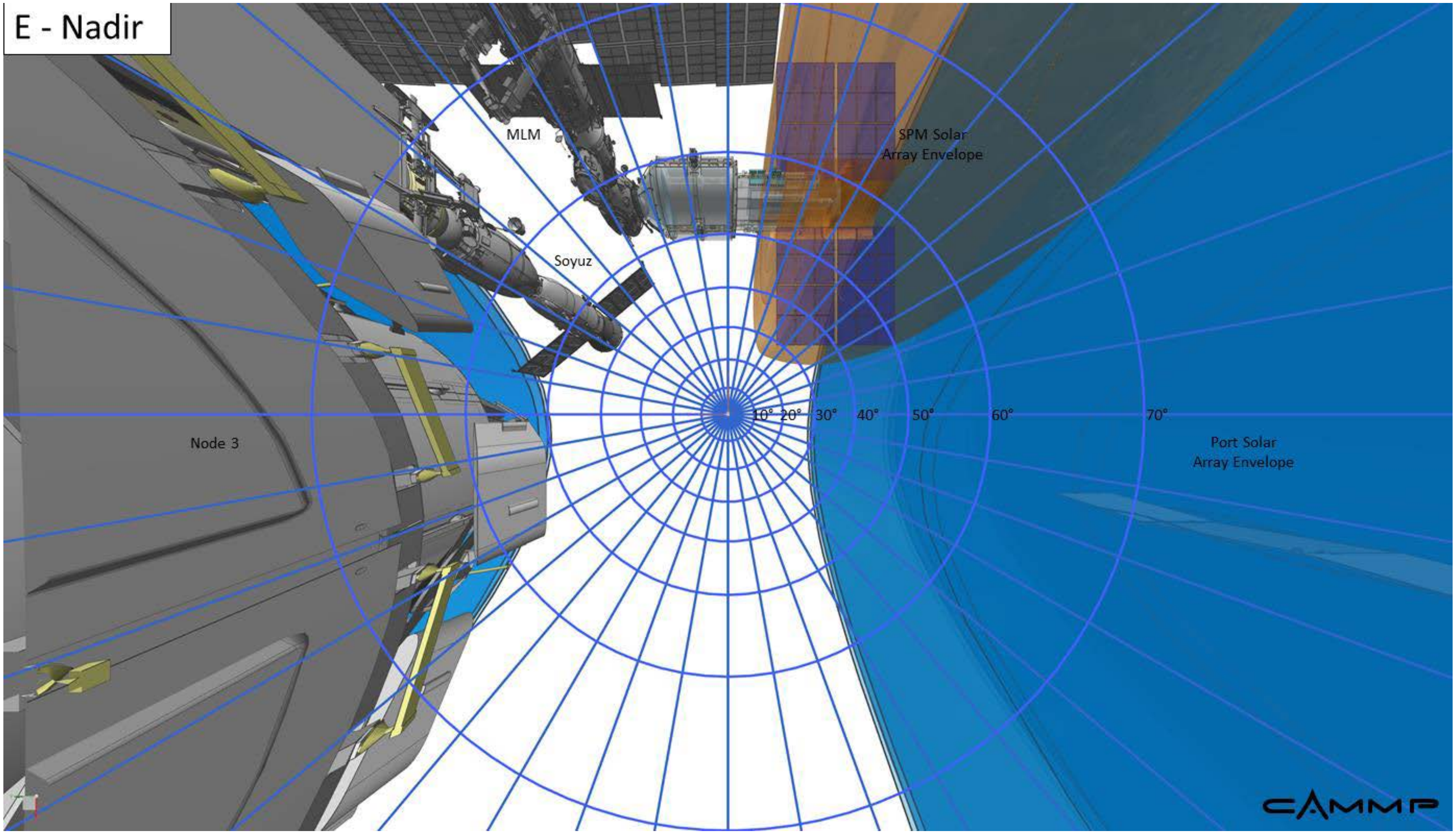


Figure 5.2.8-10: Payload E – Nadir FOV

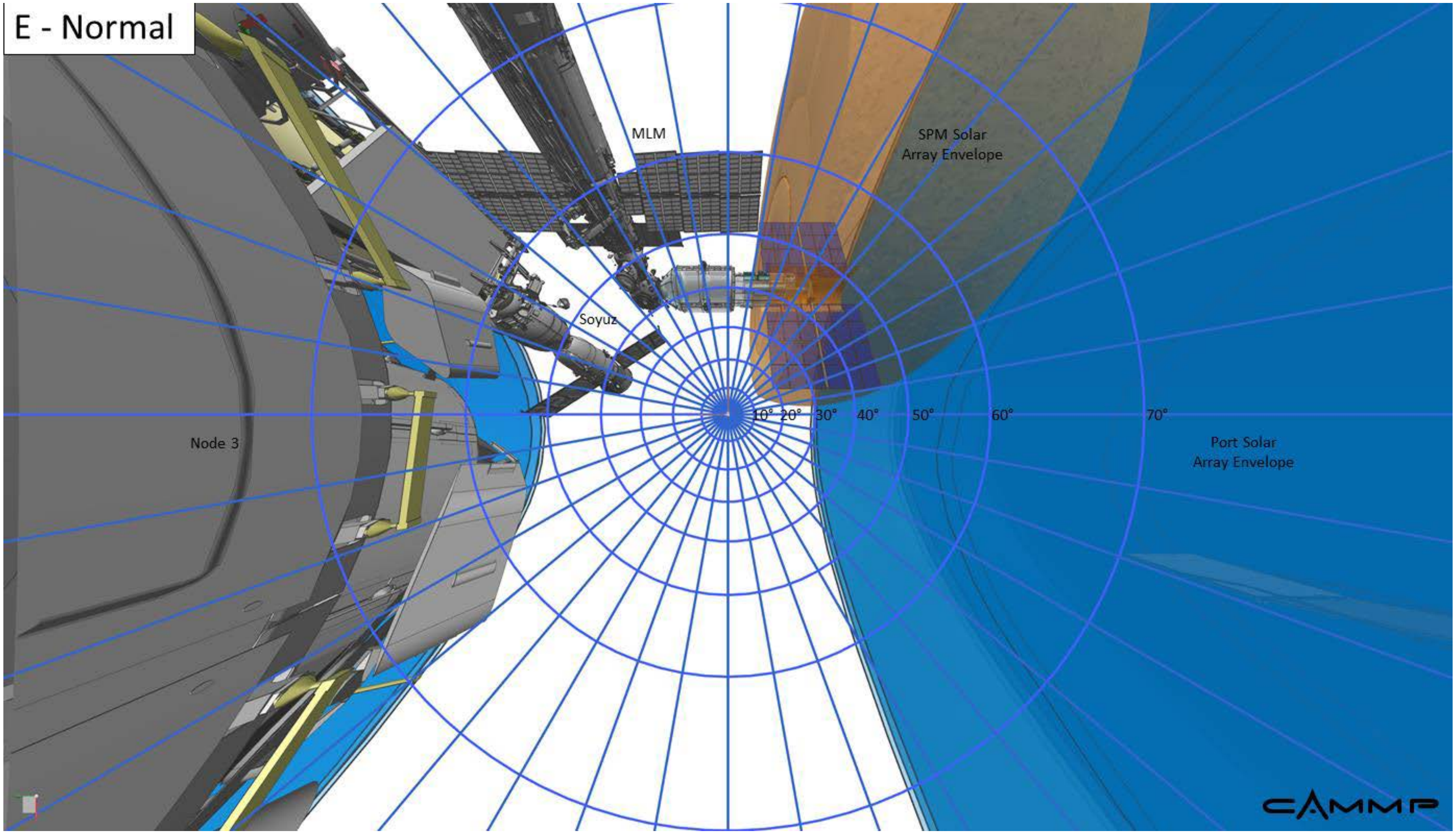


Figure 5.2.8-11: Payload E – Normal FOV

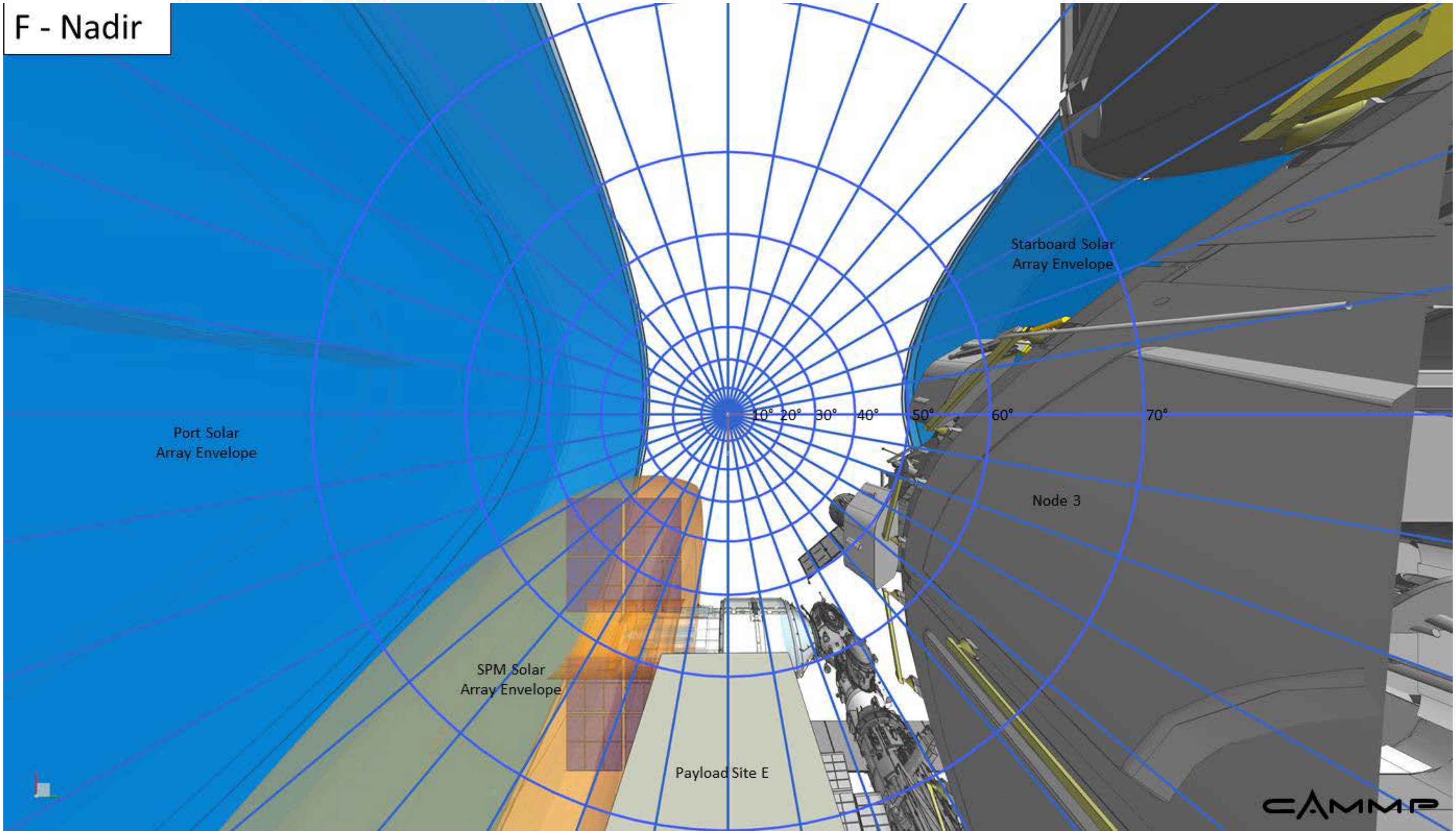


Figure 5.2.8-12: Payload F – Nadir FOV

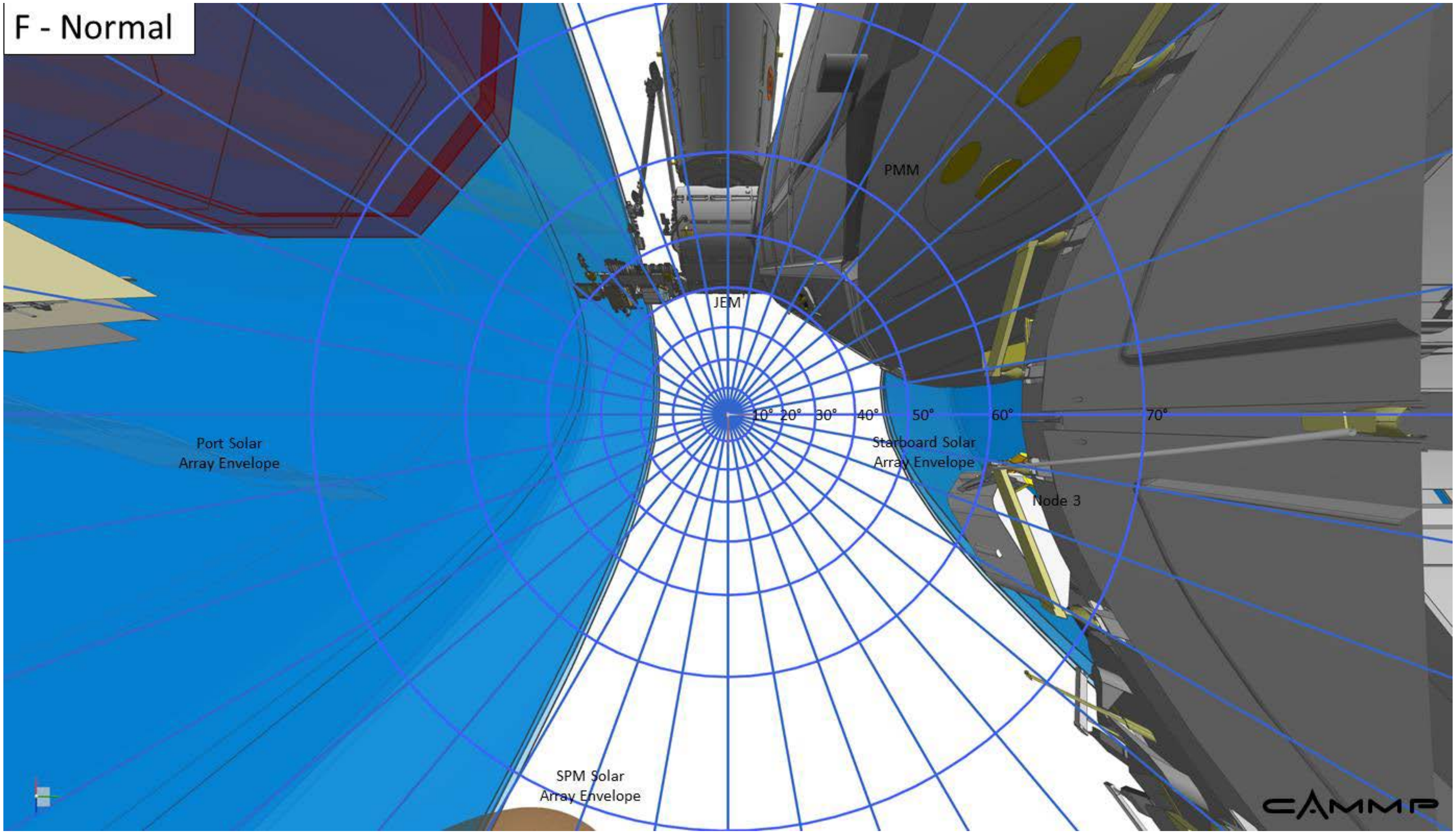


Figure 5.2.8-13: Payload F – Normal FOV

6 Payload Environments

The launch environments here are based on standard ISS cargo resupply launch vehicles as described in SSP 57000.

6.1.1 Acceleration Loads

Payload safety-critical structures shall (and other payload structures *should*) provide positive margins of safety when exposed to the accelerations documented in **Table 6.1.1-1** at the CG of the item, with all six degrees of freedom acting simultaneously. The acceleration values are applicable to both soft stowed and hard mounted hardware. (Per SSP 57000, Section D.3.1.1) Launch.

Table 6.1.1-1: Launch/Landing Load Factors Envelope

	Nx (g)	Ny (g)	Nz (g)	Rx (red/sec^2)	Ry (rad/sec^2)	Rz (rad/sec^2)
Launch	+/- 9.0	+/- 9.0	+/- 9.0	+/- 13.5	+/- 13.5	+/- 13.5
Landing	+/-10.0	+/-10.0	+/-10.0	N/A	N/A	N/A

All analysis and or testing shall be in accordance with the guidelines specified in SSP 52005 for payload hardware. Nanoracks will provide guidance on what structures are safety critical and how to complete structural analysis.

6.1.2 Random Vibration Loads Environment

Payload safety-critical structures packed in foam or bubble wrap and enclosed in hard containers such as lockers, boxes, or similar structures, and payload safety-critical structures packed in foam or bubble wrap and soft stowed in bags shall maintain structural integrity when exposed to the random vibration environments defined in **Table 6.1.2-1.** Contact Nanoracks for the proper vibration test procedure. The standard stowage configuration is the payload wrapped in bubble wrap. Otherwise, test to the stowage requirements as set in the payload ICA.

Table 6.1.2-1: Unattenuated and Attenuated Random Vibration Environments Ref. SSP 57000-IRD-PIRN-0001A Table D.3.1.2-1

FREQUENCY (Hz)	PROTOFLIGHT TEST LEVEL (g^2/Hz)
20	0.35
100	0.35
100 - 160	-15.4 dB/octave slope
160 - 500	0.04
500-2000	-3 dB/octave slope
2000	0.01
Overall	8.8 grms

Duration	1 min/axis

6.1.3 Launch Shock Environment

Integrated end items packed in the foam or bubble wrap materials do not experience significant mechanical shock. Shock verification is not required for launch events. Any mechanical or electrical components that are highly sensitive to shock should be assessed on a case-by-case basis as defined in the payload ICA.

6.1.4 IVA Loads Environment

The payload shall provide positive margins of safety when exposed to the crew induced loads defined in **Table 6.1.4-1**, Crew-Induced Loads (reference SSP 57000, Table 3.1.1.1.2-1). The payload ICA will detail specific exclusions to these loads based on keep out zones and special operational constraints. The payload shall provide positive margins of safety for on–orbit loads of 0.2 g acting in any direction for nominal on-orbit operations per SSP 57000, Rev R, Section 3.1.1.1.1.

Table 6.1.4-1: Crew-Induced Loads

CREW SYSTEM OR STRUCTURE	TYPE OF LOAD	LOAD	DIRECTION OF LOAD
Levers, Handles, Operating Wheels, Controls	Push or Pull concentrated on most extreme edge	222.6 N (50 lbf), limit	Any direction
Small Knobs	Twist (torsion)	14.9 N-m (11 ft-lbf), limit	Either direction
Exposed Utility Lines (Gas, Fluid, and Vacuum)	Push or Pull	222.6 N (50 lbf)	Any direction
Rack front panels and any other normally exposed equipment	Load distributed over a 4 inch by 4 inch area	556.4 N (125 lbf), limit	Any direction

Legend:
ft = feet, m = meter, N = Newton, lbf = pounds force

6.1.5 EVA Loads Environment

The payload shall provide positive margins of safety when exposed to EVA kick loads of 125 lbf over a 0.5 inch diameter circle as stated in Section 3.1.3-1 of SSP 57003. The payload ICA will detail specific data products, as required, to support the processing of any exceptions.

6.1.6 On-orbit Acceleration Environment

The payload shall meet structural integrity requirements in an on–orbit acceleration environment having peak transient accelerations of up to 0.2 g's, with a vector quantity acting in any direction as stated in Section 3.5.9 of SSP 57003. On-orbit scenarios include EVR operations, both direct (payload transfer) and indirect (relocation of NRAL), with the payload in all possible configurations (locked, unlocked, stowed, unstowed, etc.).

6.1.7 SSRMS Impact Energy

All unprotected portions of the Payload hardware shall maintain positive margins of safety after being subjected to a contact energy of 1 J for the following scenarios:

- Within one foot (12 inches) of the SSRMS during grappling operations, or
- Within one foot (12 inches) of fixed structure when SSRMS is moving the Payload either directly or indirectly, or
- Within one foot (12 inches) of other equipment robotically manipulated directly or indirectly by the SSRMS.

6.1.8 SPDM Impact Energy

All unprotected portions of the Payload hardware (excluding GFE robotic or FRAM components) shall maintain positive margins of safety after being subjected to a contact energy of 1 J when being manipulated by SPDM for the following scenarios:

- within eight (8) inches of the SPDM interface during approach/grasp operations (3 inches beyond the OTCM mechanical envelope), or
- within six (6) inches of surrounding fixed structure when being manipulated by SPDM outside of worksite proximity operations, or
- within six (6) inches of equipment being robotically manipulated by the SPDM. Portions of the Payload that are protected by other Payload structure which can withstand the 1J impact do not need to be assessed.

6.1.9 SPDM Load Limit

Payload hardware that is inside the SPDM approach envelopes or within 3 inches of hardware manipulated by SPDM shall show positive margins of safety for nominal contact forces of 50 lbf (222.4 N) resolved at the point of contact.

6.1.10 Grasp Interface Structural Loads

The Payload shall maintain positive margins of safety for the nominal loads transmitted through the grasp fixture during OTCM or Tool grasp and manipulation as shown in **Table 6.1.10-1**.

Table 6.1.10-1: Grasp Interface Structural Loads

Fixture	Force(1,3) (lbf)	Moment(2,3) (ft-lbf)
Micro Fixture or MCF (through RMCT)	50	125(4)
H-fixture	50	250

Notes:
1) Forces are shear and tensile/compressive
2) Moments are bending and torsional
3) Resultant forces and moments can be applied simultaneously in any direction
4) Worst case failure moment is 172.5 ft-lbf

6.1.11 Thermal Environment

Expected thermal environments for all phases of payload integration are summarized in **Table 6.1.11-1** Expected Thermal Environments. Payloads with special thermal constraints should coordinate with Nanoracks.

Table 6.1.11-1: Expected Thermal Environments
Ref SSP 50835, Table E.2.10-1

Ground Transport (Customer facility to Nanoracks)	Determined for each payload
Ground Processing Nanoracks	Determined for each payload
Ground Processing NASA	10°C to 35°C (50°F to 95°F)
Dragon Pressurized Cargo	18.3°C to 29.4°C (65°F to 85°F)
Cygnus Pressurized Cargo	10°C to 46°C (50°F to 115°F)
On-orbit, Pre-deployment, U.S. and JEM Modules	16.7°C to 28.3°C (62°F to 83°F)
On-orbit installed in the Airlock with Airlock still berthed and pressurized	16.7°C to 28.3°C (62°F to 83°F)
On-orbit installed inside/outside the Airlock when it's been deployed from Node 3	To be analyzed during mission specific thermal analysis for the payload
On-orbit installed on the outside of the Airlock (GOLD-2 external payload)	To be analyzed during mission specific thermal analysis for the payload

6.1.12 Passive Thermal Interface

The temperature of the Payload SPDM grasp fixture installation(s) just prior to and during acquisition by the SPDM OTCM shall be no less than -130 °F or greater than +145 °F

6.1.13 Humidity

The relative humidity will be 25% to 75% RH for ascent and on-orbit phases of flight. Payloads with special humidity control requirements should coordinate with Nanoracks.

6.1.14 Airlock Depressurization

The pressure inside the airlock is described as follows (the pressure when the air is vacuumed or re-pressurized with the inner/outer hatches closed). The payload shall survive the pressure range and depressurization/re-pressurization rate.

- Airlock Pressure: 0 to 104.8kPa
- Airlock pressure depressurization/re-pressurization rate: 1.0kPa/sec

6.1.15 Atomic Oxygen

The Payload will be exposed to a long term average ram atomic oxygen flux of 5.0×1021 atoms per cm2 per year for the on-orbit exposure duration. Surfaces exposed 30 days or less will be exposed to a short term peak ram atomic oxygen flux of up to 4.4×1019 atoms per cm2 per day.

6.1.16 External Contamination

The Payload will be exposed to the ISS on-orbit external contamination environment of:

- 130 Angstroms/year of total contaminant deposition from all ISS contamination sources combined (quiescent and non-quiescent),
- Molecular column densities of up to 1.0×1014 molecules/cm2 for unobstructed lines-of-sight during quiescent periods, and
- Particulate releases limited to one 100 micron particle per orbit per 1.0×10-5 steradian field-of-view during quiescent periods. The very low pressure and zero humidity on-orbit can lead to outgassing of chemical constituents for materials and components that are not vacuum stable. This outgassed material can deposit on surrounding hardware and change the optical properties of the coated components, leading to performance degradation of the material or component.

Payloads shall limit the total mass flow of each vented gas (ṁ, kg/s) to $\dot{m} \leq 6.45 \times 10^{-7} \sqrt{M_s T_0}$ where Ms is the molecular weight (kg/kg·mole) of each molecular species vented, and T0 is the temperature (K) of the vented gases at the payload outlet. Note: This limits the external environment molecular column density to less than 1×1014 molecules/cm2 along any unobstructed line of sight.

6.2 HFIT (Human Factors Implementation Team) Requirements

Generic guidance is provided to the Payload Developer to ensure compliance to ISS Program HFIT requirements. Nanoracks in coordination with the Payload Developer, reviews the satellites design. Dependent on payload design, unique requirements may be levied through the ICA between Nanoracks and the Payload Developer.

6.2.1 HFIT Requirements

Nanoracks as part of its service conducts an HFIT closeout with NASA oversight. Nanoracks also completes all verification documentation for closure to NASA. Generic requirements the payload shall comply are listed in **Table 6.2.1-1** Requirements for Payloads Using the Airlock Services.

Table 6.2.1-1: Requirements for Payloads Using the Airlock Services

#	Requirement Description	Verification
1	Payload shall provide a means to restrain the loose ends of hoses and cables.	Inspection
2	Conductors, bundles, or cables shall be secured by means of clamps unless they are contained in wiring ducts or cable retractors.	Inspection
3	Loose cables (longer than 0.33 meters (one (1) foot)) shall be restrained as follows: Length (m) Restraint Pattern (% of length) tolerances +/- 10%) 0.33-1.00 - 50% 1.00-2.00 -33%, 76% 2.00-3.00 -20%, 40%, 60%, 80% >3.0 m at least each 0.5 meters	Inspection
4	If a smooth surface is required, flush or oval head fasteners shall be used for fastening.	Inspection
5	Covers or shields through which mounting fasteners must pass for attachment to the basic chassis of the unit shall have holes for passage of the fastener without precise alignment (and hand or necessary tool if either is required to replace).	Inspection
6	Payload design within a pressurized module shall protect crewmembers from sharp edges and corners during all crew operations	Inspection
7	IVA accessible holes that are round or slotted in the range of 0.4 to 1.0 in (10.0 to 25.0 mm) and EVA accessible holes 0.5 to 1.4 in (12.0 to 36.0mm) shall be covered to prevent crew exposure to sharp surfaces and to prevent debris from entering the hole.	Inspection
8	Latches that pivot, retract, or flex so that a gap of less than 1.4 in (35 mm) exists shall be designed to prevent entrapment of a crewmember's fingers or hand.	Inspection
9	Threaded ends of screws and bolts accessible by the crew and extending more than 0.12 in (3.0 mm) shall be covered or capped to protect against sharp threads. Materials that flake or create debris if the screw/bolt has to be removed should be avoided.	Inspection
10	Levers, cranks, hooks, and controls shall not be located or oriented such that they can pinch, snag, or cut the crewmember.	Inspection
11	Safety wires or lockwire shall not be used on fasteners that are accessible to crewmembers.	Inspection

6.2.2 Recommended Compliance Methods and Best Practices

The following are recommended compliance methods and best practices to meet requirements. This information is representative of acceptable methods approved by NASA HFIT to date. As always the Payload Developer should contact Nanoracks for specific guidance.

6.2.2.1 Protuberances, Deployable Elements and Appendages

In general any protuberances, deployable elements or appendages which are potential cut or puncture risk to ISS crew during handling will not pass HFIT inspection. Examples of items which may be of concern are whip or tape antennas. Examples of proper controls might be plastic tips or space-rated RTV compound placed on the end of the antenna.

6.2.2.2 Surface Requirements Compliance

Burrs and sharp edges shall be removed by a process that leaves a radius, chamfer, or equivalent between 0.005 and 0.015. Gauges not required. If radius or chamfer methods cannot be used then consider using close-out covers which are removed by ISS crew just prior to retraction into the JEM air lock in preparation for satellite deployment.

6.2.2.3 Securing Cables

Use of nylon locking “zip” ties or cable clamps as shown in Figure 6.2.2.3-1 are examples of approved methods for securing cables. If your payload will be exposed to vacuum, then Tefzel and Halar materials should be used.

Figure 6.2.2.3-1: Example Applications of Zip ties and Cable Clamps

6.3 Payload Safety Requirements

Payloads shall be designed to preclude or control hazards present (defined below) in the following manner:

Catastrophic Hazard Definition - Any condition which may result in either:

- A disabling or fatal personnel injury,
- Loss of the ISS,
- Loss of a crew-carrying vehicle
- Loss of a major ground facility

SSP 51700 paragraph 3.1.1.2 Catastrophic HAZARDS - The payload shall be designed such that no combination of two failures, two operator errors (or one of each), can cause a disabling or fatal personnel injury or loss of one of the following: loss of ISS, loss of a crew-carrying vehicle, or loss of major ground facility.

Critical Hazard Definition - Any condition which may result in either:

- A non-disabling personnel injury or illness
- Loss of a major ISS element
- Loss of redundancy (i.e. with only a single hazard control remaining) for on-orbit life sustaining function
- Loss of JEMRMS use

SSP 50700 paragraph 3.1.1.1 CRITICAL HAZARDS - The payload shall be designed such that no single failure or single operator error can cause a non-disabling personnel injury or illness, loss of a major ISS element, loss of redundancy (i.e. with only a single hazard control remaining) for on-orbit life sustaining function, or loss of use of the JEM Remote Manipulator System (JEMRMS).

Examples of satellite features/failures to be assessed for hazard potential (critical or catastrophic)

- Structure Failure
  - Inability to sustain applied loads
  - Fracture
  - Stress corrosion
  - Mechanisms
  - Fastener integrity and secondary locking features
- Pressure System Failure
  - Explosion
  - Rupture
- Leakage of, or exposure to hazardous or toxic substances
- Propulsion system hazards
  - Including inadvertent operation
- Deployment of appendages
- RF system operation

- Battery Failure
- Flammable or toxic material usage
- Frangible material usage
- Electrical system failures causing shock or burn
  - Includes wiring, fusing, grounding
- EMI interference
- Magnetic field
- Collision with ISS including post deploy on subsequent orbits
  - Post deploy jettison policy
- Sharp edges, pinch points, and other touch hazards
  - IVA and EVA
  - Includes rotating equipment
- Operational procedures

<u>Control of Hazards</u>

Control of hazards shall be appropriate for the hazard type and occurrence. Some examples:

- Structural hazards
  - Application of factor of safety with positive margin
    - Supports design for minimum risk
  - Fault tolerance where applicable
    - Failure controlled by remaining elements will not fail under resulting load
    - Redundant mechanism
- Electrically operated systems
  - Inhibits to control inadvertent operations appropriate to the hazard level
  - Redundancy as necessary to perform required functions
  - Design controls i.e. EMI
- Leakage of toxic substances
  - Fault tolerance in seals appropriate
  - Structural strength of containers
- Flammable materials
  - Elimination of flammable materials
  - Containment
  - Wire sizing and fusing
- Pressure systems
  - Factor of safety
- RF systems
  - Design to have power below hazard level and frequency in approved range
  - Inhibits to control inadvertent operations appropriate to the hazard level
- Battery hazards
  - Containment
  - Protection circuits

6.3.1 Containment of Frangible Materials

In general the payload design shall preclude the release or generation of FOD for all mission phases. Containment or protection may be required to control the hazard of the release of frangible materials. Containment plan will be defined in the ICA.

6.3.2 Venting

Payloads shall comply with NASA venting requirements. The Maximum Effective Vent Ratio (MEVR) shall not exceed 5080cm. MEVR is calculated as follows:

$$MEVR = \left(\frac{Internal\ Volume\ (cm)^3}{Effective\ Vent\ Area\ (cm)^2}\right) \leq 5080\ cm$$

Effective vent area should be the summation of the area(s) of voids which lead to enclosed volume.

6.3.3 Secondary Locking Feature

All structural joints utilizing threaded fasteners shall be designed such that each threaded fastener has a primary and a secondary locking feature. Measured and recorded running torque and final torque can be considered the primary locking feature for each threaded fastener in a structural joint. The secondary locking feature shall be one of the following (in order of preference):

- Nut or nut element with a prevailing-torque type of locking feature
- Patch or pellet-type locking elements per NAS1283 or equivalent
- NASA-approved liquid locking compounds (contact Nanoracks safety for current list of locking compounds, primers, and application procedures)
- Bent-tab lock washers
- Safety wire and cotter pins (occasionally may be deemed acceptable only in areas that are fully inaccessible to crewmembers; contact Nanoracks safety for approval)

Split or serrated lock washers are not recommended for use on flight hardware structural joints.

For threaded fasteners (bolts and screws) that may be removed and/or reinstalled by crewmembers in planned or contingency operations, it is recommended that they be captive bolts or screws to reduce chances of lost hardware and FOD. Primary and secondary locking feature requirements are applicable to captive bolts/screws.

6.3.4 Passivity

Payloads shall be passive and self-contained from the time they are loaded for transport to the ISS up to the time they are deployed. No charging of batteries, support services, and or support from ISS crew is provided after final integration.

6.3.5 Pyrotechnics

Payloads shall not contain pyrotechnics unless the design approach is pre-approved by Nanoracks.

6.3.6 Space Debris Compliance

Payloads should not have detachable parts during launch or normal mission operations. Any exceptions will be coordinated with Nanoracks and documented in the ICA. Payloads shall comply with NASA space debris mitigation guidelines as documented in NASA Technical Standard NASA-STD-8719.14A.

6.3.7 External Payload Contingency Tie Down

Payload attachment mechanisms on ISS pressurized modules must be two-fault tolerant for inadvertent release to protect the Station from catastrophic incidental contact should the payload become detached.GOLD-2 mounted payloads shall have an EVA tether point (hole diameter greater or equal to 1 inch, material thickness less than 0.5 inch, 75 lbf load capability in all directions) capable of securing the payload to the Nanoracks Airlock structure in the unlikely event that the GOLD-2 becomes jammed during robotic payload installation or removal. Standard EVA handrails meet this requirement. The final placement and orientation of this tether point will be developed jointly with Nanoracks and documented in the ICA.

All payloads interfacing with the GOLD-2 must submit a tethering plan before Phase 1 Safety Review. A tethering plan is typically composed of drawings or images from 3D CAD. The tethering plan must demonstrate that the payload can be restricted from movement in six degrees of freedom. The plan should include:

1. Part number of Tie Down Tether used
2. Center of Gravity of Payload
3. Angles of tether to attachment point on handrails

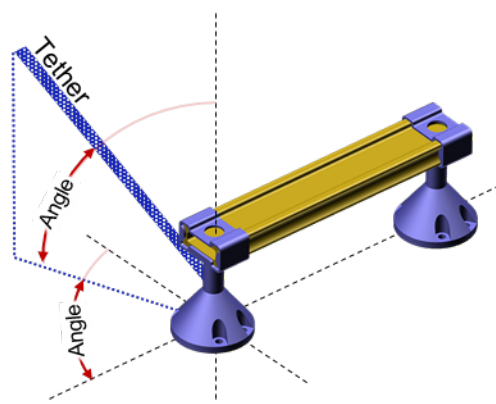


Figure 5.2.2.3-1: Example- Angle of Tether to Attachment Point

6.3.8 Batteries

Battery requirements for spacecraft flight onboard or near the ISS are derived from the NASA requirement document JSC 20793 Crewed Space Vehicle Battery Safety Requirements. Specific provisions for battery use are designed to assure that a battery is safe for ground personnel and ISS crew members to handle and/or operate during all applicable mission phases and particularly in an enclosed environment of a crewed space vehicle. These NASA provisions also assure that the battery is safe for use in launch vehicles, as well as in unpressurized spaces adjacent to the habitable portion of a space vehicle. The required provisions encompass hazard controls, design evaluation, and verification. Evaluation of the battery system must be complete prior to certification for flight and ground operations. To support this objective information on the battery system must be provided to Nanoracks as soon as possible. For example, certain battery cell chemistries and battery configurations may trigger higher scrutiny to protect against thermal runaway propagation. It is imperative that Nanoracks receive all requested technical data as early as possible to assure the necessary safety features are present to control the hazards associated with a particular battery design. True in nearly every case, redesign efforts greatly impact the payload developer both in cost and schedule. This can often be avoided by consulting with Nanoracks before hardware is actually manufactured. Cell/Battery testing associated with the verification of the safety compliance must be completed prior to safety certification of the spacecraft. To be compliant to the requirements herein, every battery design, along with its safety verification program, its ground and/or on-orbit usage plans, and its post-flight processing shall be evaluated and approved by the appropriate technical review panel in the given program or project.

6.3.8.1 Battery Hazards

The possible sources of battery hazards are listed below and shall be identified for each battery system. Applicable hazards will be evaluated to determine and to identify design, workmanship, and other features to be used for hazard control (electrical, mechanical, and/or thermal).

Potential Battery Hazards:

- Fire/Explosion Hazard
- Flammability
- Venting of Battery Enclosure
- Burst of Pressurized Battery Chemistries
- Overcharge Failure/Over-discharge Failure
- External Short Circuit
- Internal Short Circuit Failure
- Thermal Runaway Propagation
- Chemical Exposure Hazards
- Mechanical Failure
- Seals and Vents
- Electrical Hazards
- Extreme Temperature Hazards

6.3.8.2 Battery Types

Although any battery may be made safe to fly in the crewed space vehicle environment there are some batteries that are not practical to make safe. For example, lithium-sulfur dioxide cells have built-in overpressure vents that will release SO2 (sulfur dioxide) gas and other electrolyte components that are highly toxic; thus, these are unacceptable in the habitable area of a space vehicle. However, these chemistries have been used safely in the non-pressurized areas of crewed spacecraft. Often the cells used in batteries for crewed space vehicle are commercially available.

Battery types typically used in spacecraft include:

- Alkaline-manganese primary
- LeClanche (carbon-zinc) primary
- Lead-acid secondary cells having immobilized electrolyte
- Lithium/lithium-ion polymer secondary (including lithium-polymer variation)
- Lithium metal anode primary cells having the following cathodic (positive) active materials:
- Poly-carbon monofluoride
- Iodine
- Manganese dioxide
- Silver chromate
- Sulfur dioxide (external to habitable spaces only)
- Thionyl chloride
- Thionyl chloride with bromine chloride complex additive (Li-BCX)
- Iron disulfide
- Lithium sulfur
- Mercuric oxide-zinc primary
- Nickel-cadmium secondary
- Nickel-metal hydride secondary
- Silver-zinc primary and secondary
- Zinc-air primary
- Sodium-sulfur secondary (external to habitable space)
- Thermal batteries

Note: Pressurized battery chemistries required coordination with Nanoracks.

6.3.8.3 Required battery Flight Acceptance Testing

Acceptance screening tests are required for all cells intended for flight to ensure the cells will perform in the required load and environment without leakage or failure. A statement of work for acceptance testing specific to a particular battery chemistry is available for spacecraft developers from Nanoracks.

6.3.8.4 Internal Short

Protection circuity and safety features shall be implemented at the cell level.

- Application of all cells shall be reviewed by Nanoracks.
- Charger circuit, and protection circuit schematics shall be reviewed and evaluated for required failure tolerance.

6.3.8.5 External Short Circuit

- Circuit interrupters that are rated well below the battery's peak current source capability should be installed in the battery power circuit. Interrupters may be fuses, circuit breakers, thermal switches, PTCs, or other effective devices. Circuit interrupters other than fuses should be rated at a value that is equal to or lower than the maximum current that the cell is capable of handling without causing venting, smoke, explosion, fire, or thermal runaway.
- The battery case is usually grounded/bonded to the structure, the interrupters should be in the ground (negative) leg of a battery where the negative terminal is connected to ground. Where the circuit is “floating,” as in plastic battery cases used in those for portable electronic devices, the circuit interrupters can be placed in either leg. In either case, the circuit interrupters should be placed as close to the cell or battery terminals as the design will allow to maximize the zone of protection.
- All inner surfaces of metal battery enclosures shall be anodized and/or coated with a non-electrically conductive electrolyte-resistant paint to prevent a subsequent short circuit hazard.
- The surfaces of battery terminals on the outside of the battery case shall be protected from accidental bridging.
- Battery terminals that pass through metal battery enclosures shall be insulated from the case by an insulating collar or other effective means.
- Wires inside the battery case shall be insulated, restrained from contact with cell terminals, protected against chafing, and physically constrained from movement due to vibration or shock.
- In battery designs greater than 50 Vdc, corona-induced short circuits (high-voltage induced gas breakdown) shall be prevented.

6.3.8.6 Battery Charging

It should be verified that the battery charging equipment (if not the dedicated charger) has at least two levels of control that will prevent it from causing a hazardous condition on the battery being charged. The COTS chargers, if used to charge the batteries on-orbit, shall have traceable serial numbers, should be from a single lot, and charger circuitry should be provided with the standard hazard report for review and approval.

6.3.8.7 Battery Energy Density

For battery designs greater than 80-Wh energy employing high specific energy cells (greater than 80 watt-hours/kg, for example, lithium-ion chemistries) require additional assessment by Nanoracks due to potential hazard in the event of single-cell, or cell-to-cell thermal runaway.

6.3.8.8 Lithium Polymer Cells

Lithium Polymer Cells i.e. "pouch cells" shall be restrained at all times to prevent inadvertent swelling during storage, cycling, and low pressure or vacuum environments with pressure restraints on the wide faces of the cells to prevent damage due to pouch expansion. Coordinate with Nanoracks for guidance on specific implementation.

6.3.9 Pressure Vessels

Pressure vessels may be made acceptable for Flight Safety with proper controls for any hazard potential both for inside ISS and outside ISS. Payloads should expect to provide documentation with respect to the materials used, tank history (including cycles and life time assessment) and control measure to assure tank integrity (damage control plan), testing performed, fracture control measures planned, inspection process and methods, etc. wherever hazard potential is present. All pressure vessels shall be DOT certified or have a DOT issued waiver for transportation across the US. Use of non-DOT certified pressure vessels generally will not be permitted. Exceptions must be coordinated with Nanoracks during the pre-contract signing phase. Systems will have to demonstrate via test that required factors of safety are present for tanks, lines and fittings which can be exposed to pressure with 1 or 2 failures depending on hazard potential. Pressure vessels and components procured from third party vendors must have proper certification records or the PLO must develop the appropriate records to assure that the systems are safe by meeting NASA requirements. Nanoracks will assist in negotiating with NASA to define the work and analysis necessary to meet the NASA requirements.

6.3.10 Stress Corrosion Materials

Stress corrosion resistant materials from Table 1 of MSFC-SPEC-522 are preferred. Any use of stress corrosion susceptible materials (Table 2) shall be pre-coordinated with Nanoracks and documented in the ICA. Any use of Table 3 materials shall be avoided.

6.3.11 Hazardous Materials

Payloads shall comply with NASA guidelines for hazardous materials. Payload developers shall submit a Bill of Materials (BOM) to Nanoracks for assessment. Beryllium, cadmium, mercury, silver or other materials prohibited by SSP-30233 shall not be used.

6.3.12 Electrical Bonding

All payload components shall be electrically bonded to a minimum of Class S bond per SSP 30245 to ensure the payload is free from electrical shock and static discharge hazards. Typically, payload components may be bonded by either nickel plating or chemical film treated faying surfaces or dedicated bonding straps.

6.4 Customer Deliverables

Table 6.4-1 describes the list of potential customer deliverables required to certify the payload for flight. More detailed information will be provided in the payload ICA.

Table 6.4-1: Deliverables

Item	Deliverable	Description	Date
1	Structural Verification Plan	NR to provide specific guidance but in general it is an outline of structural analysis, fracture control and structural testing requirements and those requirements will be verified.	45-60 days prior Ph 1 Safety Review
2	Bill of Materials	May be utilized in lieu of out/off gas testing (require dimensional data for surface materials)	45-60 days prior Ph 1 Safety Review
3	Thermal Analysis Report	Complete on orbit thermal analysis for hot/cold cases and trace to MDP calculation (if pressure systems involved)	45-60 days prior Ph 3 Safety Review
4	Structural Analysis Report	NR to provide guidance on structural analysis requirements. Focused on primary load carrying structure of the payload	45-60 days prior Ph 3 Safety Review
5	Fracture Control Part Classification List	NR to provide guidance on fracture control classification requirements.	45-60 days prior to Ph 2 Safety Review
6	Fracture Control Summary Report	NR to provide guidance on analysis requirements. Typically a very short report (1-2 pages) for most payloads and could even be included in the structural analysis report.	45-60 days prior Ph 3 Safety Review
7	Vibration Test Report	Integrated satellite per NR standard test guidance (NR-SRD-085)	45-60 days prior Ph 3 Safety Review
8	Inspection Reports for fracture critical parts (if any fracture critical parts)	If any fracture critical parts are identified	45-60 days prior Ph 3 Safety Review
9	Inspection Reports for stress corrosion parts (if any stress corrosion sensitive parts)	If any stress corrosion sensitive parts are identified	45-60 days prior Ph 3 Safety Review

Table 6.4-1: Deliverables - CONT

Item	Deliverable	Description	Date
10	Power System Functional Test Report for EPS inhibits verification	If safety inhibits are part of the spacecraft system	45-60 days prior delivery
11	Pressure System Qualification Test Report (if Qual Test is performed)	If Pressure Systems are onboard the payload	45-60 days prior Ph 2 Safety Review
12	Provide Pressure System Acceptance Test Report	If Pressure Systems are onboard the payload	45-60 days prior Ph 3 Safety Review
13	Materials Compatibility Report for Pressure System	If Pressure Systems are onboard the payload	45-60 days prior Ph 1 Safety Review
14	Safety critical fastener CoCs (if any safety critical fasteners)	Typically no safety critical fasteners are part of payloads but will advise after receipt of Structural Analysis	45-60 days prior Ph 3 Safety Review
15	Battery Test Report	If batteries are onboard the payload	45-60 days prior Ph 2 Safety Review
16	Quality Assurance Process Summary Report	Similar to a CoC stating that the hardware was built, assembled, and tested in accordance with engineering documentation and per spacecraft provider's Quality Assurance control procedures	45-60 days prior Ph 3 Safety Review
17	Final Payload As-Measured Mass Properties	Weight, c.g., MOI and ballistic number	One Day prior to Nanoracks Delivery

7 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5	**Payload Interface Requirements**			**NVR**	
5.1	Internal Payloads	Internal payloads are defined as payloads installed into the airlock volume IVA by the crew members. They utilize the internal seat track and threaded fastener locations for mounting. They are designed to operate inside the airlock, deploy from the airlock or be brought in through the airlock. Internal payloads can also be brought into the ISS from an external location and handled by the Crew IVA.		NVR	
5.1.1	Internal Payload Envelope	The maximum payload envelope is defined below for internal payloads. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.		NVR	
5.1.1.1	Deployable Payloads	The maximum payload envelope for deployable payloads shall not exceed the dimensions defined in **Figure 5.1.1.1-1**. Note that depending on the type of deployable payload, additional envelop restrictions could become applicable based upon NASA Robotics operational assessments. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.	A	I	Drawings
5.1.1.2	Non-Deployable Payloads	The maximum payload envelope for static payloads shall not exceed the dimensions defined in **Figure 5.1.1.2-1**. Note that depending on the type of deployable payload, additional envelop restrictions could become applicable. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.	A	I	Drawings

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.1.1.3	SSRMS/SPDM Payloads	Payloads that require the SSRMS to remove from or install into the airlock shall meet a 12 inch clearance for extraction or insertion from any other structure. Payloads that require the SPDM to remove from or install into the airlock shall meet a 6 inch clearance for extraction or insertion from any other structure. Any deviation from these requirements may be allowed and will require additional analysis and need to be documented in the Payload ICA and approved by Nanoracks.	A	A, I	Drawings, MAGIK Analysis
5.1.2	Internal Payload Mass Properties	The maximum weight for internal payloads shall not exceed 1500 lbs. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.	A	I	Mass Properties Report
5.1.3	Internal Payload Seat Track Interfaces	All the seat track on the internal airlock surfaces is per SSP 57000 N.3.1.1.5-1.	NVR		
5.1.3.1	Dome Seat Track	Any payload that interfaces with the dome seat track shall utilize the location coding and meet the dimensions referenced in the figures below. The location coding for the internal Dome seat track is per **Figure 5.1.3.1-1**. The coordinate location for the dome seat track is defined in **Figure 5.1.3.1-2**. The seat track dimensions are defined in **Figure 5.1.3.1-3**.	A	I	Drawings
5.1.3.2	Cylinder Seat Track	Any payload that interfaces with the cylinder seat track shall utilize the location coding and meet the dimensions referenced in the figures below. The location coding and coordinate location for the cylinder seat track is per **Figure 5.1.3.2-1** and **Figure 5.1.3.2-2**.	A	I	Drawings
5.1.3.3	Dome Seat Track Loads	Payloads attaching to the dome seat tracks shall be within the limit loads as shown in **Table 5.1.3.3-1**. Limit loads can be applied at any one of the three locations on the seat track segments as shown in **Figure 5.1.3.3-1.** The seat track coordinate directions are shown in **Figure 5.1.3.3-2**.	A	A	Structural Report

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.1.3.4	Cylinder Seat Track Loads	Payloads attaching to the cylinder seat tracks shall be within the limit loads as shown in **Table 5.1.3.4-1**. Limit loads can be applied at any of the seat track locations, with the exception that the free edge of the track locations have a reduced loads limit as shown in **Figure 5.1.3.4-1.** The seat track coordinate directions are shown in **Figure 5.1.3.4-2**.	A	A	Structural Report
5.1.4	Internal Payload Threaded Fastener Interface	There are four different locations of threaded fasteners on the inside of the Airlock. **Figure 5.1.4-1** shows the planar location of these fasteners with respect to the X axis of the Airlock coordinate system.	NVR		
5.1.4.1	X(63.68) threaded fasteners	All payloads that interface with the X(63.68) fasteners shall meet the location coding, dimensions and threaded fastener requirements listed below. The location coding for the X(63.68) plane threaded fasteners is per **Figure 5.1.4.1-1**. The coordinate location for the X(63.68) plane threaded fasteners is defined in **Figure 5.1.4.1-2**. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.	A	I	Drawings
5.1.4.2	X(59.93) threaded fasteners	All payloads that interface with the X(59.93) fasteners shall meet the location coding, dimensions and threaded fastener requirements listed below. The location coding and coordinate location for the X(59.93) plane threaded fasteners is per **Figure 5.1.4.2-1**. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.	A	I	Drawings

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.1.4.3	X(54.31) threaded fasteners	All payloads that interface with the X(54.31) fasteners shall meet the location coding, dimensions and threaded fastener requirements listed below. The location coding and coordinate location for the X(54.31) plane threaded fasteners is per **Figure 5.1.4.3-1**. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.	A	I	Drawings
5.1.4.4	X(12.15) threaded fasteners	All payloads that interface with the X(12.15) fasteners shall meet the dimensions and threaded fastener requirements listed below. Any internal payloads that need to utilize the X(12.15) threaded hole locations will work with Nanoracks to determine which locations are available for use. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.	A	I	Drawings
5.1.4.5	Endcap Threaded Fastener	All payloads that interface with the endcap threaded fastener shall meet the threaded fastener requirements listed below. There is a single axial insert located at the center of the endcap. The insert in this location is MS51831CA203L, which is a Key-locked Insert, 0.3125-24 UNJF-3B threads, A286 CRES, dry-film lubricated, thread locking. The maximum bolt penetration (as measured from the front surface of the insert) is 0.68 inches. Note: grooved-shank type bolts are not allowed.	A	I	Drawings
5.1.4.6	Threaded Fastener Loads	All payloads that interface with the threaded fasteners shall not exceed the capabilities of the MS51831CA203L insert in 2219-T851 as stated in **Table 5.1.4.6-1**.	A	A	Structural Report

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.1.5	Internal Payload Bonding and Grounding	All payloads shall, at a minimum, be bonded to the Airlock structure either via the seat track or the structural rings of the Airlock per SSP 30245 Class S. Higher class bonds are capable and will be documented in the payload unique ICA. For the seat track, the seat track is nickel plated such that faying surfaces between the payload support structure and the seat track can be electrically conductive. For the threaded fasteners, the local area around each insert is chem film coated to allow the faying surfaces between the payload and the rings can be electrically conductive.	A	I	Drawings
5.1.6	Internal Payload Power Interfaces	Electrical services are available via 4 payload interface connectors for internal payloads. The connectors are located on the Payload Interface Unit 1 (PIU1). For each payload interface connector on PIU1, there are two power interfaces and a data interface to the payload. Each connector is identical on PIU1 for operational flexibility and redundancy. Each connector has the following type connections: • Payload Operational Power: Switchable 120 VDC (+/-2 VDC) power, nominal 350 W and maximum of 700 W; 2 feeds • Data: Ethernet, Gigabit • Bridge Detect: Loop back circuit that verifies a good mate has occurred at the PIU1 connector Details about the maximum available power and data rates will be defined and documented in the Airlock payload-specific ICA..	A	I, A	Drawings, Power Analysis
5.1.6.1	Electromagnetic Compatibility	The Airlock electrical grounding shall be in accordance with SSP 30240, section 3.1	A	A	Power Analysis
5.1.6.2	Electrical Grounding	The Payload shall be electrically bonded to the Airlock per SSP 30245, Space Station Electrical Bonding Requirements, paragraphs 3.2 and 3.3.	A	I/T	Drawings and Grounding checks

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.1.6.3	Payload Surface Electrostatic Charging	All Payload metallic hardware elements shall comply with the Class-S bond requirements of SSP 30245, Space Station Electrical Bonding Requirements.	A	I	Drawings
5.1.6.4	Insulated Materials	Hardware consisting of or containing low-conductivity material shall be bonded in accordance with SSP 30245, Section 3.3.4.4.2	A	I	Drawings
5.1.6.5	Radiation Emissions	The Payload shall not exceed emissions defined in SSP 30237, Space Station Electromagnetic Emission and Susceptibility Requirements	A	A	EMI/EMC Report
5.1.7	Internal Payload Command and Data Interfaces	The command and data interface to the payloads will be Ethernet protocol and will utilize the same connectors on the PIU1 as the power interface.	A	I	Drawings
5.1.8	Internal Power and Data Connector Interface	The payload shall meet the power and data interface defined in **Table 5.1.8-1**. The payload shall meet the specification of the interface connector provided in **Figure 5.1.8-1**	A	I	Drawings
5.1.9	Airlock Data Handling System (DHS) to Payload Software Interface	This section describes the software interface between the Airlock DHS and the payload. Adherence to the required and optional interfaces described here is essential for the successful and safe operation of Airlock payloads in space. It will ensure that an optimal amount of scientific as well as operational data from a payload can be made available to its owner	NVR		
5.1.9.1	Commanding	The Airlock DHS provides the capability to send commands to an internal payload. All Airlock payload commanding shall be performed from the Nanoracks BRIDGE by the Nanoracks Operations team.	TBD		
5.1.9.2	Health and Status Monitoring	Health and status monitoring of the payloads is unique to each payload based on their requirements and will be defined in the payload unique ICA.	TBD		

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.1.9.3	File Transfer	Using the Transmit and Receive commands, files can be transferred between a payload and the Airlock DHS. In this case, the Airlock DHS is used as an intermediary, and additional steps will be needed to transfer a file between the DHS and its original source resp. final destination. Due to the relatively low baud rate of the serial connection and the overhead of the Intel HEX format, the user data transfer rate is limited to about 2 kB/s; therefore, serial file transfer should be limited to small files. Also, consider that while the serial connection is in use by a file transfer, status monitoring for that payload is suspended, which creates a gap in payload monitoring data.	TBD		
5.2	External Payloads	The Airlock utilizes the Oceaneering Space System's (OSS) GOLD-2 connector (Reference the GOLD-2 ICD, GOLD02-SP005) shown in **Figure 5.2-1**. The passive half of the connector is mounted to the Airlock and the active half is mounted to the payload. Payloads are responsible for acquiring the active half of the GOLD-2 connector. Any assistance from Nanoracks to aid in the procurement of an active GOLD-2 connector will be documented in the payload ICA. Robotic mating/demating of the payload to the Airlock is done via the SPDM. Payloads have access to power and data through these connectors. Payloads can also utilize a combination of internal volume along with the external volume of the airlock. **Figure 5.2-1** shows the external payload location coding. See Appendix A for payloads that utilize the Airlock Payload Transfer FSE to transfer from inside the ISS to the outside of Airlock.	NVR		

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.2.1	External Payload Envelope	Payloads utilizing the external GOLD-2 interfaces on the external Airlock shall not exceed the payload envelopes defined in **Figures 5.2.1-1** through **5.2.1-4**. The external GOLD-2 locations are defined in **Figure 5.2-2**. Note that the maximum envelopes do not take into consideration any envelope restrictions with respect to the launch vehicle or how it gets from inside the ISS to its external location (i.e. launches in soft stowage). The GOLD-2 may be able to accommodate larger dimensions than those indicated below. Larger payloads may be possible based on the type and locations of other existing payloads. Any deviation from these requirements will need to be documented in the Payload ICA and approved by Nanoracks.	A	I	Drawings
5.2.1.1	Active GOLD-2 Installation on Payloads	The installation tolerance of the active side of the GOLD 2 connector is dependent on the final external stowage location on the Airlock and shall meet the tolerances based **Figures 5.2.1.1-1** through **5.2.1.1-4.**	A	I	Drawings
5.2.2	External Payload Mass Properties	The maximum weight of payloads installed on the Airlock GOLD 2 fittings shall not exceed 500 lbs. The maximum c.g., measured from the active GOLD 2 fitting (**Figure 5.2.2-1**) is TBD. Higher weights may be possible and will need to be coordinated with Nanoracks require further analysis.	A	A	Mass Properties Report
5.2.2.1	Minimum Frequency	Payloads that utilize the SPDM to transfer out of the Airlock shall have minimum frequency that does not exceed 3 Hz. Minimum payload integrated assembly frequency is resolved at the dexterous grasp fixture coordinate frame origin and assumes that the grasp fixture is the only constrained point on the User hardware for all payload configurations (e.g., locked and unlocked)	A	A	Structural Report
5.2.2.2	Maximum Moment of Inertia	Payloads that utilize the SPDM to transfer out of the Airlock shall have a maximum Moment of Inertia of 29,663 lbm-ft2. Moments of inertia are expressed with respect to the dexterous grasp fixture coordinate frame and the value applies to all components of the inertia matrix individually for all payload configurations (e.g., locked and unlocked).	A	A	Structural Report

<table>
<tr><th>Paragraph</th><th>IRD Title</th><th>Requirement Text</th><th>Payload Applicability</th><th>Verification Method</th><th>Submittal Data</th></tr>
<tr><td>5.2.3</td><td>External Payload Bonding and Grounding</td><td>Bonding and ground of the payload shall be per the GOLD02-SP005 GOLD 2 ICD, Section 4.4.</td><td>A</td><td>I</td><td>Drawings</td></tr>
<tr><td>5.2.4</td><td>External Payload Electrical Interfaces</td><td>There are two electrical buckets on the GOLD-2 that provide the power and data interfaces to the payload. Each bucket is identical and therefore redundant if redundancy is desired by the payload. Each bucket has the following type connections:
Payload Operational Power: Switchable 120 VDC (+/-2 VDC) power, nominal 350 W and maximum of 700 W.
Keep Alive Heater (Survival Heater) Power: Switchable 120 VDC power, 50 W max
Data: Ethernet, 10/100 base
Bridge Detect: Loop back circuit that verifies a good robotic mate has occurred at the GOLD-2
Details about the maximum available power and data rates will be defined and documented in the Airlock payload-specific ICA.</td><td>A</td><td>I, A</td><td>Drawings, Power Analysis</td></tr>
<tr><td>5.2.4.1</td><td>GOLD-2 Passive Module and Socket Definition</td><td>Figure 5.2.4.2-1 shows the modules that are installed in the passive GOLD-2 located on the Airlock. Table 5.2.4.2-1 shows the socket definitions for each module. Reference GOLD02-SP005 for more detailed information on each individual module</td><td>A</td><td>A</td><td>Power Analysis</td></tr>
<tr><td>5.2.4.2</td><td>GOLD-2 Active Module and Socket Definition</td><td>The payload shall have an active GOLD-2 connector with modules and interfaces as shown in Figure 5.2.4.2-1 and Table 5.2.4.2-1. Reference GOLD02-SP005 for more detailed information on each individual module.</td><td>A</td><td>I</td><td>Drawings</td></tr>
<tr><td>5.2.5</td><td>Electromagnetic Compatibility</td><td>The Airlock electrical grounding shall be in accordance with SSP 30240, paragraph 3.1.</td><td>NVR</td><td></td><td></td></tr>
<tr><td>5.2.5.1</td><td>Electrical Grounding</td><td>The Payload shall be electrically bonded to the Airlock per SSP 30245, Space Station Electrical Bonding Requirements, paragraphs 3.2 and 3.3.</td><td>A</td><td>I</td><td>Drawings</td></tr>
</table>

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.2.5.2	Payload Surface Electrostatic Charging	All Payload metallic hardware elements shall comply with the Class-S bond requirements of SSP 30245, Space Station Electrical Bonding Requirements.	A	I	Drawings
5.2.5.3	Insulated Materials	Hardware consisting of or containing low-conductivity material shall be bonded in accordance with SSP 30245, Section 3.3.4.4.2.	A	I	Drawings
5.2.5.4	Radiation Emissions	The Payload shall not exceed emissions defined in SSP 30237, Space Station Electromagnetic Emission and Susceptibility Requirements	A	A	EMI/EMC Report
5.2.6	External Payload Command and Data Interfaces	The command and data interface to the payloads shall be Ethernet protocol and will interface via the GOLD-2 ICD. The Nanoracks operations team at the Nanoracks ground facility will control and configure the Airlock DHS, payloads, and shared resources (such as data streaming destinations). The data downlink along this path includes Health and Status monitoring data for the Airlock DHS and all its payloads using the ISS's Medium Rate Data Link (MRDL), some of which are exclusively used by the Airlock DHS itself, and some shared by the payloads. The Airlock C&DH interface also includes file transfer capabilities directly between the ground and the Airlock DHS (and to/from payloads in a second step.	TBD		
5.2.7	Airlock DHS to Payload Software Interface	This section describes the software interface between the Airlock DHS and the payload. Adherence to the required and optional interfaces described here is essential for the successful and safe operation of Airlock payloads in space. It will ensure that an optimal amount of scientific as well as operational data from a payload can be made available to its owner.	NVR		
5.2.7.1	Commanding	The Airlock DHS provides the capability to send commands to an internal or external payload. All Airlock payload commanding is performed from the Nanoracks BRIDGE by the Nanoracks Operations team.	TBD		

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
5.2.7.2	Health and Status Monitoring	Health and status monitoring of the payloads is unique to each payload based on their requirements and will be defined in the payload unique ICA.	TBD		
5.2.7.3	File Transfer	Using the Transmit and Receive commands, files can be transferred between a payload and the Airlock DHS. In this case, the Airlock DHS is used as an intermediary, and additional steps will be needed to transfer a file between the DHS and its original source resp. final destination. Due to the relatively low baud rate of the serial connection and the overhead of the Intel HEX format, the user data transfer rate is limited to about 2 kB/s; therefore, serial file transfer should be limited to small files. Also, consider that while the serial connection is in use by a file transfer, status monitoring for that payload is suspended, which creates a gap in payload monitoring data.	TBD		
6.0	Payload Environments	The launch environments here are based on standard ISS cargo resupply launch vehicles as described in SSP 57000.	NVR		
6.1.1	Acceleration Loads	Payload safety-critical structures shall (and other payload structures *should*) provide positive margins of safety when exposed to the accelerations documented in **Table 6.1.1-1** at the CG of the item, with all six degrees of freedom acting simultaneously. The acceleration values are applicable to both soft stowed and hard mounted hardware. (Per SSP 57000, Section D.3.1.1)	A	A	Structural Analysis
6.1.2	Random Vibration Loads Environment	Payload safety-critical structures packed in foam or bubble wrap and enclosed in hard containers such as lockers, boxes, or similar structures, and payload safety-critical structures packed in foam or bubble wrap and soft stowed in bags shall maintain structural integrity when exposed to the random vibration environments defined in **Table 6.1.2-1.** Contact Nanoracks for the proper vibration test procedure. The standard stowage configuration is the payload wrapped in bubble wrap. Otherwise, test to the stowage requirements as set in the payload ICA.	A	A	Structural Analysis

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
6.1.3	Launch Shock Environment	Integrated end items packed in the foam or bubble wrap materials do not experience significant mechanical shock. Shock verification is not required for launch events. Any mechanical or electrical components that are highly sensitive to shock should be assessed on a case-by-case basis as defined in the payload ICA.	A	A	Structural Analysis
6.1.4	IVA Loads Environment	The payload shall provide positive margins of safety when exposed to the crew induced loads defined in **Table 6.1.4-1**, Crew-Induced Loads (reference SSP 57000, Table 3.1.1.1.2-1). The payload ICA will detail specific exclusions to these loads based on keep out zones and special operational constraints. The payload shall provide positive margins of safety for on–orbit loads of 0.2 g acting in any direction for nominal on-orbit operations per SSP 57000, Rev R, Section 3.1.1.1.1.	A	A	Structural Analysis
6.1.5	EVA Loads Environment	The payload shall provide positive margins of safety when exposed to EVA kick loads of 125 lbf over a 0.5 inch diameter circle as stated in Section 3.1.3-1 of SSP 57003. The payload ICA will detail specific data products, as required, to support the processing of any exceptions.	A	A	Structural Analysis
6.1.6	On-orbit Acceleration Environment	The payload shall meet structural integrity requirements in an on–orbit acceleration environment having peak transient accelerations of up to 0.2 g's, with a vector quantity acting in any direction as stated in Section 3.5.9 of SSP 57003. On-orbit scenarios include EVR operations, both direct (payload transfer) and indirect (relocation of NRAL), with the payload in all possible configurations (locked, unlocked, stowed, unstowed, etc.).	A	A	Structural Analysis
6.1.7	SSRMS Impact Energy	All unprotected portions of the Payload hardware shall maintain positive margins of safety after being subjected to a contact energy of 1 J for the following scenarios: · Within one foot (12 inches) of the SSRMS during grappling operations, or · Within one foot (12 inches) of fixed structure when SSRMS is moving the Payload either directly or indirectly, or · Within one foot (12 inches) of other equipment robotically manipulated directly or indirectly by the SSRMS.	A	A	Structural Analysis

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
6.1.8	SPDM Impact Energy	All unprotected portions of the Payload hardware (excluding GFE robotic or FRAM components) shall maintain positive margins of safety after being subjected to a contact energy of 1 J when being manipulated by SPDM for the following scenarios: • within eight (8) inches of the SPDM interface during approach/grasp operations (3 inches beyond the OTCM mechanical envelope), or • within six (6) inches of surrounding fixed structure when being manipulated by SPDM outside of worksite proximity operations, or • within six (6) inches of equipment being robotically manipulated by the SPDM. Portions of the Payload that are protected by other Payload structure which can withstand the 1J impact do not need to be assessed.	A	A	Structural Analysis
6.1.9	SPDM Load Limit	Payload hardware that is inside the SPDM approach envelopes or within 3 inches of hardware manipulated by SPDM shall show positive margins of safety for nominal contact forces of 50 lbf (222.4 N) resolved at the point of contact.	A	A	Structural Analysis
6.1.10	Grasp Interface Structural Loads	The Payload shall maintain positive margins of safety for the nominal loads transmitted through the grasp fixture during OTCM or Tool grasp and manipulation as shown in **Table 6.1.10-1**.	A	A	Structural Analysis
6.1.11	Thermal Environment	Expected thermal environments for all phases of payload integration are summarized in **Table 6.1.11-1** Expected Thermal Environments. Payloads with special thermal constraints should coordinate with Nanoracks.	A	A	Thermal Analysis
6.1.12	Passive Thermal Interface	The temperature of the Payload SPDM grasp fixture installation(s) just prior to and during acquisition by the SPDM OTCM shall be no less than -130 °F or greater than +145 °F	A	A	Thermal Analysis
6.1.13	Humidity	The relative humidity will be 25% to 75% RH for ascent and on-orbit phases of flight. Payloads with special humidity control requirements should coordinate with Nanoracks.	NVR		

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
6.1.14	Airlock Depressurization	The pressure inside the airlock is described as follows (the pressure when the air is vacuumed or re-pressurized with the inner/outer hatches closed). The payload shall survive the pressure range and depressurization/re-pressurization rate. • Airlock Pressure: 0 to 104.8kPa • Airlock pressure depressurization/re-pressurization rate: 1.0kPa/sec	A	A	Structural Analysis
6.1.15	Atomic Oxygen	The Payload will be exposed to a long term average ram atomic oxygen flux of 5.0×1021 atoms per cm2 per year for the on-orbit exposure duration. Surfaces exposed 30 days or less will be exposed to a short term peak ram atomic oxygen flux of up to 4.4×1019 atoms per cm2 per day.	NVR		
6.1.16	External Contamination	The Payload will be exposed to the ISS on-orbit external contamination environment of: • 130 Angstroms/year of total contaminant deposition from all ISS contamination sources combined (quiescent and non-quiescent), • molecular column densities of up to 1.0×1014 molecules/cm2 for unobstructed lines-of-sight during quiescent periods, and	A	I, A	BOM, MIUL, Contam. Analysis

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
		• particulate releases limited to one 100 micron particle per orbit per 1.0×10-5 steradian field-of-view during quiescent periods. The very low pressure and zero humidity on-orbit can lead to outgassing of chemical constituents for materials and components that are not vacuum stable. This outgassed material can deposit on surrounding hardware and change the optical properties of the coated components, leading to performance degradation of the material or component.. Payloads shall limit the total mass flow of each vented gas (ṁ, kg/s) to $\dot{m} \leq 6.45 \times 10^{-7}\sqrt{M_s T_0}$ where Ms is the molecular weight (kg/kg·mole) of each molecular species vented, and T0 is the temperature (K) of the vented gases at the payload outlet. Note: This limits the external environment molecular column density to less than 1×1014 molecules/cm2 along any unobstructed line of sight.			
6.2	HFIT (Human Factors Implementation Team) Requirements	Generic guidance is provided to the Payload Developer to ensure compliance to ISS Program HFIT requirements. Nanoracks in coordination with the Payload Developer, reviews the satellites design. Dependent on payload design, unique requirements may be levied through the ICA between Nanoracks and the Payload Developer.	NVR		
6.2.1	HFIT Requirements	Nanoracks as part of its service conducts an HFIT closeout with NASA oversight. Nanoracks also completes all verification documentation for closure to NASA. Generic requirements the payload shall comply are listed in **Table 6.2.1-1** Requirements for Payloads Using the Airlock Services	A	I	Drawings and Hardware
6.3	Payload Safety Requirements		Verified through the Safety Verification Process		

Appendix A: Payload Transfer FSE

A.1 Introduction

This appendix provides information for payloads that will utilize the Airlock Transfer FSE to transfer them from within the ISS to outside the ISS. This system is designed to accommodate payloads with the GOLD-2 interface system (e.g. Airlock external sites or Bartolomeo sites). The system is designed to be modular and can allow for single or multiple payloads to be transferred during a single Airlock operation. For instance, a single payload can be transferred per Airlock operation or up to 4 payloads can be transferred at a time. However, as the number of payloads increases, the size of the each payload must decrease in order to accommodate them in the Airlock. In addition, the system will allow for a mixed configuration of payloads with some transfer type payloads and some deployable or fixed type payloads within the Airlock. All of these type of payload configurations will be discussed with Nanoracks during the feasibility study phase.

In general, for payloads that will be going to be installed on the Airlock external sites, if they are in compliance with the requirements in Section 5.2 of this document, they will meet the requirements for this equipment unless it's the four payload configuration. That configuration is detailed in the following sections.

For Airlock external payloads, this Appendix covers additional requirements for the payload design process that may not be in the main sections of the IDD. For other payloads using this system, they will have to meet these requirements plus those described in the IDD for that particular payload location.

A.2 Physical Description

The Airlock Transfer FSE is primarily a structural system with a passive GOLD-2 mounted to a bracket (**Figure A.2.0-1**). Power and data cables connect to the GOLD-2 and interface with the payload connectors on the Airlock PIU1 (**Figure A.2.0-2**)

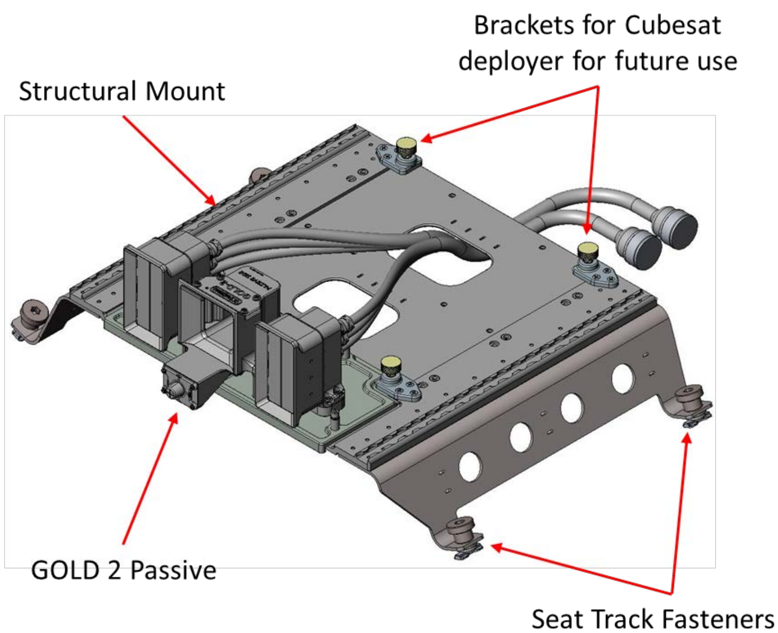


Figure A.2-1: Airlock Transfer FSE

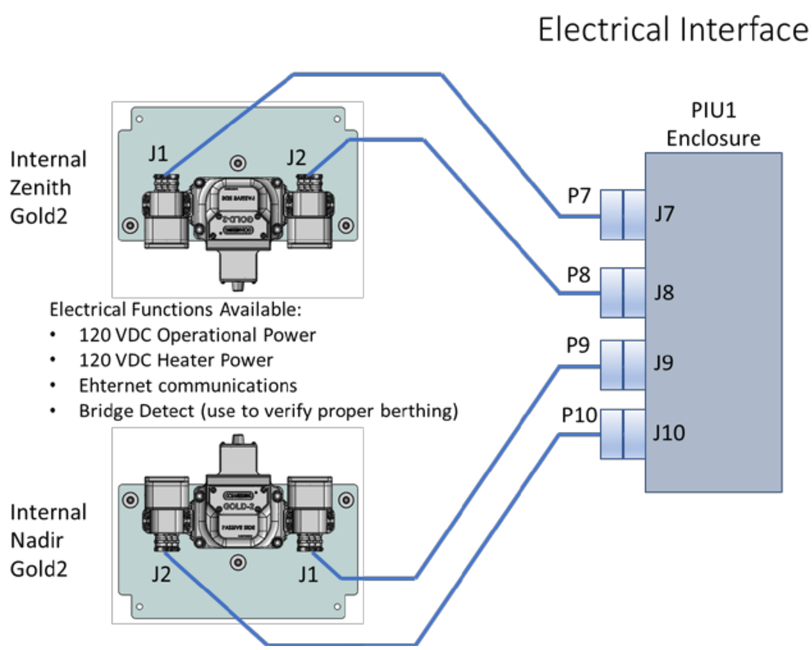


Figure A.2-2: Airlock Transfer FSE Electrical Interface

A.3 Payload Envelope

The payload envelope for the Payload Transfer FSE varies based on the number of payloads to be transferred per Airlock operations. For single payload transfer operations, the full size envelope for the Airlock external sites or the Bartolomeo sites can be accommodated. Those sizes are as follows:

- Airlock: 24x24x28 inches (610x610x710 mm)
- Bartolomeo: 27.5x31.5x39.3 inches (700x800x1000 mm; per Bartolomeo IDD)

However, for the two payload configuration (**Figure A3.0-1**), the size (payload height, distance from GOLD-2 interface plane) decreases slightly to the following:

- Two identical payloads: 21.7x31.6x39.3 inches (551x802x1000 mm)

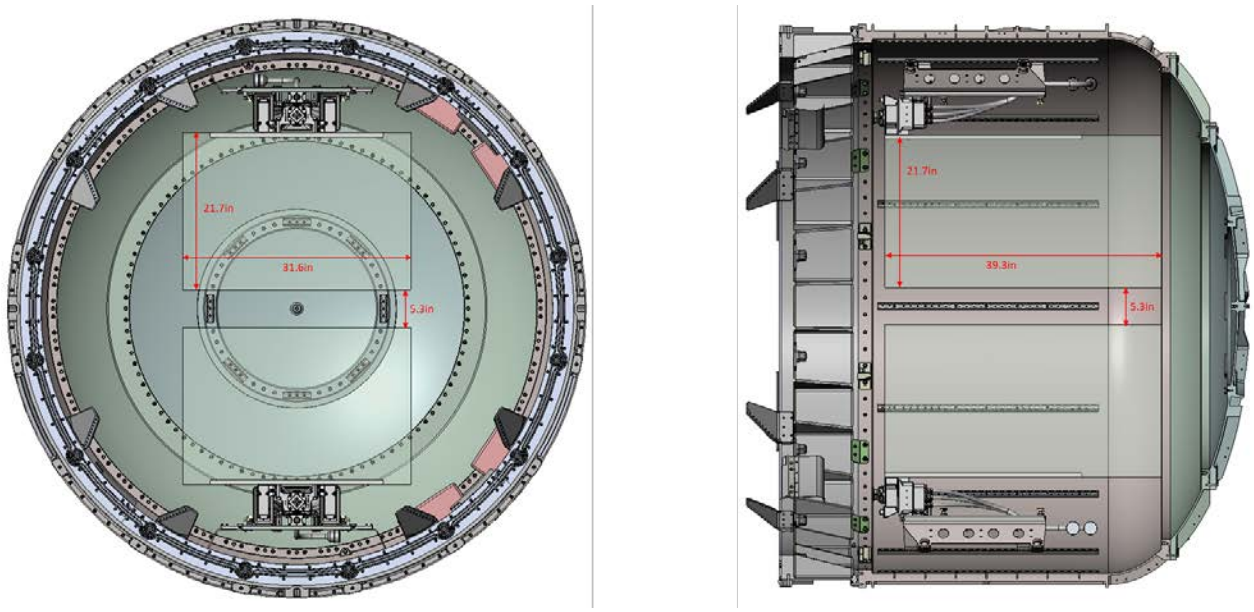


Figure A.3-1: Airlock Transfer FSE Envelope – 2 Payloads

Note: This is for two identically sized payloads which may be unlikely and so if one payload is shorter in height, than a larger envelope for the second payload may be achievable. This combination of payloads and their assessment will be performed by Nanoracks as part of the feasibility study.

Also, for payloads that are close to one another, their surfaces may need to be sized to accommodate the SPDM contact energy/forces described in Section 6.1.8

For the 4 payload configuration (**Figure A.3.0-2: Airlock Transfer FSE Envelope – 4 Payloads**), the payload size decreases significantly. Therefore, this is an unlikely configuration to be utilized due to the restriction on payload volume, but it is available for discussion..

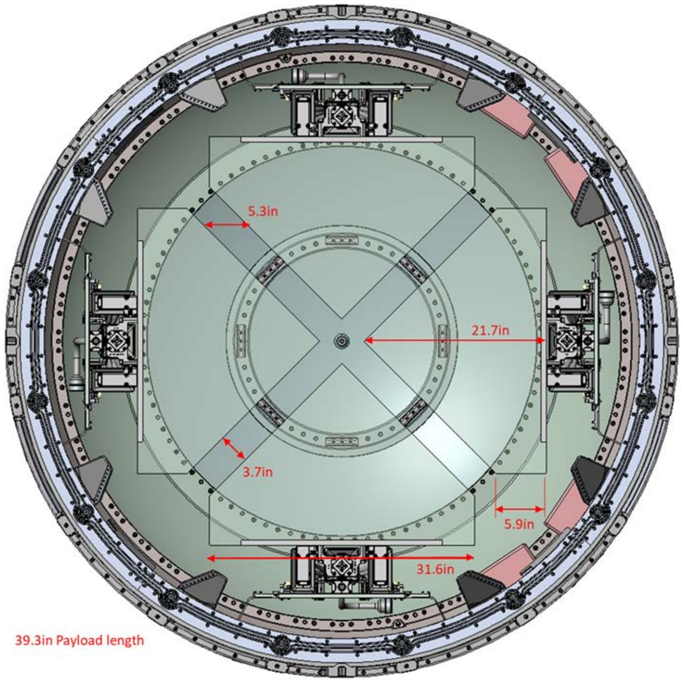


Figure A.3-2: Airlock Transfer FSE Envelope – 4 Payloads

A.4 Electrical Interfaces

While mounted within the Airlock on the Transfer FSE, the payload is able to receive power and data from the Airlock. The connection is from the passive GOLD-2 connector to the Airlock PIU1 internal payload connectors. For each payload interface connector on PIU1, there are two power interfaces and a data interface to each bucket of the GOLD-2 connector. Each bucket of the GOLD-2 has the following type connections:

- Payload Operational Power: Switchable 120 VDC power, nominal 350 W and maximum of 700 W
- Payload Survival Heater Power: Switchable 120 VDC power, nominal 350 W and maximum of 700 W
- Data: Ethernet, Gigabit
- Bridge Detect: Loop back circuit that verifies a good mate has occurred at the GOLD-2 connector

Both buckets are wired identically, and all four power feeds may be powered at the same time. However, total power draw to the entire Airlock is limited so total power draw is dependent on the payload complement on the Airlock at the time of the transfer operations.

Details about the maximum available power and data rates will be defined and documented in the Airlock payload-specific ICA.

Figure A4-1 shows the modules that are installed in the passive GOLD-2 located on the Airlock Payload Transfer FSE. **Table A4-1** shows the socket definitions for each module. Reference GOLD02-SP005 for more detailed information on each individual module.

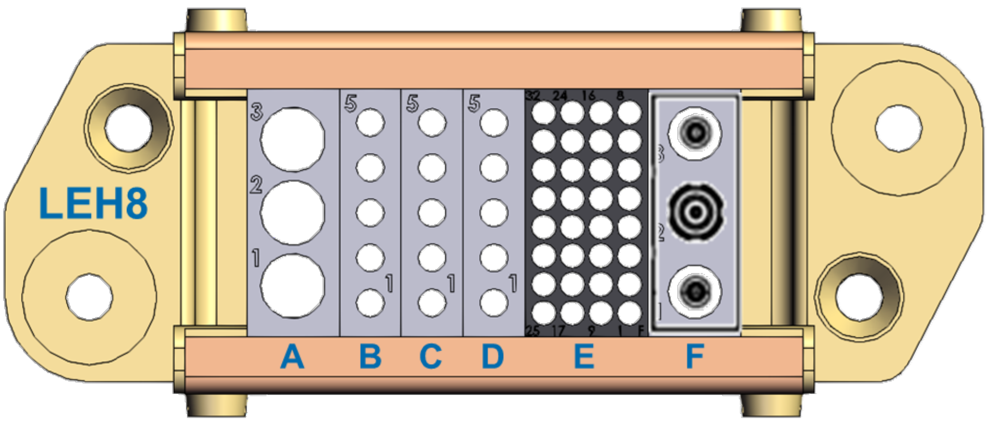


Figure A4-1: GOLD-2 Passive Module

Table A4-1 Airlock Payload Transfer GOLD-2 Passive Socket Definitions

Module P/N	Module Insert Id	Socket No.	Wire (AWG)	Contact P/N	Description
LSF4	A	1	16 AWG	YSK025-013AH	120 VDC Operational
		2	16 AWG	YSK025-013AH	120 VDC RTN Operational
		3	16 AWG	YSK025-013AH	Chassis
LRF1	B	1	16 AWG	YSK015-013AH	120 VDC Survival Heater
		2	16 AWG	YSK015-013AH	120 VDC RTN Survival Heater
		3	16 AWG	YSK015-013AH	Chassis
		4	N/A	Empty	Not connected
		5	N/A	Empty	Not connected
LRF1	C	1	22 AWG	YSK015-013AH	Bridge Detect/Bucket Mate POS
		2	24 AWG	YSK015-013AH	ENET DA+ (TX+)
		3	24 AWG	YSK015-013AH	ENET DA- (TX-)
		4	24 AWG	YSK015-013AH	ENET DB+ (RX+)
		5	24 AWG	YSK015-013AH	ENET DB- (RX-)
LRF1	D	1	22 AWG	YSK015-013AH	Bridge Detect/Bucket Mate RTN
		2	24 AWG	YSK015-013AH	ENET DC+
		3	24 AWG	YSK015-013AH	ENET DC-
		4	24 AWG	YSK015-013AH	ENET DD+
		5	24 AWG	YSK015-013AH	ENET DD-
LWFRTAH	E	1	N/A	Guidepost	Guidepost
		2	N/A	Empty	Not connected
		3	N/A	Empty	Not connected
		4	N/A	Empty	Not connected
		5	N/A	Empty	Not connected
		6	N/A	Empty	Not connected
		7	N/A	Empty	Not connected
		8	N/A	Empty	Not connected
		9	N/A	Empty	Not connected
		10	N/A	Empty	Not connected

		11	N/A	Empty	Not connected
		12	N/A	Empty	Not connected
		13	N/A	Empty	Not connected
		14	N/A	Empty	Not connected
		15	N/A	Empty	Not connected
		16	N/A	Empty	Not connected
		17	N/A	Empty	Not connected
		18	N/A	Empty	Not connected
		19	N/A	Empty	Not connected
		20	N/A	Empty	Not connected
		21	N/A	Empty	Not connected
		22	N/A	Empty	Not connected
		23	N/A	Empty	Not connected
		24	N/A	Empty	Not connected
		25	N/A	Empty	Not connected
		26	N/A	Empty	Not connected
		27	N/A	Empty	Not connected
		28	N/A	Empty	Not connected
		29	N/A	Empty	Not connected
		30	N/A	Empty	Not connected
		31	N/A	Empty	Not connected
		32	N/A	Guidepost	Guidepost
YPC0432	F	1	N/A	Empty	Not connected
		2	N/A	Empty	Not connected
			N/A	Empty	Not connected

The payload shall have an active GOLD-2 connector with modules and interfaces as shown in **Figure A4-2** and **Table A4-2**. Reference GOLD02-SP005 for more detailed information on each individual module.

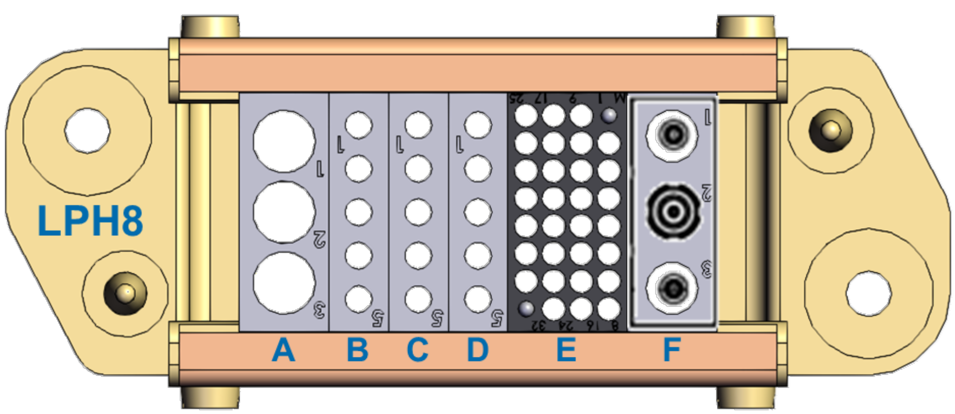


Figure A4-2: GOLD-2 Active Module

Table A4-2 Airlock Payload Transfer GOLD-2 Passive Socket Definitions

Module P/N	Module Insert Id	Socket No.	Wire (AWG)	Contact P/N	Description
LSF4	A	1	16 AWG	YPN025-011RH	120 VDC Operational
		2	16 AWG	YPN025-011RH	120 VDC RTN Operational
		3	16 AWG	YPN025-011RH	Chassis
LRF1	B	1	16 AWG	YPN015-009RH	120 VDC Survival Heater
		2	16 AWG	YPN015-009RH	120 VDC RTN Survival Heater
		3	16 AWG	YPN015-009RH	Chassis
		4	N/A	Empty	Not connected
		5	N/A	Empty	Not connected
LRF1	C	1	22 AWG	YPN015-009RH	Bridge Detect/Bucket Mate POS
		2	24 AWG	YPN015-009RH	ENET DA+ (TX+)
		3	24 AWG	YPN015-009RH	ENET DA- (TX-)
		4	24 AWG	YPN015-009RH	ENET DB+ (RX+)
		5	24 AWG	YPN015-009RH	ENET DB- (RX-)
LRF1	D	1	22 AWG	YPN015-009RH	Bridge Detect/Bucket Mate RTN
		2	24 AWG	YPN015-009RH	ENET DC+
		3	24 AWG	YPN015-009RH	ENET DC-
		4	24 AWG	YPN015-009RH	ENET DD+
		5	24 AWG	YPN015-009RH	ENET DD-
LWFRTAH	E	1	N/A	Guidepost	Guidepost
		2	N/A	Empty	Not connected
		3	N/A	Empty	Not connected
		4	N/A	Empty	Not connected
		5	N/A	Empty	Not connected
		6	N/A	Empty	Not connected
		7	N/A	Empty	Not connected
		8	N/A	Empty	Not connected
		9	N/A	Empty	Not connected
		10	N/A	Empty	Not connected
		11	N/A	Empty	Not connected
		12	N/A	Empty	Not connected
		13	N/A	Empty	Not connected
		14	N/A	Empty	Not connected
		15	N/A	Empty	Not connected
		16	N/A	Empty	Not connected
		17	N/A	Empty	Not connected
		18	N/A	Empty	Not connected
		19	N/A	Empty	Not connected
		20	N/A	Empty	Not connected
		21	N/A	Empty	Not connected
		22	N/A	Empty	Not connected
		23	N/A	Empty	Not connected
		24	N/A	Empty	Not connected
		25	N/A	Empty	Not connected
		26	N/A	Empty	Not connected
		27	N/A	Empty	Not connected
		28	N/A	Empty	Not connected
		29	N/A	Empty	Not connected
		30	N/A	Empty	Not connected
		31	N/A	Empty	Not connected

		32	N/A	Guidepost	Guidepost
YPC0432	F	1	N/A	Empty	Not connected
		2	N/A	Empty	Not connected
			N/A	Empty	Not connected

A.5 Payload Operations

The payload operations scheme will include both crew IVA operations and external EVR operations. Below is a rough outline of the operations with additional details provided in TBD.

1. Crew installation of Payload Transfer FSE
2. Crew installation of payload(s)
3. Payload power ON (if required)
4. Crew prepares Airlock for sortie (eg vestibule operations, Airlock power down, disconnect cables from Node 3, hatch closure)
5. SSRMS grapple of Airlock and power up if needed
6. Airlock depressurization and leak checks
7. Airlock unberth from Node 3
8. Airlock maneuver to Mobile Base System (MBS) Payload ORU Adapter (POA) for parking
9. SSRMS released from Airlock and retrieves SPDM
10. Payload power OFF (if it was ON)
11. SPDM grasps payload and extracts and maneuvers to destination site and installs
12. SPDM releases payload and repeats for additional payload(s)
13. Once all payloads transferred, SSRMS parks SPDM
14. SSRMS grapples Airlock and Airlock released from MBS POA
15. Airlock maneuvered back to Node 3 and installed
16. Airlock pressurized and leak checked
17. Crew opens hatch, performs vestibule outfitting
18. Crew removes payload transfer FSE and stows