Nanoracks External Platform (NREP) Interface Definition Document (IDD)

List of Revisions

Revision	Revision Date	Revised By	Revision Description
-	3/16/2016	Steve Stenzel	Initial Release
A	4/20/2016	Steve Stenzel	Update logo on cover page
B	11/14/2016	C. Cummins	Replace Proprietary Statement with a Copyright statement.
C	10/18/2021	Maggie Ahern	Updated NREP drawings and interface descriptions

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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 External Platform (NREP). This IDD also defines the requirements to the International Space Station (ISS) flight safety program when using the NREP. This IDD also defines the various environments applicable to the payload design process. 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. The ICA also defines the technical responsibilities of NREP service provider, i.e., Nanoracks with Airbus DS Space Systems, and the payload representative.

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). The interface requirements defined herein primarily address the Payload to the Japanese Experiment Module (JEM) as a staging facility along with the Canadian Space Agency, Special Purpose Dexterous Manipulator (SPDM) as a platform.

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 Interface Control Agreement (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
CD&H	Command Data & Handling
CMC	Cargo Missions Contract
CMC	Cargo Missions Contract
DHS	Data Handling System
ECM	Electronic Control Module
FTP	File Transfer Protocol
HFIT	Human Factors Interface Test
ICA	Interface Control Agreement
IDD	Interface Definition Document
IP	Internet Protocol
JEM	Japanese Experiment Module
JEM-EF	JEM Exposed Facility
MIUL	Material Identification Usage List
MRDL	Medium Rate Data Link
NREP	Nanoracks External Platform
NREP-P	Nanoracks External Platform Payload
PIU	Payload Interface Unit
SPDM	Special Purpose Dexterous Manipulator
STELLA	Software Toolkit for Ethernet Lab-Like Architecture
TCP	Transmission Control Protocol
UDP	Universal Datagram Protocol

Table 2-2: Applicable Documents

Doc No.	Rev	Title
SSP 57000	R	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 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

3 Nanoracks NREP Overview

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

3.1 NREP Physical Descriptions

“NREP" is defined as an External Payload Platform (ref. Fig 3.1-1) capable of accommodating internal ISS payload removal and replacement, transfer of integrated payload through ISS JEM Airlock to the JEM External Facility. The NREP will operate experiment payloads in the open space environment while attached to the JEM-EF.

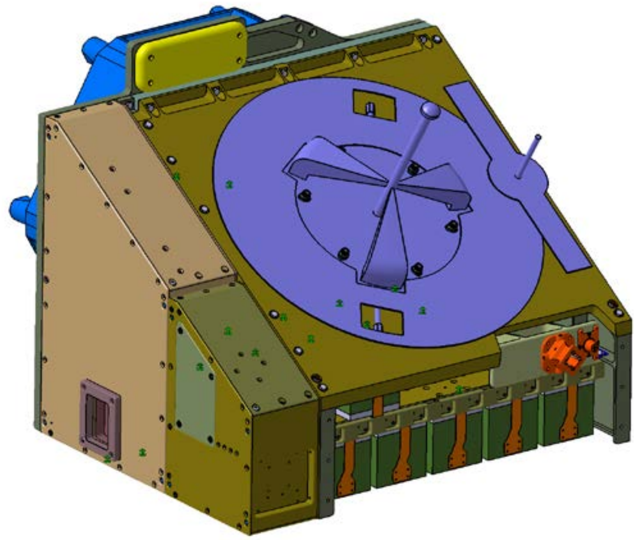

Figure 3.1-1: Nanoracks External Platform

3.1.1 NREP-P Baseplate

The NREP-P Baseplate (ref. Fig 3.1.1-1) is defined as the NREP – Payload interface to the Nanoracks External Platform. This interface will provide common attach interfaces to the payload, allowing a standardized mechanical, electrical, thermal, and data interface.

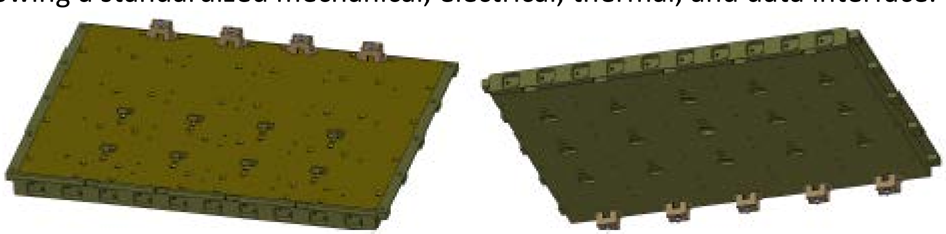

Figure 3.1.1-1: NREP-P Baseplate

3.1.2 Nanoracks External Plate - Payload

The NREP–Payload (NREP-P) (ref Fig. 3.1.2-1) is the experiment package developed by the user/customer. The nominal experiment package is a 4U Form Factor (40cmx10cmx10cm), equipped with a standardized USB 2.0 interface, allowing for a plug-and-play interface. Other payload experiment packages can be accommodated per unique interface agreements.

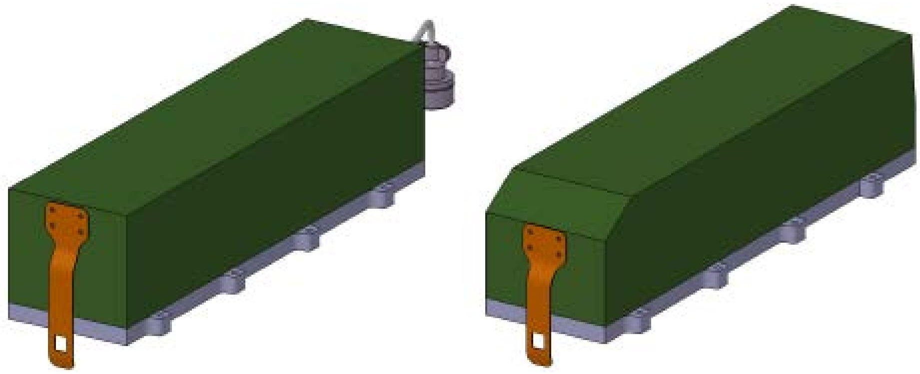

Figure 3.1.2-1: NREP-P

3.1.3 NREP Coordinate System

The coordinate system of the NREP is a right-handed system shown in Fig. 3.1.3-1. Its origin is the center of the mating surface of PIU to the NREP, the X-axis is normal to the mating surface, and the Z-axis points to the Nadir direction.

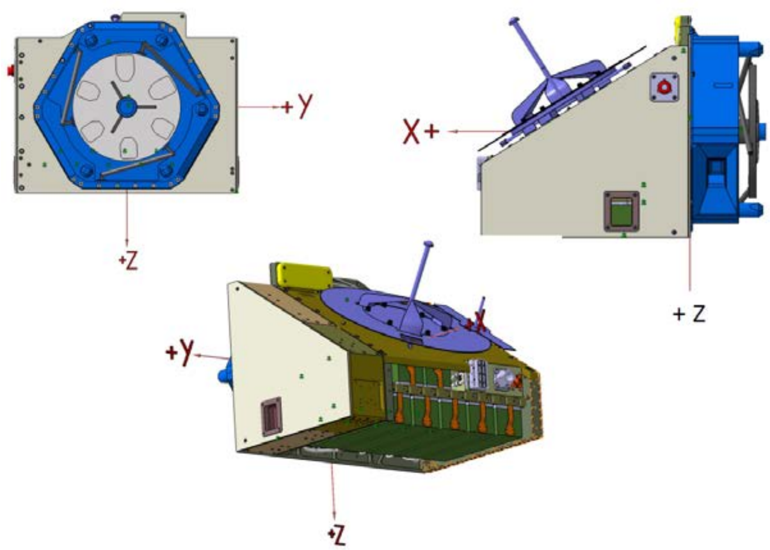

Figure 3.1.3-1: NREP Coordinate System

3.1.4 NREP General Dimensions

The coordinate system of the NREP is a right-handed system shown in Fig. 3.1.4-1. Its origin is the center of the mating surface of PIU to the NREP, the X-axis is normal to the mating surface, and the Z-axis points to the Nadir direction.

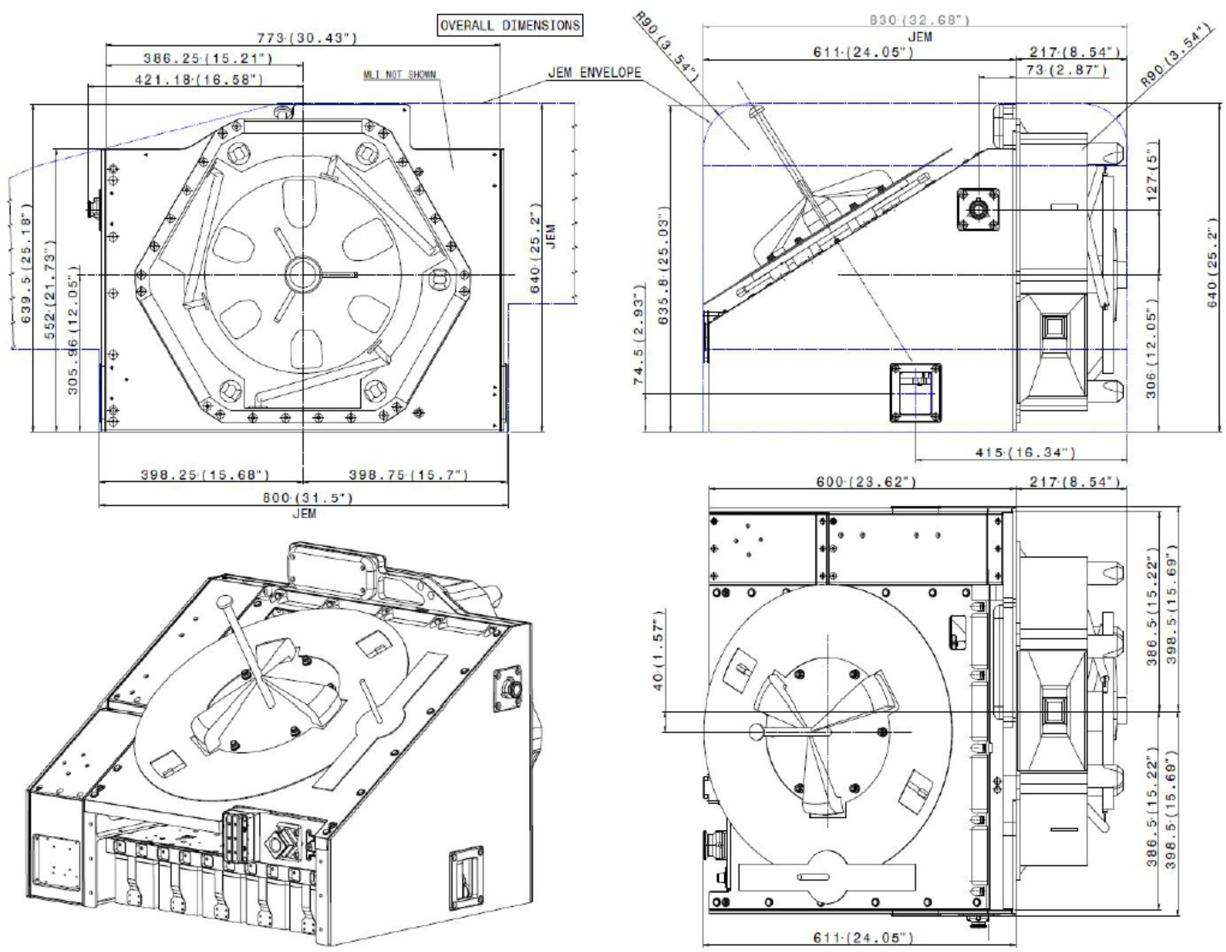

Figure 3.1.4-1: NREP Envelope Dimensions

3.1.5 NREP Payload Configurations

NREP payloads can be attached in various configurations to the NREP Baseplate. The baseplate can accommodate up to 5 powered 4U payloads and up to 4 unpowered 3U payloads or unique geometry agreed to per interface control agreement.

3.1.6 NREP Baseplate Location Numbering System

The NREP location numbering system is shown in Figure 3.1.6-1 and indicated by labels on the Experiment Base Plate. For payloads shorter than 4U the sites are subdivided by letters A through D (see Figure 3.1.6-2 and Figure 3.1.6-3)

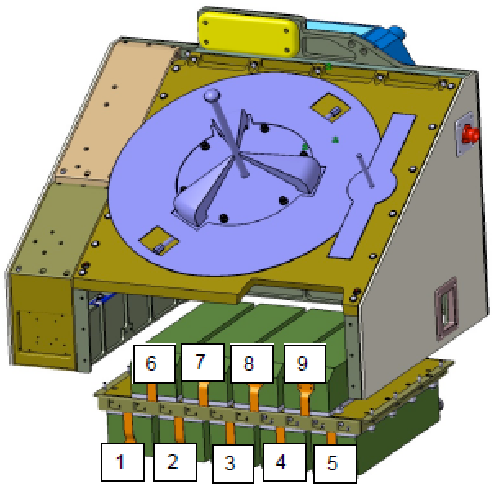

Figure 3.1.6-1: Payload Numbering System

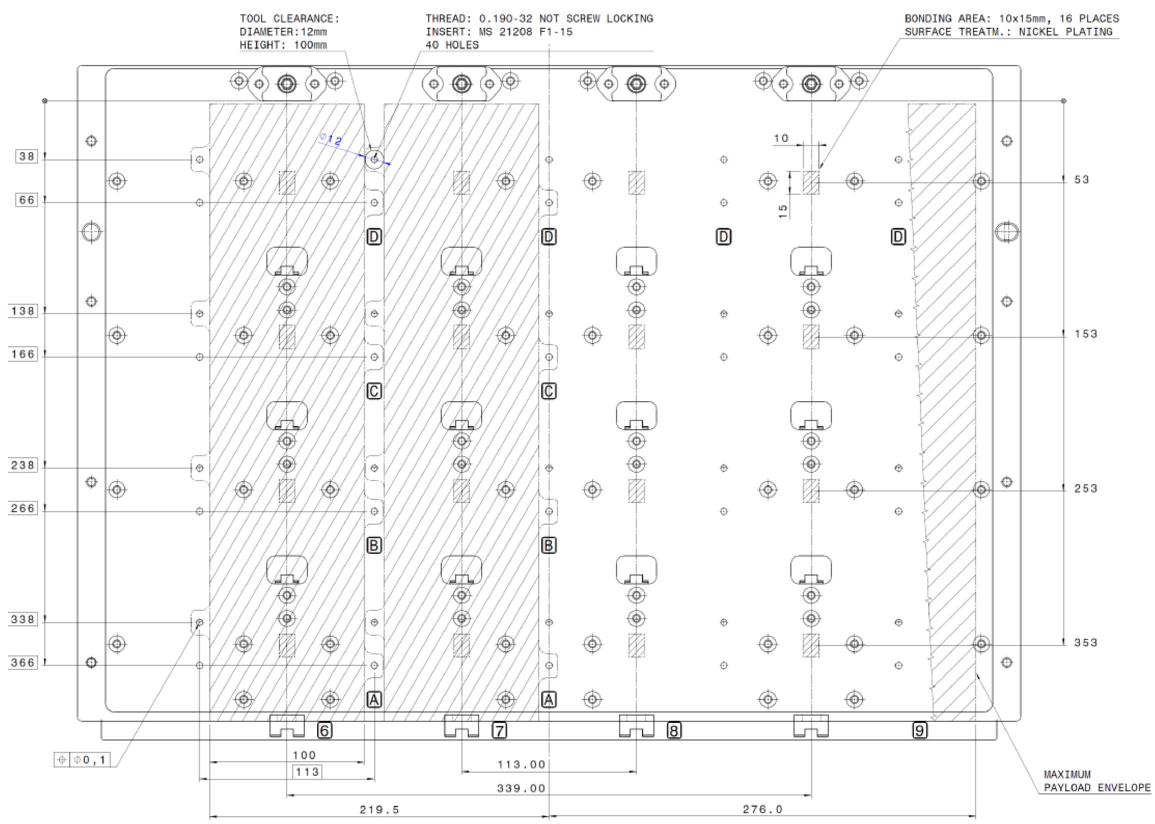

Figure 3.1.6-2: Experiment Baseplate Interfaces, Top Side

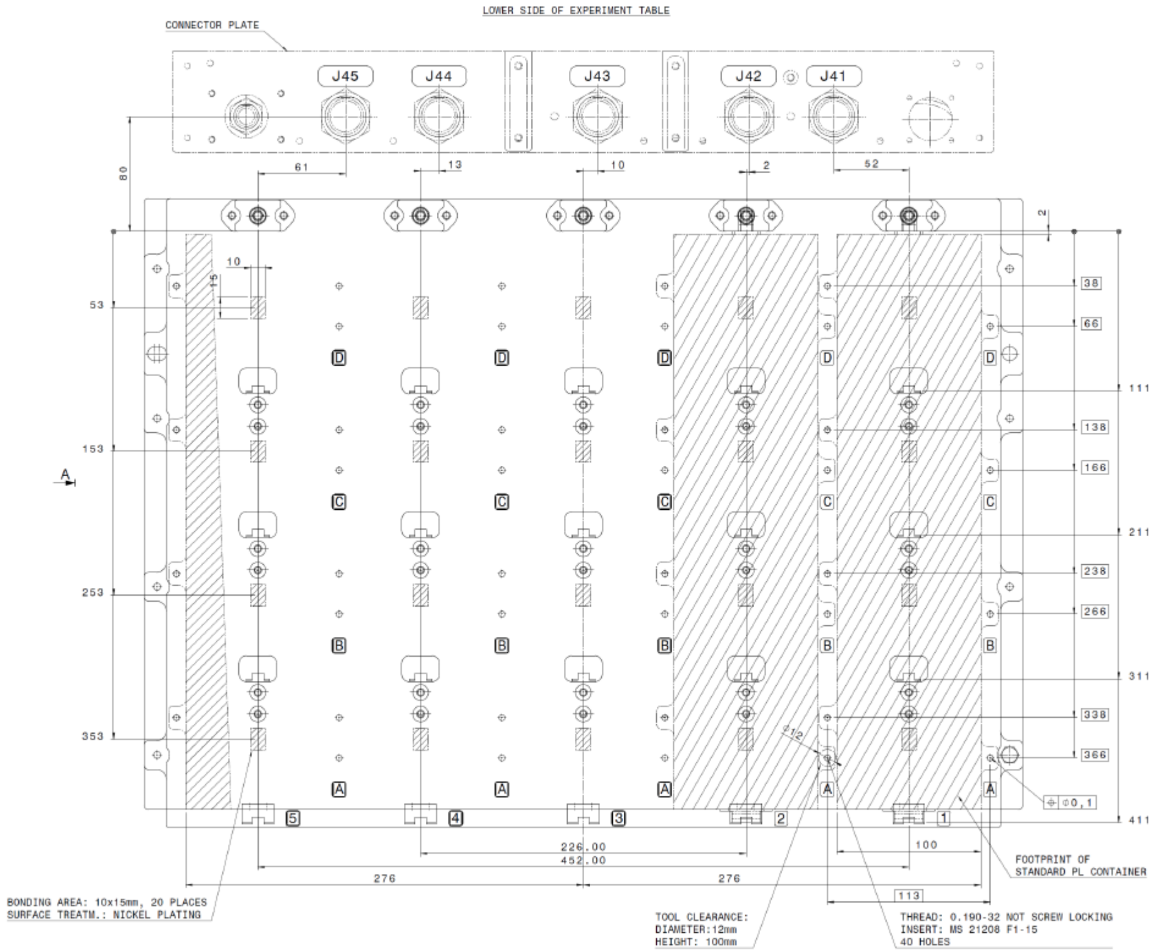

Figure 3.1.6-3: Experiment Baseplate Interfaces, Bottom Side

3.2 NREP Operations Overview

The launch, on-orbit installation and operation for 15 weeks is a standard NREP-P service. The payload representative will be notified of the status of its hardware. Ten working days prior to NREP-P activation the NREP-P representative will be notified and shall ensure his support for flight operations.

3.2.1 Schedule

Table 3.2.1-1 is a standard template schedule. The detailed payload schedule will be coordinated through the individual Interface Control Agreement between Nanoracks and the Payload provider.

Table 3.2.1-1: Milestone Schedule

Milestone/Activity	Launch-minus Dates (months)
Contract Signing	L – 12
Interface Control Agreement Start	L – 11.5
Deliveries: Functional Description, Interface Drawings, MIUL, Budget Report	L – 10
NREP service provider starts ISS safety process	L – 10
Payload delivery: Thermal Model or equivalent data	L – 9
Power and data cable provided to payload provider	L – 6
Payload delivery: Flight operations description	L - 6
Payload prototype/mock-up to Nanoracks Facility in Houston	L – 5
Preliminary payload software testing	L - 5
Deliveries: Structural and Loads Analysis	L - 5
Deliveries: Fastener and Bolt-out Analysis	L - 4
Payload handover to Nanoracks Facility in Houston	L - 3
Payload Environmental tests and Functional test within NREP test bed	L - 3 to L – 1
Payload Certification for flight and handover to launch authority	L - 1
Launch	L - 0
Payload installation into NREP	L + 4
Payload operation	L + 4 to L + 7
Payload return to payload provider	L + 13

3.2.2 Ground Operations

3.2.2.1 Delivery to Nanoracks

The payload customer will deliver the integrated payload to the Nanoracks Houston facility, or another facility as determined by the ICA, by the dates listed in the schedule. Any special requirements, such as lifting equipment, ground handling hardware, special handling instructions, etc., will be documented in the payload specific ICA.

3.2.2.2 Nanoracks Inspection

Nanoracks will inspect the combined payload assembly to verify it meets the appropriate safety and ICA. This includes, but is not limited to, the NASA Human Factors Interface Test (HFIT) inspection, leak checks, mass properties and overall dimensions.

3.2.2.3 Nanoracks Data Gathering for Operations

Nanoracks will assess the payload to develop products and procedures in support of crew interaction and on-orbit assembly of the payload onto NREP. To efficiently assemble the payload, minimize crew time, and maximize mission success, Nanoracks will gather information on the payload including an overall evaluation, pictures, and other products as needed. This information will be used to create an effective way for crew to assemble and install the payload, develop supporting procedures, and ensure successful deployment of NREP payload.

3.2.2.4 Nanoracks Testing

Nanoracks will perform any agreed to testing of the completed assembly based on the Interface Control Agreement. This may include, but is not limited to, grounding checks, bonding checks, testing of release mechanism, verification of the concept of operations, and other testing as required. Any special requirements will be documented in the payload specific ICA.

3.2.2.5 Customer Ground Servicing

The customer is allowed to perform last minute payload activities at the Nanoracks facilities prior to final packaging, based on the agreements in the ICA. Once the payload has been delivered to the Cargo Mission Contract, no further payload servicing will be allowed. Any special requirements will be documented in the payload specific ICA.

3.2.2.6 Nanoracks Packaging and Delivery

Nanoracks will integrate all payloads onto the experiment baseplate. Nanoracks will deliver the completed NREP payload assembly to the Caro Mission Contracts area for incorporation into its final stowage configuration.

3.2.3 Launch

Cargo Missions Contract is responsible for delivering the final stowed configuration to the appropriate launch site facility and integrated into the ISS visiting vehicle.

3.2.4 On-Orbit operations

3.2.4.1 Payload Destow

Once the launch vehicle is on orbit and berthed, the crew is responsible for transferring the payload and placing it in the appropriate on-orbit stowage location until it is time deploy the payload.

3.2.4.2 Payload assembly

Once NASA schedules the payload deployment window (subject to various constraints such as visiting vehicles, crew time, etc.) the on-orbit crew is responsible for unpacking the payload and installing it onto the NREP Experiment Plate. The NREP with payloads will then be installed onto the JEM Airlock Slide Table for external deployment.

3.2.4.3 JEM Operations

The JEM operations are managed by JAXA controllers. The air lock slide table retracts into the JEM airlock. The inner door is closed and the airlock is depressurized. The JEM airlock outer door is opened and the table is transitioned outside the JEM module to be accessed by the JEMRMS. Figures 3.2.4.3-1 through -3 provide an overview of the components and location on ISS.

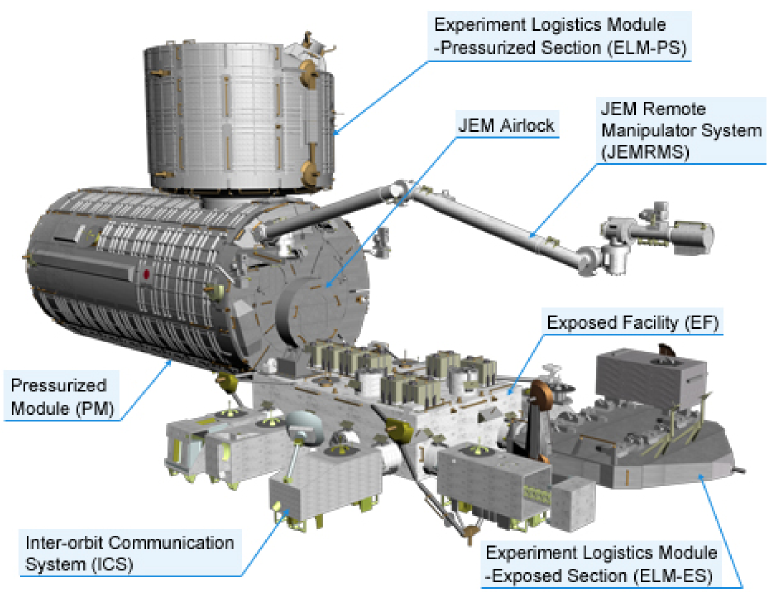

Figure 3.2.4.3-1: JEM Exposed Facility

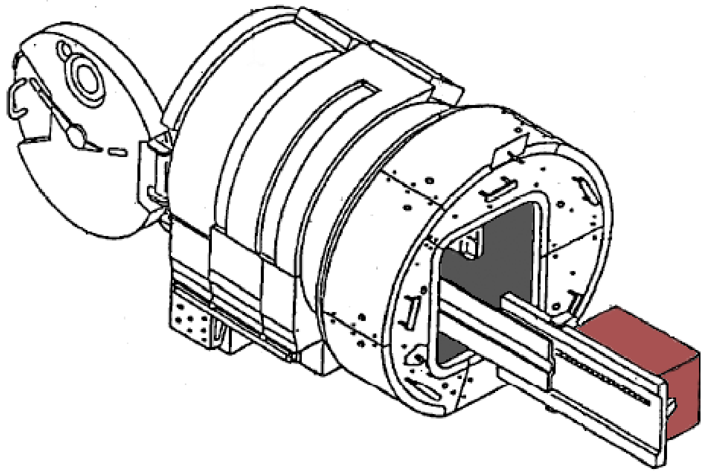

Figure 3.2.4.3-2: JEM Slide Table

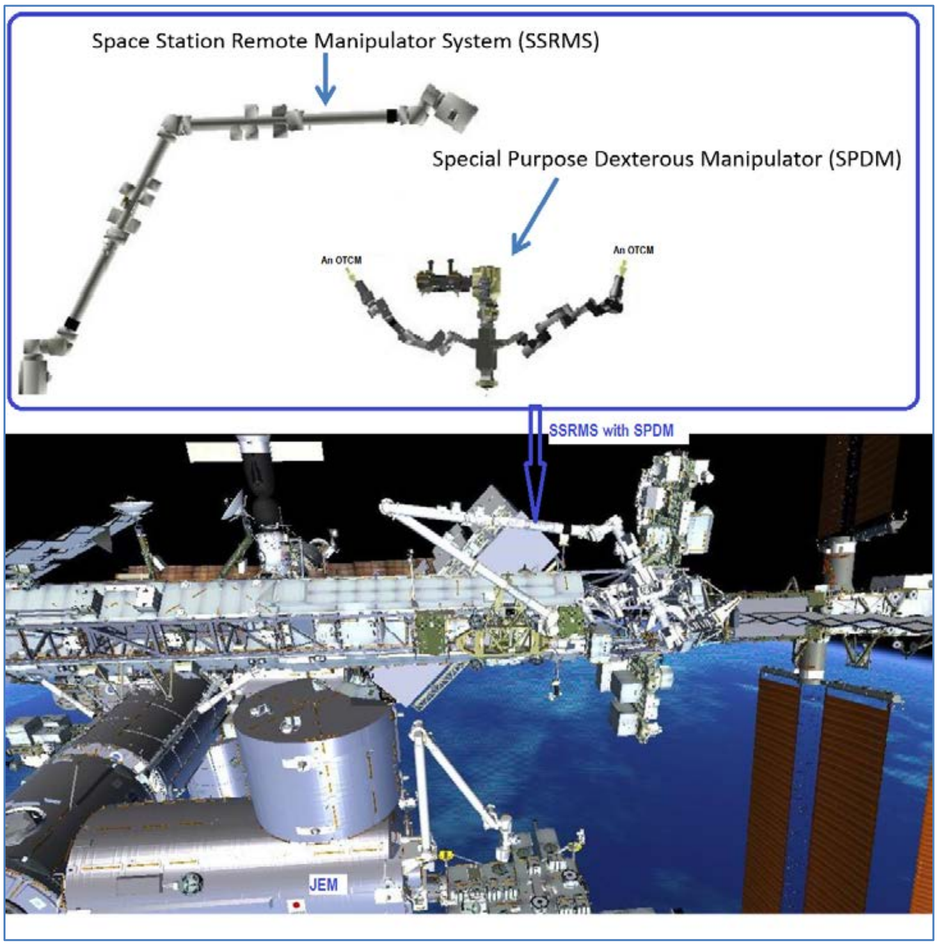

Figure 3.2.4.3-3: View of SRMS with SPDM OTCM in Relation to JEM

3.2.4.4 EVR Operations

The JEMRMS grapples the Nanoracks Experiment Plate by the Flight Releasable Grapple Fixture (FRGF) and translates the NREP to the JEM-EF EFU site.

3.2.4.5 Experiment Operations

Experiment operations are performed by Nanoracks operations personnel from the Nanoracks control center (the BRIDGE) in Webster, TX. The payload developer does not typically have direct access to control the payload on-orbit except in off-nominal cases for troubleshooting purposes.

During the experiment deployment, the user can update his experiment via file uplink. Frequency and lead-time for updates will be defined in the ICA. During and after the experiment deployment, the NREP-P provider will receive its data in a format and according to a schedule as defined in the NREP-P ICA. If parts of or the complete NREP-P need to be returned to the ground, this will be defined in the ICA.

3.2.4.5.1 Ground to Payload Communication

There are two separate command and data paths between the ground and the NREP (and hence, the NREP-P payloads). The standard ISS Command and Data Handling (C&DH) path is utilized by Nanoracks operations to send commands and receive health and status telemetry from NREP and NREP-P payloads. The ISS Joint Station LAN path will be used to downlink payload generated files using internal Nanoracks platforms. This network can also provide MRDL telemetry streams that can be used to downlink live streaming of payload data.

3.2.4.5.2 Data Streaming

The NREP provides two MRDL telemetry streams that may be shared by all payloads. The NREP DHS multiplexes incoming UDP data packets from multiple payloads in such a way that the Nanoracks Ground Facility can de-multiplex them into separate data streams, addressed to payload owners. In the current NREP DHS version, incoming packets are limited to 1484 bytes. The NREP also supports up to 5 configurable streaming destinations (by IP address/port), which can, e.g., be set up in such a way that they correspond to configured Nanoracks internal platforms and/or Ku-band IP based services. This service is typically more complex to configure and set up, so Nanoracks recommends only using data streaming when absolutely required for real-time data; nominally, Nanoracks recommends the use of log files to be downlinked for health & status monitoring.

4 Payload Interface Requirements

The requirements contained in this section will be complied to certify a payload for integration into NREP as well as the ISS JEM module. This section is divided by the following disciplines: Structural, Electrical, Command and Data Handling, Thermal Control, Vacuum, Safety and Human Factors

4.1 Satellite Payload Structural Requirements

4.1.1 NREP-P Attachment to Experiment Baseplate

All small standard and non-standard payloads shall utilize captive and of hex socket (Allen) type fasteners. For positive fastener locking the bolts shall be equipped with locking features (e.g., according to NAS1283 type P). Two fastener locations are provided per 100mm payload length. A payload provider with a 2 U or larger payload might opt to not use all available positions; however, a minimum of 4 fasteners is required. Large non-standard payloads shall provide for a bolted attachment identical to the Experiment Baseplate. The fasteners shall be captive and have an M6 thread. The bolts interface with self-locking nut-plates so the bolts do not need their own locking feature.

4.1.2 NREP-P Soft Dock Feature

All standard and non-standard payloads shall provide a soft dock feature. Reference Figures in section 4.1.4.1 for examples of standard and alternative soft dock features. Large non-standard payloads achieve soft dock through holes that interface to pins with spring loaded balls.

4.1.3 NREP-P Bonding to Experiment Baseplate.

The payloads shall provide for structural bonding to the designated bonding areas shown on the Experiment Baseplate as identified on Figures 4.1.1-2 and 4.1.1-3. An example of a bonding tab is shown in Figure 4.1.3-1. For large non-standard payloads, the payload shall provide for a nickel-plated surface at the interface to the NREP structure for faying surface bonding.

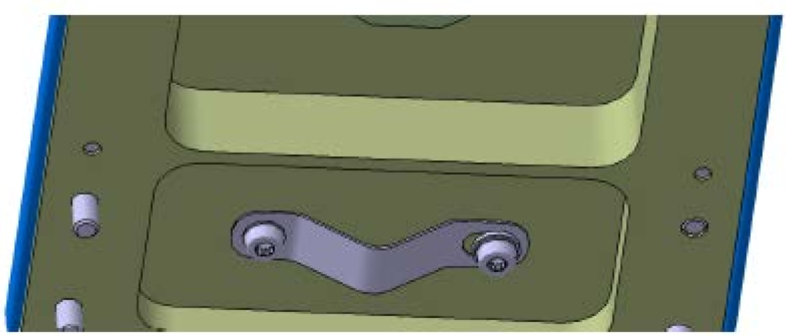

Figure 4.1.3-1: Example of a Bonding Tab

4.1.4 Payload Envelope for Standard and Small Non-Standard Payloads

The NREP allows for various configurations with different standard sizes of payloads. An example is shown in Figure 4.1.4-1. Figures 4.1.4-2 and 4.1.4-3 show the interface points for payload attachment to the top and the bottom of the Experiment Base Plate and the location of the payload interface connectors. The shaded areas indicate the footprint of a standard 4U payload. Figure 4.1.4-4 details the geometric constraints on the height of payloads attached to the top side and bottom side of the plate.

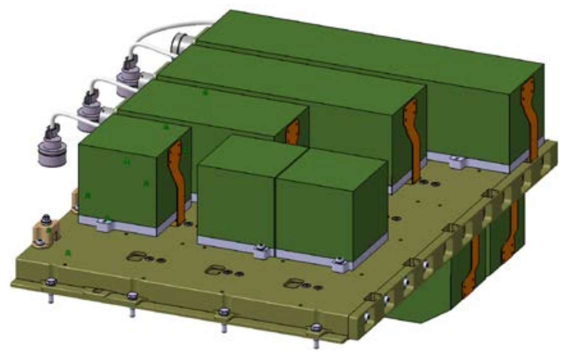

Figure 4.1.4-1: Payload Configuration Example (view from bottom)

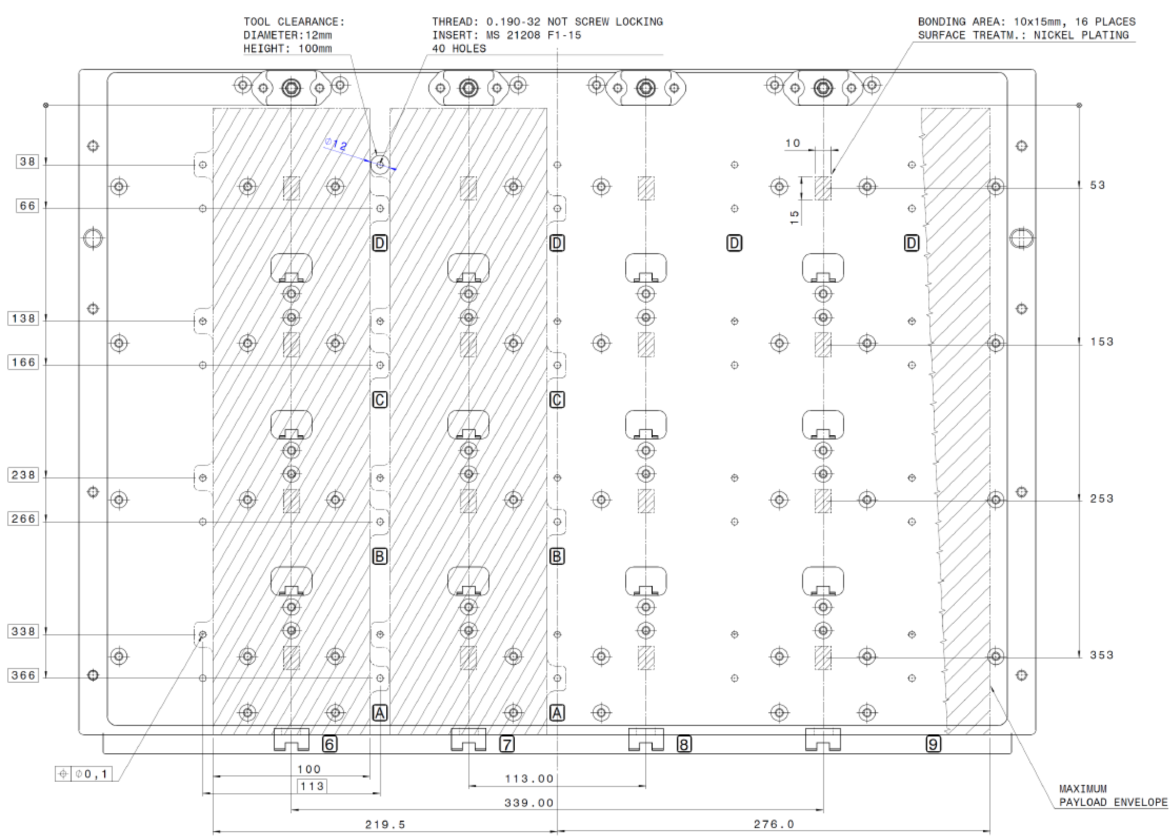

Figure 4.1.4-2: Experiment Baseplate Interfaces on Top Side

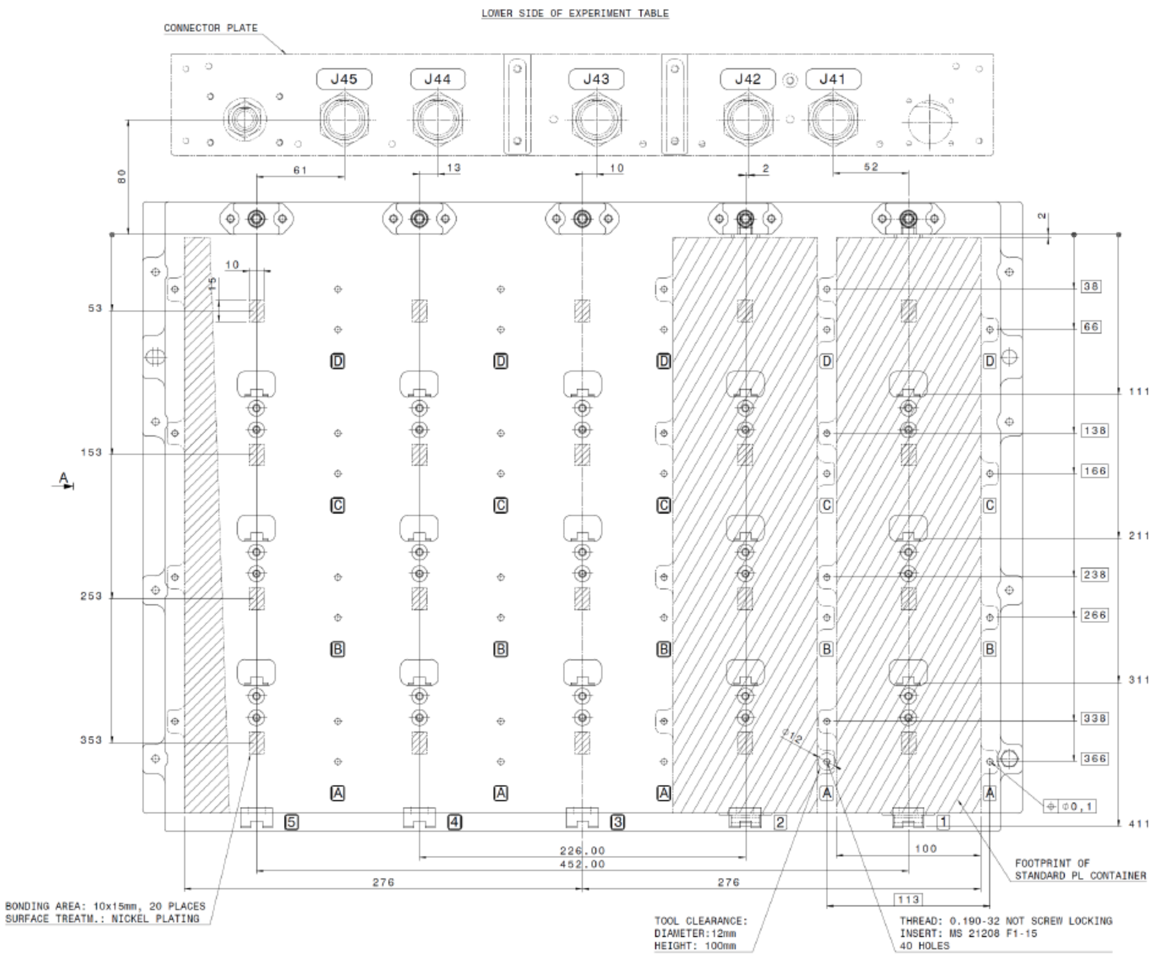

Figure 4.1.4-3: Experiment Baseplate Interfaces on Bottom Side

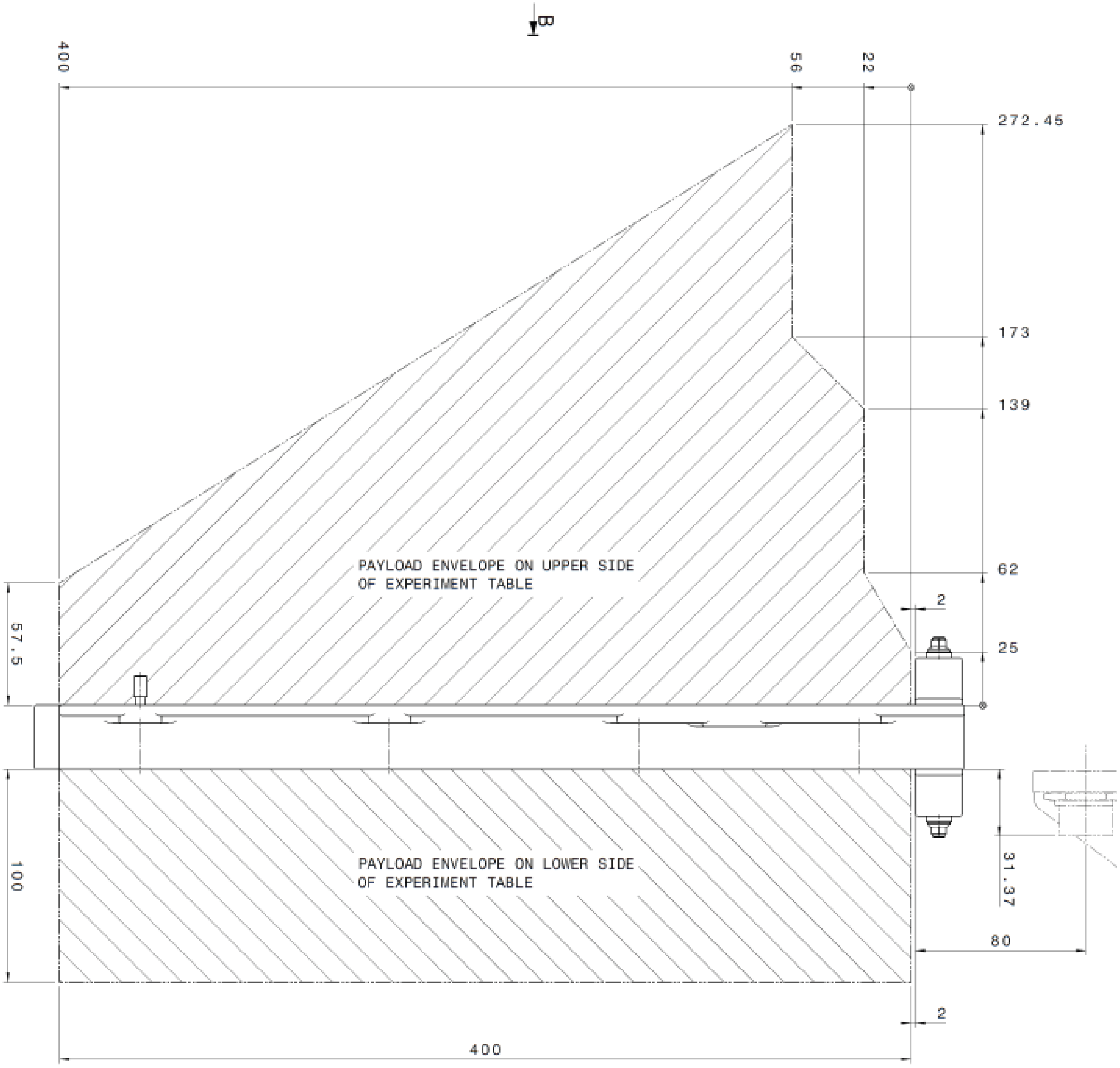

Figure 4.1.4-4: Payload Envelope – Side View

4.1.4.1 Payload Envelope for Standard Payloads

Standard Payloads have a width and a height of 100 mm and a length from 1U (=100mm) up to 4 U (=400mm). Figures 4.1.4.1-1 through 4.1.4.1-5 show the dimensions for the standard payloads.

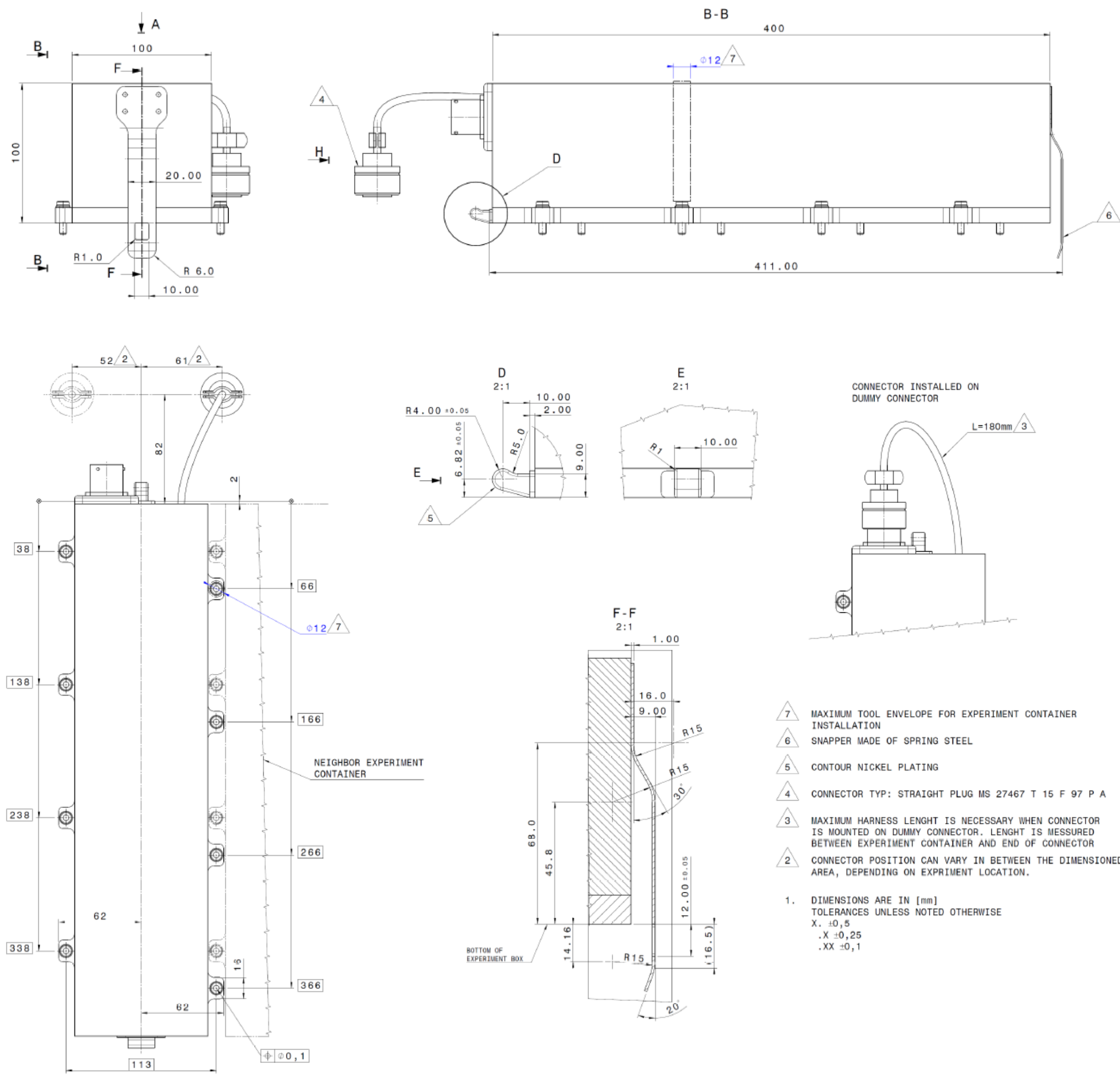

Figure 4.1.4.1-1: Bottom mounted 4U Standard Payload including soft-dock feature

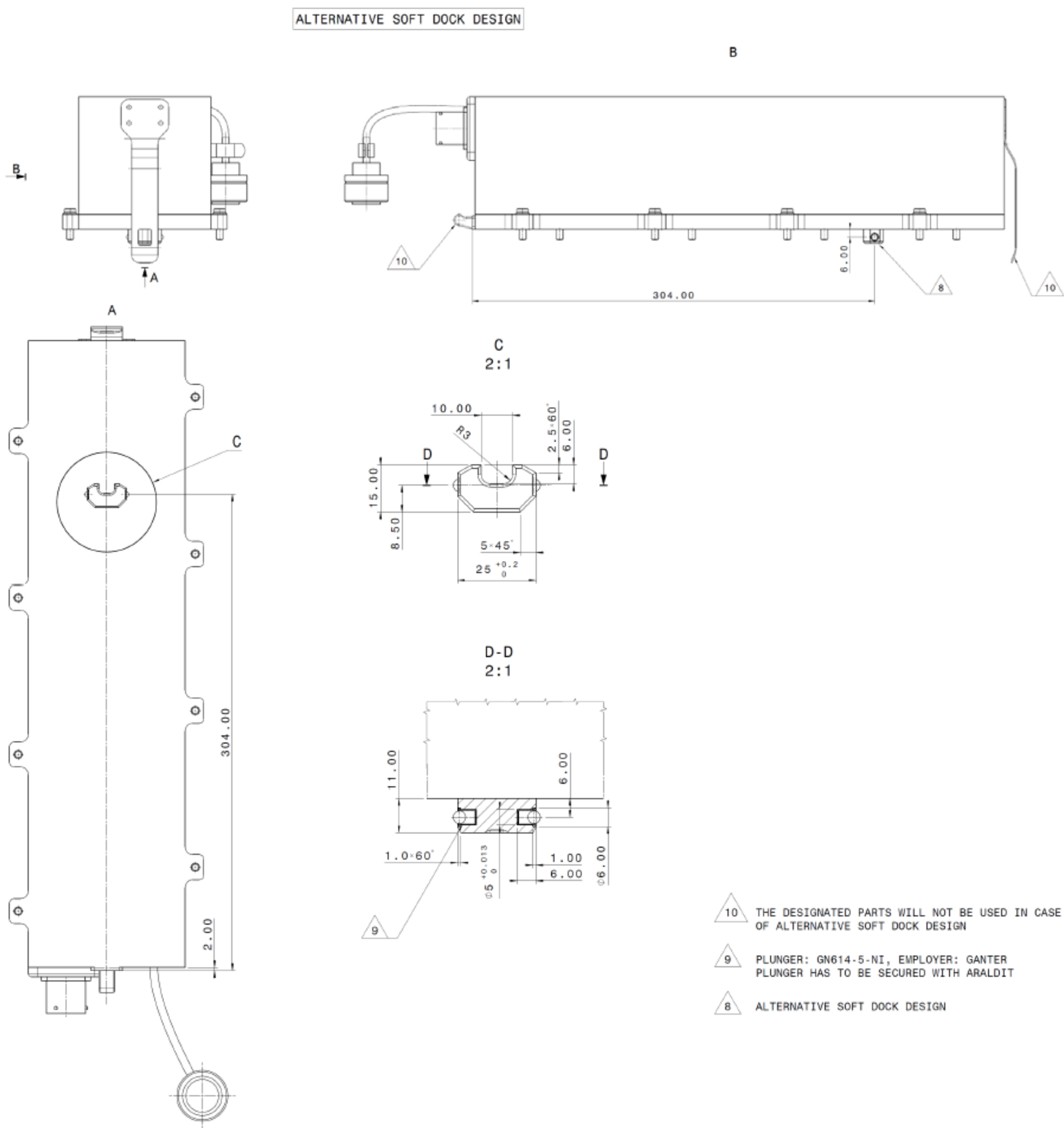

Figure 4.1.4.1-2: Bottom mounted 4U Standard Payload including alternative soft-dock feature

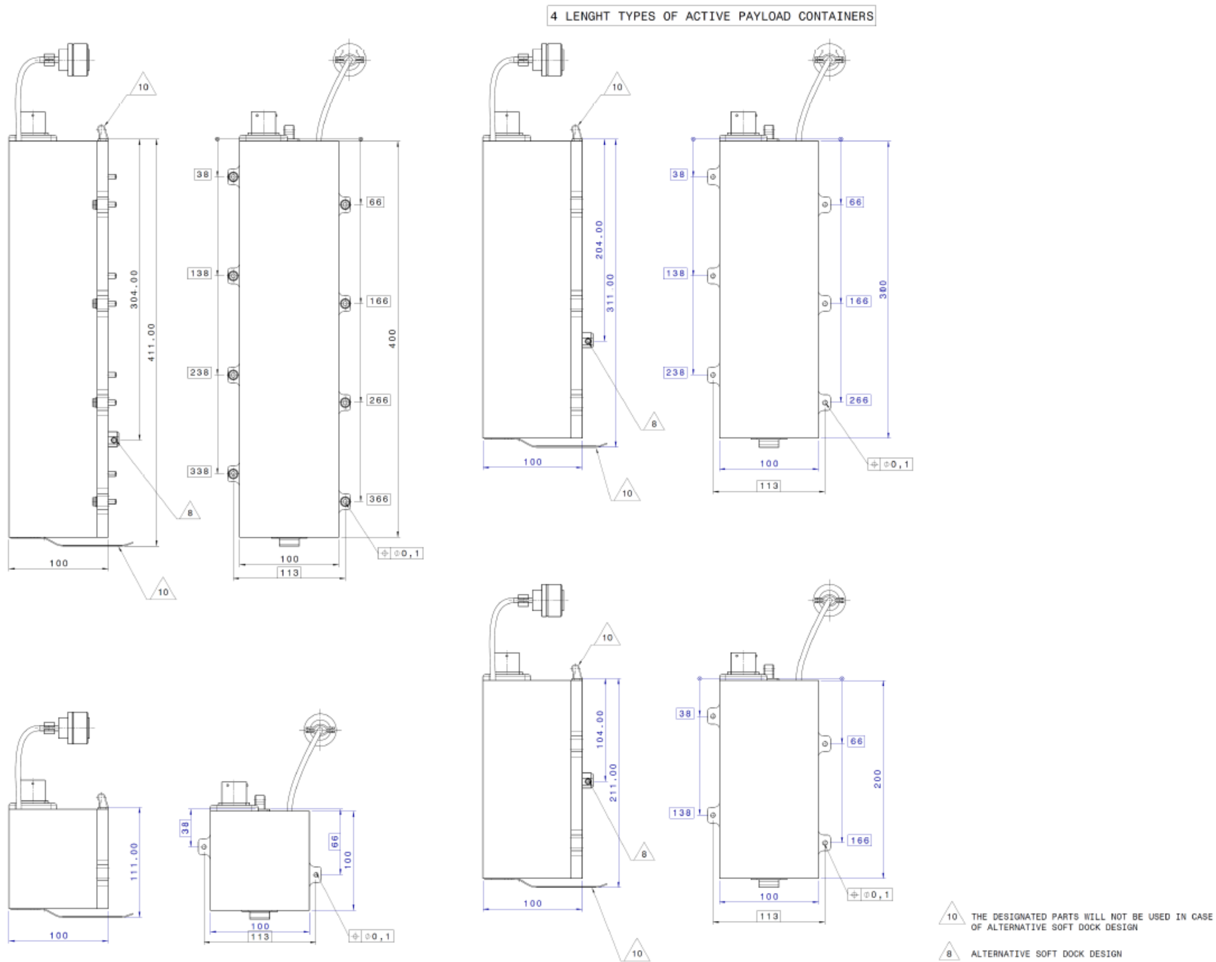

Figure 4.1.4.1-3: Dimensions for different bottom mounted payload sizes.

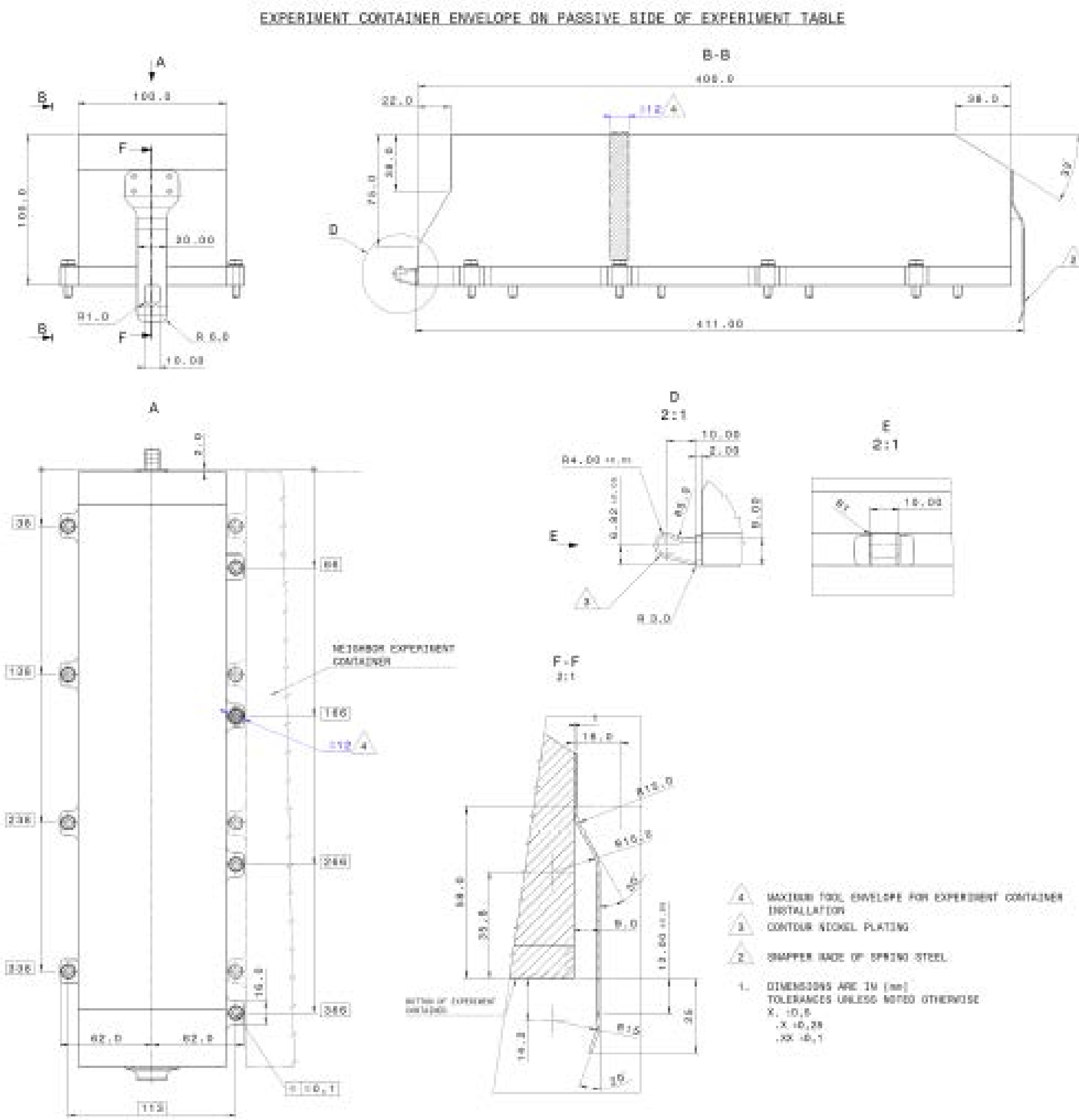

Figure 4.1.4.1-4: Top mounted 4U Standard Payload including standard soft-dock feature

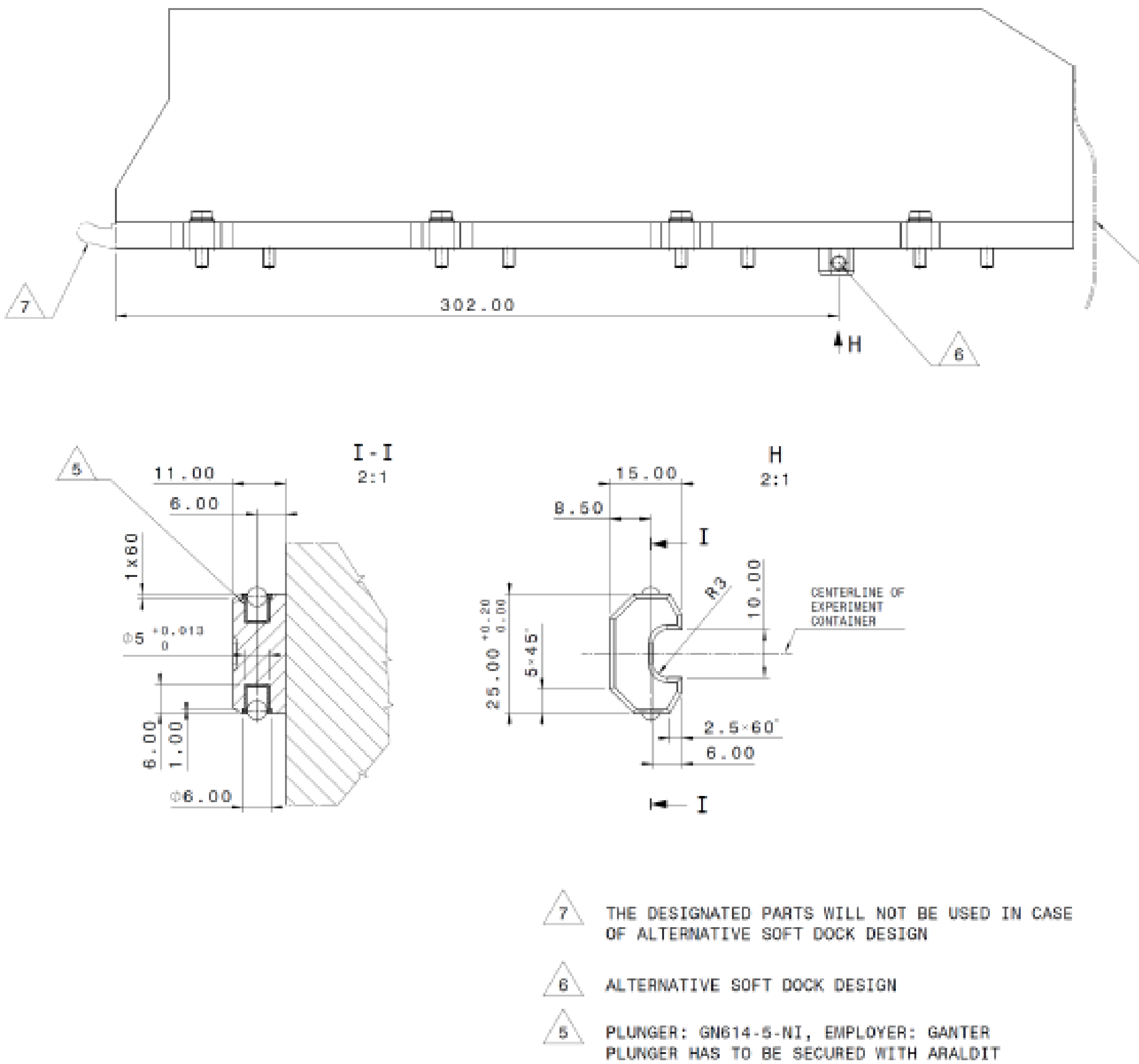

Figure 4.1.4.1-5: Top mounted 4U Standard Payload including alternative soft-dock feature

4.1.4.2 Payload Envelope for Non-Standard Payloads

Payloads with non-standard sizes may either use the available attachment interfaces and volume on the Experiment Base Plate (as described in Figure 4.1.4-2 through Figure 4.1.4-4) or, in case of large payloads they may use the entire available volume (see Figure 4.1.4.2-1).

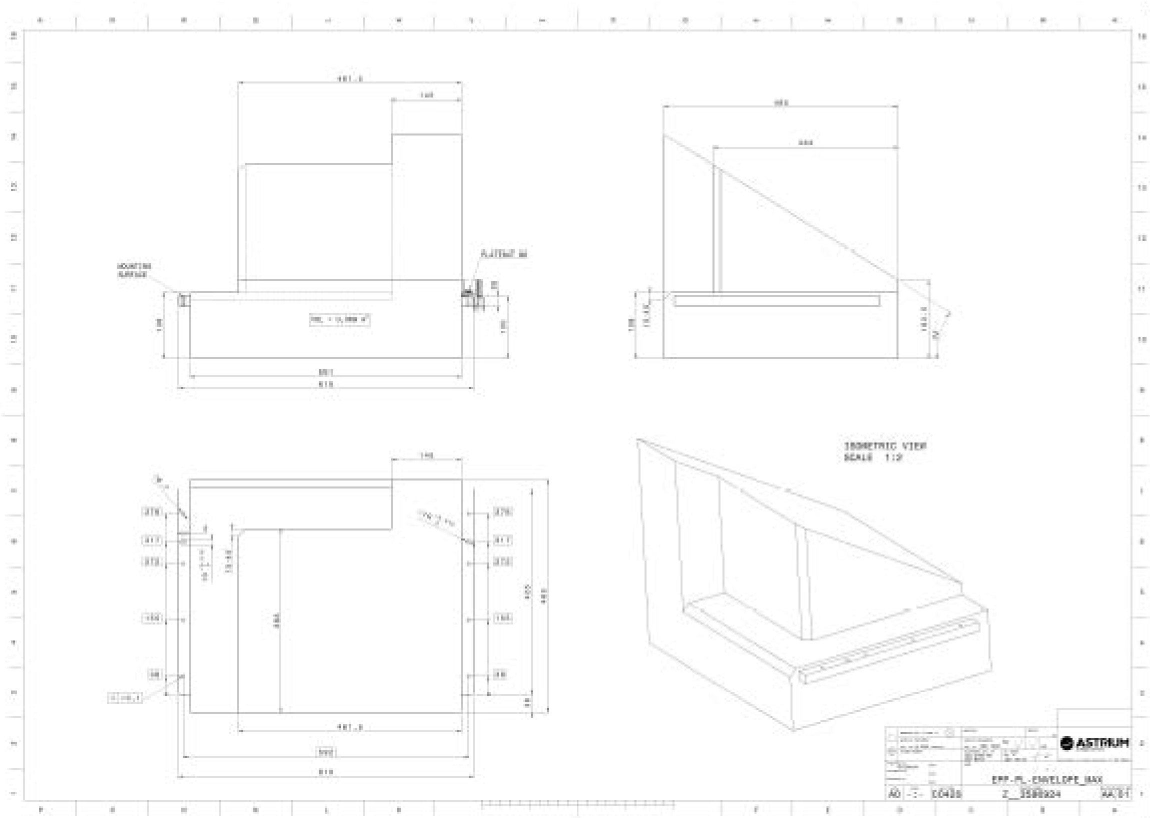

Figure 4.1.4.2-1: Payload Envelope for Large Non-Standard Payloads

4.1.5 Mass Properties

The maximum gross NREP payload mass capacity is as follows. For NREP-P 4U (Standard Payloads), the nominal mass is 4kg. Any larger mass will need to be negotiated. The total NREP-P base-plate capacity is 35 kg.

4.2 Satellite Electrical and Data Interfaces

Electrical services are available via 5 NREP payload interface connectors. The connectors are located at the rear side of the baseplate. The interface to the payload provides a switchable 28 VDC power outlet with a maximum power of 50 W @ 28 VDC. Additionally, a 5 VDC power supply is provided with the USB 2.0 data bus. The maximum current is 500 mA. The 5 V power is non switchable and available while the DHS is powered. Details about the maximum available 28 VDC power is defined and documented in the NREP payload-specific ICA.

Where required, additional NREP non-standard services, such as 120 VDC power interface, can be provided and are defined and documented in the NREP payload-specific ICA.

4.2.1 Electrical Provisions – 28V DC

4.2.1.1 Constraints – 28V DC

The NREP provides bracket-mounted connectors for up to 5 payloads. Each connector provides 28 VDC power and a USB 2.0 data interface including a separate non-switchable 5 V/500 mA bus power. The 28 V DC NREP electrical receptacle interface is defined in Table 4.2.1.1-1. The specification of the interface connector is provided in Table 4.2.1.1-2.

Table 4.2.1.1-1: Receptacle Interface Definition – 28V DC and USB

Designation: J41….J45 Signals: NREP-P Power and USB Lines Location: NREP						
Pin No.	**Signal Name**	**Contact Size**	**Wire Size**	**Class**	**Voltage Level**	**Max. Current**
C	Power +	16	16 STP		28 VDC	2 A
M	Power Return	16	16 STP		0	
G	Ground	16	16 HUW		0	
L	Spare	16				
A	USB data +	20	24 STP			
B	USB data -	20	24 STP			
K	USB DATA SHLD	20	24 STP			
J	USB PWR SHLD	20	24 STP			
D	USB PWR +	20	24 STP		5 VDC	500 mA
E	USB PWR -	20	24 STP		0	
F	PWR SHLD	20	16 STP			
H	Spare	20				

Each payload that requires power and data interfaces has to provide a harness pigtail with the specified connector. The standard exposed length of the cable shall be 180 mm with any non-standard sizes documented in the ICA. The wire size inside NREP-P shall be at least 20 AWG up to an internal fuse. Each NREP payload shall provide a dummy connector to hold the connector cap of the NREP power outlet while the NREP payload is attached to the NREP.

Table 4.2.1.1-2: Connector Specification

Designation	Description	Nomenclature	Quantity	Size
J41..J45	Jam Nut Receptacle	MS 27468 T 15 F 97 S A	5	15
P1	Straight Plug	MS 27467 T 15 F 97 P A	5	15
-	Contacts		4	AWG 16
-	Socket		4	AWG 16
	Contacts		8	AWG 20
	Socket		8	AWG 20
	Back Shell	MS 27506 F 14 2 (or AS85049/49-2S14N or AS85049/121@14N)	5	

4.2.1.2 28 VDC Power Characteristics

The payload shall be compatible with the defined standard 28 VDC power outlet characteristics:

Voltage range: 28 V +/- 2V

Transient over-voltage: 40 V

Nominal power: 30 W at 28 V

Maximum current: 2 A

Over-current protection: 4.8 A, trim time 2ms

4.2.1.3 5 VDC USB Power

The 5 VDC USB power is specified according to the USB 2.0 High Power standard, allowing a maximum current draw of 500 mA. The power is permanently applied on the NREP side; however, to be able to control all power draw by a payload, the payload is required to inhibit any 5 VDC USB power draw while the 28 VDC power is not applied.

Figure 6.2.1.3-1 shows a possible implementation of payload power control. The two shown relays inside the payload, Relay 1 and Relay 2, both default to an "off" position. Relay 1 is activated by the external 28 VDC power and connects the 5 VDC USB power. Relay 2, an optional means to control power to the actual experiment, is controlled by software (default "off", may be commanded to "on" or back to "off").

A payload that uses only the 5 VDC/500 mA USB power shall switch that power draw based on the presence or absence of the 28 VDC power. Conversely, a payload that does not use USB power at all does not have to take measures to disconnect it.

Analogous to the USB power control requirement, an internal payload is also required not to show USB data activity while the 28 VDC power is off.

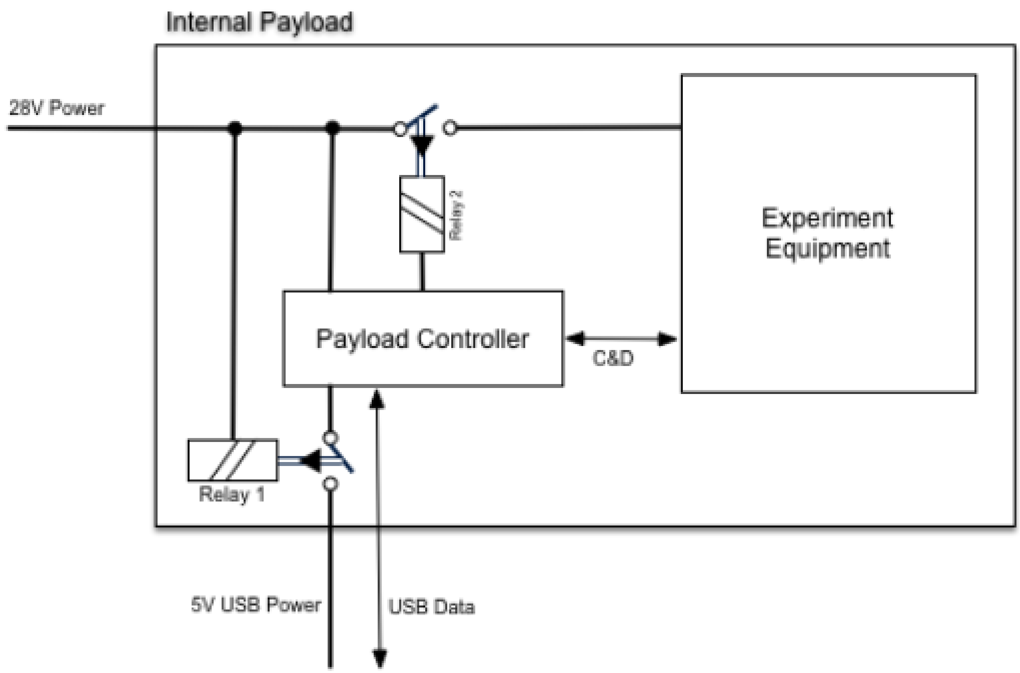

Figure 4.2.1.3-2: Payload Power Control

4.2.1.4 Electrical Provisions – 120 VDC

120 VDC electrical power is a non-standard service and shall be defined and documented in the payload-specific ICA.

4.2.2 Electromagnetic Compatibility

The NREP-P electrical grounding shall be in accordance with SSP 30240, paragraph 3.2.

4.2.2.1 Electrical Grounding

The NREP-P shall be electrically bonded to the NREP base plate per SSP 30245, Space Station Electrical Bonding Requirements, paragraphs 3.2 and 3.3.

4.2.2.2 Payload Surface Electrostatic Charging

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

4.2.2.3 Insulated Materials

Hardware consisting of or containing low-conductivity material shall be bonded in accordance with SSP 30245, Section 3.3.4.3.2.

4.2.2.4 Radiation Emissions

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

4.2.3 Command and Data Interfaces

The communication path, between the NREP and the ground, is used by the operators at the Nanoracks ground facility, to control and configure the NREP DHS itself, including all internal payloads and shared resources, such as data streaming destinations.

The data downlink along this path includes Health and Status monitoring data for the NREP DHS and all its payloads using the ISS's standard low-rate MIL-1553B data bus, plus additional telemetry data streams using the (faster) Medium Rate Data Link (MRDL), some of which are exclusively used by the NREP DHS itself, and some shared by the NREP-P payloads.

The NREP C&DH interface also includes file transfer capabilities directly between the ground and the NREP DHS (and from the to/from NREP-P payloads in a second step), or between the NREP DHS and the Nanoracks internal platforms on orbit.

NREP-P payload owners do not have direct access to this command interface but may receive data from the Nanoracks ground facility, in the form of (a) streaming Health and Status data, derived from NREP Health and Status information filtered by payload, and (b) telemetry data related to their payload, de-multiplexed from the NREP telemetry streams.

4.2.3.1 NREP DHS to Payload Software Interface

This section describes the software interface between the NREP DHS and the NREP-P payloads. Adherence to the required and optional interfaces described here is essential for the successful and safe operation of NREP 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.

An NREP internal payload is connected to the NREP Data Handling System (DHS) via a USB port, where the DHS is the USB host, and the internal payload is the USB client. The NREP DHS supports USB 2.0, with backward compatibility for USB 1.1 devices. All connected USB 2.0 devices share the theoretical USB 2.0 bandwidth of 480 Mbps, i.e., if more than one USB 2.0 device is connected, the full USB 2.0 bandwidth will not be available.

If the payload's 28 VDC power is not applied to a payload, the payload is also not allowed to draw 5 VDC power on its USB port. It should be in a completely passive state and should not show any activity on the USB port.

Once the 28 VDC power is applied, as the payload starts up, it will advertise its device class(es) over the USB port, so that the communication between the NREP and the payload can begin.

To accommodate payloads with a wide range of capabilities and computing resources, from simple microcontrollers to more complex networking-capable payload controllers, the NREP DHS supports USB device classes of varying complexity.

In the simplest case, an internal payload must implement a very basic RS-232 style serial communication protocol over USB, to receive simple commands from the DHS and return simple status messages.

Payloads with more advanced internal computing capabilities will be able to use TCP/IP networking over USB, for which the NREP DHS provides automatic network configuration by DHCP, NTP for time synchronization, FTP for file transfer, and telemetry streaming options.

A payload may also advertise itself as a USB mass storage device for (limited) data transfer.

4.2.3.1.1 CDC Abstract Control Model (Serial Communication)

For basic commanding and monitoring, an internal payload is required to implement a USB serial communications device (CDC Abstract Control Model subclass, see RD 2.2.2).

The NREP DHS will use the resulting virtual serial port for sending commands to and receiving status messages from the payload (see sect. 11.3.1 for details).

The serial port configuration will be set to 57,600 bd, with 8 data bits, no parity, and 1 stop bit. Upon connection to this device class, the NREP DHS will establish a serial communication channel to the internal payload, which is maintained if the payload is powered. For commanding and status collection purposes, each internal payload is required to provide one and only one CDC ACM device.

4.2.3.1.2 CDC Ethernet Control Model (Networking)

Optionally, an internal payload may implement a networking device (CDC Ethernet Control Model subclass, see RD 2.2.3). A payload implementing this device class must configure its network interface in compliance with settings defined in the NREP-P ICA. The provided router address will be the internal subnet interface of the NREP DHS, which is also the host address for DHS services (telemetry, sect. 11.3.4, and network time, sect. 11.3.5).

Each payload may connect up to 5 internal networking devices, each of which will receive a predefined IP address on a separate subnet. All payload networking devices can communicate with each other as well as with external hosts (e.g., for file transfer or data streaming), using the NREP DHS as their default router.

On the NREP DHS side, the CDC ECM communication is handled by the Linux usbnet framework (RD 2.2.5), which is also recommended for internal payload controllers based on Linux 2.6 or later.

4.2.3.1.3 Mass Storage Device Class

Optionally, a payload may implement the Mass Storage device class (see RD 2.2.4). Upon connection of a Mass Storage Device with a supported file system type, the NREP DHS will mount the file system as an external drive. Supported file system types are Fat16, Fat32, ext2fs, ext3fs.

Note that while a Mass Storage Device is mounted by the NREP DHS, the payload is not allowed to modify the content of the provided file system in any way. Only the NREP DHS is allowed to write to a mounted file system. For this reason, using the Mass Storage Device class for an internal payload is only of limited value, as there is no way of un-mounting in a controlled way. The handling of mounted Mass Storage Device file systems by the NREP DHS (e.g., mount points, pathnames) needs to be documented in the Interface Control Agreement.

4.2.3.2 Commanding

The NREP DHS provides the capability to send commands to an internal payload. Most commands originate from commands that the payload operator on the ground sends to the NREP DHS via ISS commanding channels (operator commands). Only the Status command (11.3.1.1) is sent autonomously by the NREP DHS to request the status of an internal payload.

The serial communication channel (sect. 11.2.1.1), which is mandatory for all internal payloads, is used to send commands to the internal payload. The communication is always initiated by the NREP DHS by sending an ASCII <ESC> (0x1B) character, which is used for synchronization; i.e., the payload is expected to discard any characters received before the first <ESC> character. The <ESC> character is followed by a command consisting of a single command character, followed by command parameters as described below. Each command ends with an ASCII <LF> (0x0A) character.

For the Status command (11.3.1.1), a status response in a defined format is expected; for all other commands (operator commands), the payload is expected to send either one of the following:

OK[:<description>]<LF> in case of successful execution

NOK[:<description>]<LF> in case of unsuccessful execution

It is strongly recommended to provide a <description> string, in particular for negative responses. If an optional1 <description> string, separated by a colon (‘:’), is provided, it will be echoed in the Health & Status payload status message field (up to 32 characters, see 11.3.2; i.e., any response characters past the 36th character will be discarded).

An ASCII <LF> (0x0A) character delimits the payload response.

In general, the DHS to payload communication is synchronous. The DHS will not send another command until a response from the payload has been received. Payload responses are, however, expected to be received completely (including the terminating <LF>) within 5 seconds; otherwise, the NREP DHS will time out and report an error. Therefore, potentially time-consuming operations should be acknowledged first and then executed asynchronously; the completion of an asynchronous operation and its success or failure may be reported in the payload’s status message in response to the Status command.

When a payload receives an <ESC> character before sending its own response, it must assume that a timeout has occurred and should suppress its not yet transmitted response in order to re-synchronize with the DHS.

A deviation from the synchronous command/response pattern is possible during a Transmit operation over the serial connection (11.3.1.4), to allow the DHS to abort a file transfer.

4.2.3.2.1 S: Status Command

Description

The status command is sent periodically (nominally once per second) by the NREP DHS to collect status information from each internal payload. Status data collected by the Status command will be reported in the NREP Health & Status (H&S) data (sect. 11.3.2).

Additionally, the Status command is time-tagged, to allow an internal payload to synchronize its own time base with the NREP DHS system time (see also sect. 11.3.5).

Syntax

S<timestamp><LF>

<timestamp> extended ISO 8601 format with UTC time zone and second fraction (see 11.3.5 for an example); reflects the current DHS system time at the moment that the Status command is sent.

Payload Response

The internal payload responds with a ASCII status string of the following syntax:

<payload-ID>:[<temp-1>]:[<temp-2>]:[<current-1>]:[<current-2>]:<status-code>:[<status-msg>]<LF>

with the following field definitions:

<payload-ID> a string of up to 8 characters identifying the payload (not containing a colon)

<temp-[1|2]> temperature measurements in oC in the range [-128..127] (integer)

<current-[1|2}> electrical current measurements in mA in the range [0..65535] (integer) (Note: the actual maximum sustained current per payload is 2 A.)

<status-code> payload specific status code, range [2..255] (integer; 0 and 1 are reserved)

<status-msg> free-form message string extending from the 6th colon to the terminating <LF>; up to 32 characters

All numeric fields shall be represented without blanks or leading zeros, to keep the response length to a minimum. Hence, the maximum useful response length will be 67 characters. Excessive responses may be truncated by the DHS.

Empty strings between colons denote measurements that are not provided by the payload (in general or temporarily). The last known value for not provided measurements, if any, will continue to be reported in the NREP H&S data; the initial value for all fields is zero.

Status code and status message are payload specific and not interpreted by the DHS, only reported.

The status message included in the payload H&S data (11.3.2) is shared by Status command responses and operator command responses (any string returned with an OK or NOK response). It will be updated only whenever a non-empty status message is received from the payload; otherwise, the last received message will be retained in H&S. Since the Status command is sent once per second and might overwrite a previous message, such as an operator command response, it is suggested to normally return an empty <status-msg> unless a noteworthy event occurs, such as the completion of an asynchronous operation. This will allow the operator more time to read a previous command response.

Example

ABCrystl:-4:12:1560::2:file transfer complete<LF>

Meaning:

<payload-ID> ABCrystl

<temperature-1> –4 oC

<temperature-2> +12 oC

<current-1> 1560 mA

<current-2> (not provided by payload)

<status-code> 2 (payload specific – 2 could mean “success”)

<status-msg> “file transfer complete”

4.2.3.2.2 N/O: Internal Power Commands

Description

A payload may contain an optional internal switch to control the 28 VDC power to its experiment equipment (see Figure 6-1). The Internal Power commands are used to control this internal switch, if available.

For a payload that does not contain the optional switch, the payload response should be NOK.

Syntax

N<LF> turn on internal 28 VDC power switch

O<LF> turn off internal 28 VDC power switch

Payload Response

OK[:<description>] power switching successful

NOK[:<description>] power switching failed

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4.2.3.2.3 W: Warmboot Command

Description

Upon receipt of the Warmboot command, the payload is expected to reset/reinitialize itself to a defined, initialized state (details are up to the payload).

Syntax

W<LF>

Payload Response

OK[:<description>] Warmboot command received, reset about to occur

NOK[:<description>] Warmboot command rejected (a reason should be given)

After an OK, the payload should perform a reset/re-initialization, during which the serial connection may drop. Disconnection and re-connection will be reflected in H&S data.

4.2.3.2.4 T: Transmit File Command

Description

The Transmit File command instructs the payload to transmit a specified file to the NREP DHS through the serial connection, using the Intel HEX format (RD 2.2.6).

Syntax

T<filename><LF> command the payload to transmit the file named <filename>

Payload Response

Upon receipt of the Transmit File command, if the request cannot be satisfied (e.g., file not found, or feature not supported), the payload responds NOK[:<description>].

Otherwise, the payload starts sending the file content across the serial connection using the Intel HEX format.

At any point during the transmission, the DHS may send an Abort command (11.3.1.9), upon which the payload should end the transmission.

After the file transfer finishes (either normally or aborted), the payload outputs a final

OK[:<description>] or NOK[:<description>] message.

At any point during the transmission, up to and including the final OK/NOK, the DHS will consider the transmission failed after a 5 second period of inactivity of the payload.

See sect. 11.3.3 for general file transfer considerations.

4.2.3.2.5 R: Receive File Command

Description

The Receive File command instructs the payload to receive a specified file from the NREP DHS through the serial connection, using the Intel HEX format (RD 2.2.6).

Syntax

R<filename><LF> command the payload to receive the file named <filename>

Payload Response

After sending the Receive File command, the NREP DHS will start sending the file content across the serial connection using the Intel HEX format.

At any point during the transmission, the payload may send NOK[:<reason>] if it encounters a problem (invalid file path name, not enough space, feature not supported), upon which the NREP DHS will abort the file transfer and report the error condition. In such a case, it is recommended that the payload provide a <reason> for the NOK.

Upon receiving an abort command from the ground operator during an ongoing file transfer, the DHS may abort the transfer by sending the Abort command (11.3.1.9) to the payload instead of the next line of the Intel HEX protocol. In this case, the payload should abort the receiving process and discard or disregard the partially transferred file.

After the file transfer finishes (either normally or aborted), the payload reports overall success and/or failure by responding OK or NOK[:<reason>], which is then reported by the NREP DHS.

If the final OK/NOK is not received from the payload within 5 seconds of the end-of-file record, the DHS will consider the transmission failed.

See sect. 11.3.3 for general file transfer considerations.

4.2.3.2.6 P/G: FTP File transfer Commands

Description

The FTP File Transfer command instructs a payload that supports a USB network interface (see 11.2.1.2) to perform a file transfer to/from a specified server using the FTP protocol.

Syntax

Instruct payload to perform an FTP "get" operation:

G<server-address>:<port-number>:<username>:<password>:<folder>:<filename><LF>

Instruct payload to perform an FTP "put" operation:

P<server-address>:<port-number>:<username>:<password>:<folder>:<filename><LF>

Parameters for both commands:

<server-address> IPv4 address of an FTP serve

<port-number> the port number to be used for FTP

<username> the username to be used for logging into the FTP server

<password> the password to be used for logging into the FTP server

<folder> target directory name (potentially an empty string) on the FTP server

<filename> the file/pathname to be used on the payload

Payload Response

The internal payload acknowledges receipt of the command (not completion) by responding OK or NOK[:<reason>] (e.g., unsupported feature). If the response was OK, the payload is expected to initiate the actual file transfer asynchronously and report the final success or failure to the operator in the payload status message (in response to the Status command, 11.3.1.1).

The NREP DHS does not monitor the progress and finalization of FTP transfers by the payload.

If the ground operator, via the DHS, sends an Abort command (11.3.1.9) while an FTP transfer is still ongoing, the payload should abort the FTP transfer.

See sect. 11.3.3 for general file transfer considerations.

4.2.3.2.7 D: Data Streaming Command

Description

The Data Streaming command informs a payload that supports a USB network interface

(see 11.2.1.2) of a server, port, and protocol to be used for data streaming.

Up to 4 data streams, identified by a <format-ID>, are supported per payload, which can be controlled separately. If only the <format-ID> is given, followed directly by <LF>, the payload must stop the specified data stream.

The <data-rate>, in kB/s, must be implemented by the payload to ensure flexibility when streaming data and minimize risk of packet dropouts due to bandwidth issues.

If payload is dependent on time stamps as part of the data streaming, the payload must include the NREP DHS distributed time in it's raw data stream. Payload cannot depend on Nanoracks ground operations to provide time stamps outside of the payload data stream.

Syntax

D<format-ID>[:<server-address>:<port-number>:<protocol>[:<data-rate>]]<LF>

<format-ID> single letter ['A'..'D'] identifying one of up to 4 data streams

<server-address> IPv4 address of the stream destination host

<port-number> port number on the destination host

<protocol> [0..15] stream protocol (0 = UDP; others payload specific)2

<data-rate> data rate in kB/s

Payload Response

The internal payload acknowledges receipt of the command (not completion) by responding OK or NOK[:<reason>] (e.g., unsupported feature), which will be reported by the NREP DHS.

4.2.3.2.8 X: Execute Command

11.3.1.8 X: Execute Command

Description

The Execute command may be used to pass a command string directly to a payload. Interpretation and execution of the command string are the sole responsibility of the payload.

Syntax

X<command-string><LF>

<command-string> command string to be interpreted by the payload (up to 100 ASCII characters)

Payload Response

The internal payload responds OK or NOK[:<reason>] based on its interpretation/execution of the given command. In the case of NOK, the payload should provide a <reason> that will be reported by the NREP DHS.

Since the NREP DHS expects a response (either OK or NOK) within 5 seconds, payload commands that require a longer period of time should be executed asynchronously; in this case, an OK response would only acknowledge receipt/acceptance of the command, a NOK response would indicate immediate rejection of the command; final success/failure should be reported in the payload status message (11.3.1.1).

If the payload receives an Abort command (11.3.1.9) while executing an Execute command asynchronously, it may, but is not required to, abort that execution.

4.2.3.2.9 A: Abort Command

Description

The Abort command is sent to abort a previously commanded asynchronous operation, such as an FTP file transfer (11.3.1.6) or an operation started by an Execute command (11.3.1.8).

Syntax

A<LF>

Payload Response

The internal payload responds OK or NOK[:<reason>] based on its interpretation/execution of the given command. In the case of NOK, the payload should provide a <reason> that will be reported by the NREP DHS.

If no asynchronous operation was pending (anymore), the payload may simply respond OK.

If two or more asynchronous operations were pending, the reaction of the payload is up to the payload (e.g., abort the last one).

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4.2.3.3 Health and Status Monitoring

The serial communication channel is used periodically by the NREP DHS to query internal payloads for their internal status, by sending the Status command, at a nominal rate of once per second (except during the execution of other commands).

Additionally, the NREP DHS keeps track of payload configuration data that was submitted successfully to a payload (payload response "OK"), such as streaming data destinations.

The following data items are monitored for each internal payload (1 through 5) and reported as part of the overall NREP Health and Status data:

Table 4.2.3.3-1: Internal Payload Health and Status Items

Data Item	Values	Length	Source	cf. sect.
ID String	payload ID string	8 bytes	PL status	11.3.1.1
Status String	payload status message	32 bytes	PL status	11.3.1.1
Status Code	payload status code (0: unconnected, 1: unknown, 2..255: payload specific)	8 bits	DHS/PL	11.3.1.1
Power Status	ext. 28 VDC on/off	1 bit	DHS	
Internal Power Status	int. 28 VDC off, on, or N/A	2 bits	DHS	11.3.1.2
Network I/F #1/2/3/4/5	up/down	1 bit each	DHS	11.2.1.2
28 VDC current	in mA	16 bits	DHS	
Internal current #1/2	in mA	16 bits each	PL	11.3.1.1
Internal temperature #1/2	in C, range [-128..127]	8 bits signed each	PL	11.3.1.1
Downlink packet counter	number of network packets received	16 bits	DHS	11.2.1.2
Stream dest. A/B/C/D	configured destination index [1..5]	3 bits each	DHS	0/11.3.4
Stream status A/B/C/D	disabled/enabled	1 bit each	DHS	0/11.3.4

4.2.3.4 File Transfer

There are two ways to transfer files to/from an internal payload. The preferred way is to use the FTP protocol, if the payload supports networking over USB, because this allows a better data rate, increased flexibility, and a reduced number of steps to perform a file transfer end-to-end, compared to the fallback solution of transferring files over the USB serial connection. For files transferred between a payload and the NREP DHS, either over the serial connection or by FTP to/from the FTP server provided by the DHS itself, there are multiple uplink and downlink paths from/to the ground, which are described in the NREP User Manual.

4.2.3.4.1 FTP File Transfers

An internal payload that supports networking over USB can be commanded to perform a file transfer via the FTP protocol (RD 2.2.8). Any reachable FTP server may be used as a source and/or destination, including the Nanoracks platforms in the EXPRESS racks onboard the ISS, from/to where they can be further transported, e.g., to/from the ground, as needed, or the FTP server provided by the NREP DHS itself.

4.2.3.4.2 File Transfer via Serial Connection

Using the Transmit and Receive commands, files can be transferred between a payload and the NREP DHS. In this case, the NREP 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.

4.3 Satellite Environments

4.3.1 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 4.3.1-1 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)

Table 4.3.1-1: Launch/Landing Load Factors Envelope

	Nx (g)	Ny (g)	Nz (g)	Rx (rad/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.

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4.3.2 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 meet the specified performance requirements when exposed to the maximum flight random vibration environments defined in **Table 4.3.2-1.** 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 4.3.2-1: Unattenuated and Attenuated Random Vibration Environments Ref. SSP 57000, Rev R, Table D.3.1.2-1

Frequency (Hz)	Max. Flight RV Env[1]	0.3" Bubble Wrap[2]	0.5" Minicel[3, 4]	2.0" Pyrell[5]	2.0" Pyrell w/Nomex[6]
20	0.057 (g^2/Hz)	0.2 (g^2/Hz)	0.07 (g^2/Hz)	0.2 (g^2/Hz)	0.2 (g^2/Hz)
20-40	0 (dB/oct)	0 (dB/oct)	0 (dB/oct)	0 (dB/oct)	0 (dB/oct)
40	0.057 (g^2/Hz)	0.2 (g^2/Hz)	0.07 (g^2/Hz)	0.2 (g^2/Hz)	0.2 (g^2/Hz)
40-80	0 (dB/oct)	-12.5 (dB/oct)	+4.27 (dB/oct)	-12.16 (dB/oct)	-12.16 (dB/oct)
80	0.057 (g^2/Hz)	0.011 (g^2/Hz)	0.187 (g^2/Hz)	0.012 (g^2/Hz)	0.012 (g^2/Hz)
80-100	0 (dB/oct)	-12.5 (dB/oct)	+4.27 (dB/oct)	-12.16 (dB/oct)	-12.16 (dB/oct)
100	0.057 (g^2/Hz)	4.45×10^{-3} (g^2/Hz)	0.257 (g^2/Hz)	4.93×10^{-3} (g^2/Hz)	4.93×10^{-3} (g^2/Hz)
100-153	0 (dB/oct)	-12.5 (dB/oct)	+4.27 (dB/oct)	-12.16 (dB/oct)	-12.16 (dB/oct)
153	0.057 (g^2/Hz)	7.61×10^{-4} (g^2/Hz)	0.469 (g^2/Hz)	8.85×10^{-4} (g^2/Hz)	8.85×10^{-4} (g^2/Hz)
153-160	+7.67 (dB/oct)	-12.5 (dB/oct)	+4.27 (dB/oct)	-12.16 (dB/oct)	-12.16 (dB/oct)
160	0.064 (g^2/Hz)	6.32×10^{-4} (g^2/Hz)	0.5 (g^2/Hz)	7.39×10^{-4} (g^2/Hz)	7.39×10^{-4} (g^2/Hz)
160-190	+7.67 (dB/oct)	-12.5 (dB/oct)	-8.31 (dB/oct)	-12.16 (dB/oct)	-12.16 (dB/oct)
190	0.099 (g^2/Hz)	3.09×10^{-4} (g^2/Hz)	0.311 (g^2/Hz)	3.69×10^{-4} (g^2/Hz)	3.69×10^{-4} (g^2/Hz)
190-200	0 (dB/oct)	-12.5 (dB/oct)	-8.31 (dB/oct)	-12.16 (dB/oct)	-12.16 (dB/oct)
200	0.099 (g^2/Hz)	2.5×10^{-4} (g^2/Hz)	0.27 (g^2/Hz)	3.0×10^{-4} (g^2/Hz)	3.0×10^{-4} (g^2/Hz)
200-250	0 (dB/oct)	-7.83 (dB/oct)	-15.44 (dB/oct)	-9.56 (dB/oct)	-9.56 (dB/oct)
250	0.099 (g^2/Hz)	1.4×10^{-4} (g^2/Hz)	0.086 (g^2/Hz)	1.48×10^{-4} (g^2/Hz)	1.48×10^{-4} (g^2/Hz)
250-750	-1.61 (dB/oct)	-7.83 (dB/oct)	-15.44 (dB/oct)	-9.56 (dB/oct)	-9.56 (dB/oct)
750	0.055 (g^2/Hz)	8.02×10^{-6} (g^2/Hz)	3.06×10^{-4} (g^2/Hz)	4.5×10^{-6} (g^2/Hz)	4.5×10^{-6} (g^2/Hz)
750-2000	-3.43 (dB/oct)	-7.83 (dB/oct)	-15.44 (dB/oct)	-9.56 (dB/oct)	-9.56 (dB/oct)
2000	0.018 (g^2/Hz)	6.25×10^{-7} (g^2/Hz)	2.0×10^{-6} (g^2/Hz)	2.0×10^{-7} (g^2/Hz)	2.0×10^{-7} (g^2/Hz)
OA (grms)	**9.47**	**2.56**	**7.82**	**2.58**	**2.58**

Notes:
1) Unattenuated RV levels are from Table D.3.1.2-3.
2) Bubble wrap refers to SECO 88 manufactured by Seco Industries, 6909 East Washington Blvd. Montebello, CA 90640.
3) Minicel refers to Minicel L200 manufactured by Voltek, 73 Shepard St. Lawrence, MA 01843.
4) Zotek refers to Zotek F30 distributed by Zotefoams, 55 Precision Dr. Walton, KY 41094, Ref. Tables I.3-2 & I.3-3.
5) Pyrell refers to Pyrell#2 manufactured by Foamex, 1500 E. 2nd St. Eddystone, PA 19022.
6) Nomex refers to HT90-40 manufactured by Stern & Stern Industries, 188 Thacher St., Hornell, NY 14843.

4.3.3 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.

4.3.4 IVA Loads Environment

The payload shall provide positive margins of safety when exposed to the crew induced loads defined in **Table 4.3.4-1**, 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 4.3.4-1: 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

4.3.5 JEM Slide Table Translation Loads Environment

During JEM slide table translation, the payloads must be compatible accelerations no greater than 0.2 g’s in the +Z direction. If the total mass with the NREP system is less than 40 kg, then the payload must be compatible with 0.41 g’s.

4.3.6 EVA Loads Environment

The ISS Program requires all payloads to be able to withstand EVA kick loads of 125 lbf over a 0.5 inch diameter circle as stated in Section 3.1.3-1 of SSP 57003. It is Nanoracks’ experience that no Kaber class payloads should reasonable be expected to meet this requirement and as such, Nanoracks has and will continue to seek exceptions to this requirement. The payload ICA will detail specific data products, as required, to support the processing of any exceptions.

4.3.7 EVR Loads Environment

For EVR operations, 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.

4.3.8 Thermal Environment

Expected thermal environments for all phases of payload integration are summarized in **Table 4.3.8-1** Expected Thermal Environments. Payloads with special thermal constraints should coordinate with Nanoracks.

Table 4.3.8-1 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)

4.3.9 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.

4.3.10 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

4.4 HFIT (Human Factors Implementation Team) Requirements

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

4.4.1 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 satellite external chassis shall comply are listed in Table 4.4.1-1 HFIT Requirements for Payloads Using the NREP Services

Table 4.4.1-1: Requirements for Payloads Using the NREP 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.	Holes that are round or slotted in the range of 0.4 to 1.0 in (10.0 to 25.0 mm) 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

4.4.2 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 PD should contact Nanoracks for specific guidance.

4.4.2.1 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.

4.4.2.2 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.

4.4.2.3 Securing Cables

Use of nylon locking “zip” ties or cable clamps as shown in Figure 4.4.2.3-1 are examples of approved methods for securing cables.

Figure 4.4.2.3-1: Example Applications of Zip ties and Cable Clamps

4.5 Satellite Safety Requirements

Satellites 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 50700 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
- Sharp edges, pinch points, and other touch hazards
  - IVA and EVA
  - Includes rotating equipment
- Operational procedures

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Control of Hazards

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

4.5.1 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.

4.5.2 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.

4.5.3 Secondary Locking Feature

A secondary locking feature is required for fasteners external to the payload chassis that will not be held captive by the spacecraft structure and enclosure should they come loose. Note that measured and recorded fastener torque is considered the primary locking feature. Mechanical or liquid locking compounds methods are approved. Mechanical secondary locking features are preferred and may be either a locking receptacle such as a locking helical insert or locknut. Approved secondary locking compounds include Loctite and Vibratite. Contact Nanoracks for specific types of approved compounds. Self-priming liquid-locking compounds are not approved. Other secondary locking methods must be approved by Nanoracks.

4.5.4 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.

4.5.5 Pyrotechnics

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

4.5.6 Space Debris Compliance

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

4.5.7 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 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.

4.5.7.1 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

4.5.7.2 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.

4.5.7.3 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.

4.5.7.4 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.

4.5.7.5 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.

4.5.7.6 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.

4.5.7.7 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.

4.5.7.8 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.

4.5.8 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.

4.5.9 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.

4.5.10 Hazardous Materials

Payloads shall comply with NASA guidelines for hazardous materials. Satellite 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.

4.5.11 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.

4.6 Customer Deliverables

Table 4.6-1 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 4.6-2: 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.	30 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)	30 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)	30 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	30 days prior Ph 3 Safety Review
5	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.	30 days prior Ph 3 Safety Review
6	Vibration Test Report	Integrated satellite per NR standard test guidance (NR-SRD-085)	30 days prior Ph 3 Safety Review

Item	Deliverable	Description	Date
7	Inspection Reports for fracture critical parts (if any fracture critical parts)		30 days prior Ph 3 Safety Review
8	Inspection Reports for stress corrosion parts (if any stress corrosion sensitive parts)		30 days prior Ph 3 Safety Review
9	Power System Functional Test Report for EPS inhibits verification	If safety inhibits are part of the spacecraft system	30 days prior delivery
10	Pressure System Qualification Test Report (if Qual Test is performed)	If Pressure Systems are onboard the payload	30 days prior Ph 2 Safety Review
11	Provide Pressure System Acceptance Test Report	If Pressure Systems are onboard the payload	30 days prior Ph 3 Safety Review
12	Materials Compatibility Report for Pressure System	If Pressure Systems are onboard the payload	30 days prior Ph 1 Safety Review
13	Safety critical fastener CoCs (if any safety critical fasteners)	To be advised after receipt of Structural Analysis	30 days prior Ph 3 Safety Review
14	Battery Test Report	If batteries are onboard the payload	30 days prior Ph 2 Safety Review
15	Material Certifications	Raw material certifications, outsourced process certifications and COTS quality documentation.	30 days prior Ph 3 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	30 days prior Ph 3 Safety Review
17	Final Satellite As-Measured Mass Properties	Weight, e.g., MOI and ballistic number	One Day prior to Nanoracks Delivery

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1	**Structural Requirements**			**NVR**	
4.1.1	NREP-P Attachment to Experiment Baseplate	All small standard and non-standard payloads shall utilize captive and of hex socket (Allen) type fasteners. For positive fastener locking the bolts shall be equipped with locking features (e.g., according to NAS1283 type P). Two fastener locations are provided per 100mm payload length. A payload provider with a 2 U or larger payload might opt to not use all available positions; however, a minimum of 2 fasteners is required. Large non-standard payloads shall provide for a bolted attachment identical to the Experiment Baseplate. The fasteners shall be captive and have an M6 thread. The bolts interface with self-locking nut-plates so the bolts do not need own locking feature.	A	I	Hardware Drawings
4.1.2	NREP-P Soft Dock Feature	All standard and non-standard payloads shall provide a soft dock feature. Reference Figures in section 4.1.4.1 for examples of standard and alternative soft dock features. Large non-standard payloads achieve soft dock through holes that interface to pins with spring loaded balls.	A	I	Hardware Drawings

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1.3	NREP-P Bonding to Experiment Baseplate	The payloads shall provide for structural bonding to the designated bonding areas shown on the Experiment Baseplate as identified on Figures 4.1.1-2 and 4.1.1-3. An example of a bonding tab is shown in Figure 4.1.3-1. For large non-standard payloads, the payload shall provide for a nickel-plated surface at the interface to the NREP structure for faying surface bonding.	A	I	Hardware Drawings
4.1.4	Payload Envelope for Standard and Small Non-Standard Payloads	The NREP allows for various configurations with different standard sizes of payloads. An example is shown in Figure 4.1.4-1. Figures 4.1.4-2 and 4.1.4-3 show the interface points for payload attachment to the top and the bottom of the Experiment Base Plate and the location of the payload interface connectors. The shaded areas indicate the footprint of a standard 4U payload. Figure 4.1.4-4 details the geometric constraints on the height of payloads attached to the top side and bottom side of the plate.	NVR		
4.1.4.1	Payload Envelope for Standard Payloads	Standard Payloads have a width and a height of 100 mm and a length from 1U (=100mm) up to 4 U (=400mm). Figures 4.1.4.1-1 through 4.1.4.1-5 show the dimensions for the standard payloads.	A	I	Hardware Drawings

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1.4.2	Payload Envelope for Non-Standard Payloads	Payloads with non-standard sizes may either use the available attachment interfaces and volume on the Experiment Base Plate (as described in Figure 4.1.4-2 through Figure 4.1.4-4) or, in case of large payloads they may use the entire available volume (see Figure 4.1.4.2-1).	A	I	Hardware Drawings
4.1.5	Mass Properties	The maximum gross NREP payload mass capacity is as follows. For NREP-P 4U (Standard Payloads), the nominal mass is 4kg. Any larger mass will need to be negotiated. The total NREP-P base-plate capacity is 35 kg.	A	I	Table 4.6-1 #16
4.2	**Electrical and Data Interfaces**				
4.2.1	Electrical Provisions – 28V		NVR		
4.2.1.1	Constraints – 28V DC	The NREP provides bracket-mounted connectors for up to 5 payloads. Each connector provides 28 VDC power and a USB 2.0 data interface including a separate non-switchable 5 V/500 mA bus power. The 28 V DC NREP electrical receptacle interface is defined in Table 4.2.1.1-1. The specification of the interface connector is provided in Table 4.2.1.1-2.	A	I	Hardware Drawings

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.1.2	28 VDC Power Characteristics	The payload shall be compatible with the defined standard 28 VDC power outlet characteristics: Voltage range: 28 V +/- 2V Transient over-voltage: 40 V Nominal power: 30 W at 28 V Maximum current: 2 A Over-current protection: 4.8 A, trim time 2ms	A	T	Table 4.6-1 #9

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.1.3	5 VDC USP Power	The 5 VDC USB power is specified according to the USB 2.0 High Power standard, allowing a maximum current draw of 500 mA. The power is permanently applied on the NREP side; however, in order to be able to control all power draw by a payload, the payload is required to inhibit any 5 VDC USB power draw while the 28 VDC power is not applied. Figure 6.2.1.3-1 shows a possible implementation of payload power control. The two shown relays inside the payload, Relay 1 and Relay 2, both default to an “off” position. Relay 1 is activated by the external 28 VDC power and connects the 5 VDC USB power. Relay 2, an optional means to control power to the actual experiment, is controlled by software (default “off”, may be commanded to “on” or back to “off”). A payload that uses only the 5 VDC/500 mA USB power shall switch that power draw based on the presence or absence of the 28 VDC power. Conversely, a payload that does not use USB power at all does not have to take measures to disconnect it. Analogous to the USB power control requirement, an internal payload is also required not to show USB data activity while the 28 VDC power is off.	A	T	Table 4.6-1 #9

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.1	Electrical Provisions – 120V	120 VDC electrical power is a non-standard service and shall be defined and documented in the payload-specific ICA.	A	T	Table 4.6-1 #9
4.2.2	Electromagnetic Compatibility	**The NREP-P electrical grounding shall be in accordance with SSP 30240, paragraph 3.2**	A	T	Table 4.6-1 #9
4.2.2.1	Electrical Grounding	The NREP-P shall be electrically bonded to the NREP base plate per SSP 30245, Space Station Electrical Bonding Requirements, paragraphs 3.2 and 3.3.	A	T	Table 4.6-1 #9
4.2.2.2	Payload Surface Electrostatic Charging	All NREP-P metallic hardware elements shall comply with the Class-S bond requirements of SSP 30245, Space Station Electrical Bonding Requirements.	A	T	Table 4.6-1 #9
4.2.2.3	Insulated Materials	Hardware consisting of or containing low-conductivity material shall be bonded in accordance with SSP 30245, Section 3.3.4.3.2.	A	T	Table 4.6-1 #9
4.2.2.4	Radiation Emissions	The NREP-P shall not exceed emissions defined in SSP 30237, Space Station Electromagnetic Emission and Susceptibility Requirements	A	T	Table 4.6-1 #9
4.2.3	Command and Data Interfaces		NVR		

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.3.1	NREP DHS to Payload Software Interface	This section describes the software interface between the NREP DHS and the NREP-P payloads. Adherence to the required and optional interfaces described here is essential for the successful and safe operation of NREP 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		
4.2.3.1.1	CDC Abstract Control Model	For basic commanding and monitoring, an internal payload is required to implement a USB serial communications device (CDC Abstract Control Model subclass, see RD 2.2.2). The NREP DHS will use the resulting virtual serial port for sending commands to and receiving status messages from the payload (see sect. 11.3.1 for details). The serial port configuration will be set to 57,600 bd, with 8 data bits, no parity, and 1 stop bit. Upon connection to this device class, the NREP DHS will establish a serial communication channel to the internal payload, which is maintained as long as the payload is powered. For commanding and status collection purposes, each internal payload is required to provide one and only one CDC ACM device.	A	I	Hardware Drawings

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.3.1.2	CDC Ethernet Control Model	Optionally, an internal payload may implement a networking device (CDC Ethernet Control Model subclass, see RD 2.2.3). A payload implementing this device class must configure its network interface in compliance with settings defined in the NREP-P ICA. The provided router address will be the internal subnet interface of the NREP DHS, which is also the host address for DHS services (telemetry, sect. 11.3.4, and network time, sect. 11.3.5). Each payload may connect up to 5 internal networking devices, each of which will receive a predefined IP address on a separate subnet. All payload networking devices can communicate with each other as well as with external hosts (e.g., for file transfer or data streaming), using the NREP DHS as their default router. On the NREP DHS side, the CDC ECM communication is handled by the Linux usbnet framework (RD 2.2.5), which is also recommended for internal payload controllers based on Linux 2.6 or later.	A	I	Hardware Drawings

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.3.1.3	Mass Storage Device Class	Optionally, an internal payload may implement the Mass Storage device class (see RD 2.2.4). Upon connection of a Mass Storage Device with a supported file system type, the NREP DHS will mount the file system as an external drive. Supported file system types are Fat16, Fat32, ext2fs, ext3fs. Note that while a Mass Storage Device is mounted by the NREP DHS, the payload is not allowed to modify the content of the provided file system in any way. Only the NREP DHS is allowed to write to a mounted file system. For this reason, using the Mass Storage Device class for an internal payload is only of limited value, as there is no way of un-mounting in a controlled way. The handling of mounted Mass Storage Device file systems by the NREP DHS (e.g., mount points, pathnames) needs to be documented in the Interface Control Agreement.	A	I	Hardware Drawings

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.3.2	Commanding	The NREP DHS provides the capability to send commands to an internal payload. Most commands originate from commands that the payload operator on the ground sends to the NREP DHS via ISS commanding channels (operator commands). Only the Status command (11.3.1.1) is sent autonomously by the NREP DHS to request the current status of an internal payload. The serial communication channel (sect. 11.2.1.1), which is mandatory for all internal payloads, is used to send commands to the internal payload. The communication is always initiated by the NREP DHS by sending an ASCII <ESC> (0x1B) character, which is used for synchronization; i.e., the payload is expected to discard any characters received before the first <ESC> character. The <ESC> character is followed by a command consisting of a single command character, followed by command parameters as described below. Each command ends with an ASCII <LF> (0x0A) character.	A	I	Software Plan

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.3.3	Health and Status Monitoring	The serial communication channel is used periodically by the NREP DHS to query internal payloads for their internal status, by sending the Status command, at a nominal rate of once per second (except during the execution of other commands). Additionally, the NREP DHS keeps track of payload configuration data that was submitted successfully to a payload (payload response “OK”), such as streaming data destinations.	A	I	Software Plan
4.2.3.4	File Transfer	There are two ways to transfer files to/from an internal payload. The preferred way is to use the FTP protocol, if the payload supports networking over USB, because this allows a better data rate, increased flexibility, and a reduced number of steps to perform a file transfer end-to-end, compared to the fallback solution of transferring files over the USB serial connection. For files transferred between a payload and the NREP DHS, either over the serial connection or by FTP to/from the FTP server provided by the DHS itself, there are multiple uplink and downlink paths from/to the ground, which are described in the NREP User Manual.	A	I	Software Plan

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2.3.4.1	FTP File Transfers	An internal payload that supports networking over USB can be commanded to perform a file transfer via the FTP protocol (RD 2.2.8). Any reachable FTP server may be used as a source and/or destination, including the Nanoracks platforms in the EXPRESS racks onboard the ISS, from/to where they can be further transported, e.g., to/from the ground, as needed, or the FTP server provided by the NREP DHS itself.	A	I	Software Plan
4.2.3.4.2	File Transfer via Serial Connection	Using the Transmit and Receive commands, files can be transferred between a payload and the NREP DHS. In this case, the NREP 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.	A	I	Software Plan

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.3	**Environments**			**NVR**	
4.3.1	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 4.3.1-1 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	Table 4.6-1 #4
4.3.2	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 meet the specified performance requirements when exposed to the maximum flight random vibration environments defined in **Table 4.3.2-1.** 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	I	Table 4.6-1 #6
4.3.3	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.		NVR	

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.3.4	IVA Loads Environment	The payload shall provide positive margins of safety when exposed to the crew induced loads defined in **Table 4.3.4-1**, 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	T	Table 4.6-1 #4
4.3.5	JEM Slide Table Translation Loads Environment	During JEM slide table translation, the Satellites must be compatible accelerations no greater than 0.2 g's in the +Z direction. If the total mass with Kaber deployment system is less than 40 kg, then the payload must be compatible with 0.41 g's.	A	A	Table 4.6-1 #4
4.3.6	EVA Loads Environment	The ISS Program requires all payloads to be able to withstand EVA kick loads of 125 lbf over a 0.5-inch diameter circle as stated in Section 3.1.3-1 of SSP 57003. It is Nanoracks' experience that no Kaber class payloads should reasonable be expected to meet this requirement and as such, Nanoracks has and will continue to seek exceptions to this requirement. The payload ICA will detail specific data products, as required, to support the processing of any exceptions.	A	A	Table 4.6-1 #4

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.3.7	EVR Loads Environment	For EVR operations, 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.	A	A	Table 4.6-1 #4
4.3.8	Thermal Environment	Expected thermal environments for all phases of payload integration are summarized in **Table 4.3.9-1** Expected Thermal Environments. Payloads with special thermal constraints should coordinate with Nanoracks.	A	I	Table 4.6-1 #3
4.3.9	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	A	A	Table 4.6-1 #2
4.3.10	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, T	Table 4.6-1 #10, 11, 12

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.4	**HFIT Requirements**				
4.4.1	HFIT Requirements for Small Satellites	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 satellite external chassis shall comply are listed in Table 4.4.1-1 HFIT Requirements for Small Satellites Using the Kaber Service	A	I	Hardware Drawings and Table 4.6-1 #15
4.4.2	Recommended Compliance Methods	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 PD should contact Nanoracks for specific guidance		NVR	
4.5	**Safety Requirements**				
4.5.1	Containment of Frangible Materials	In general the satellite design shall preclude the release or generation of FOD for all mission phases. Primary concern is exposed frangible materials on the satellite exterior e.g. solar cells, glass items etc. Containment or protection may be required to control the hazard of the release of frangible materials. Containment plan will be defined in the ICA.	A	I	Hardware Drawings

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.2	Venting	Satellite and any enclosed containers internal to it 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.			Table 4.6-1 #15
4.5.3	Secondary Locking Features	A secondary locking feature is required for fasteners external to the satellite chassis that will not be held captive by the spacecraft structure and enclosure should they come loose. Note that measured and recorded fastener torque is considered the primary locking feature. Mechanical or liquid locking compounds methods are approved. Mechanical secondary locking features are preferred and may be either a locking receptacle such as a locking helical insert or locknut. Approved secondary locking compounds include Loctite and Vibratite. Contact Nanoracks for specific types of approved compounds. Lockwire may be used as a secondary locking feature only in areas inaccessible to the crew. Self-priming liquid-locking compounds are not approved. Other secondary locking methods must be approved by Nanoracks.	A	I	Table 4.6-1 #13

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.4	Passivity	Satellites 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	A	I, T	Hardware Drawings and Table 4.6-1 #9
4.5.5	Pyrotechnics	Satellites shall not contain pyrotechnics unless the design approach is pre-approved by Nanoracks. Electrically operated melt-wire systems for deployables that are necessary controls for hazard potentials are permitted	A	I	Table 4.6-1 #2
4.5.6	Debris	Satellites should not have detachable parts during launch or normal mission operations. Any exceptions will be coordinated with Nanoracks and documented in the ICA. Satellites shall comply with NASA space debris mitigation guidelines (Ref. NASA Standard 8719.14)	A	I	Hardware Drawings and Table 4.6-1 #7
4.5.7	Batteries	Battery requirements for spacecraft flight onboard or near the ISS are derived from the NASA requirement document JSC 20973 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.		NVR	

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.7.1	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	A	I	Table 4.6-1 #14
4.5.7.2	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.		NVR	
4.5.7.3	Required Battery Flight Acceptance Test	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.	A	T	Table 4.6-1 #14
4.5.7.4	Internal Short	Protection circuity and safety features shall be implemented at the cell level to prevent internal short circuits	A	I, T	Table 4.6-1 #9, 14
4.5.7.5	External Short Circuit	Battery design and safety features shall be implemented to prevent an external short circuit	A	I, T	Table 4.6-1 #9, 14

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.7.6	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.	A	I, T	Table 4.6-1 #9, 14
4.5.7.7	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.	A	I	Hardware Drawings
4.5.7.8	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.	A	I	Hardware Drawings

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.8	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.	A	I, T	Table 4.6-1 #11, 12

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.9	Stress Corrosion Materials	Stress corrosion resistant materials from Table I of MSFC-SPEC-522 are preferred. Any use of stress corrosion susceptible materials (Table II) shall be pre-coordinated with Nanoracks and documented in the ICA. Any use of Table III materials shall be avoided.	A	I	Table 4.6-1 #8
4.5.10	Hazardous Materials	Satellites shall comply with NASA guidelines for hazardous materials. Satellite 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.	A	I	Table 4.6-1 #2
4.5.11	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.	A	I, T	Hardware Drawings and Table 4.6-1 #9