NanoRacks Kaber Deployment System Interface Definition Document (IDD)

3/17/2016

List of Revisions

Revision	Revision Date	Revised By	Revision Description
-	3/17/2016	Steve Stenzel	Initial Release

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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 Kaber Deployment System (NRKDS). This IDD also defines the requirements to the International Space Station (ISS) flight safety program when using the NRKDS. This IDD defines the various environments applicable to the payload design process. NanoRacks verifies compliance on behalf of satellite developers based on incremental data requests.

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 all 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 from which satellites are deployed.

1.3 Use

This document levies design interface and verification requirements on payload developers (i.e. Kaber satellite customers). 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.

An 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
BOM	Bill of Materials
CD&H	Command Data & Handling
CLPA	Camera Light and Pan Tilt Assembly
CoC	Certificate of Compliance
CSA	Canadian Space Agency
EF	Exposed Facility
ESD	Electrostatic Discharge
EPS	Electrical Power System
EVR	Extravehicular Robotics
FOD	Foreign Object Debris
HFIT	Human Factors Implementation Team
ICA	Interface Control Agreement
IDD	Interface Definition Document
I/F	Interface
ISS	International Space Station
JCAP	JEM CLPA Adapter Plate
JEM	Japanese Experiment Module
MWA	Maintenance Work Area
NRKDS	NanoRacks Kaber Deployment System
NRSS	NanoRacks Separation System
ORU	Orbit Replaceable Unit
OTCM	ORU Tool Changeout Mechanism
POIF	Payload Operations Integration Function
RBF	Remove Before Flight
SE&I	Systems Engineering & Integration
SPDM	Special Purpose Dexterous Manipulator
SSRMS	Space Station Remote Manipulator System
STEP	Slide Table Extension Plate
TIM	Technical Interchange Meeting

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 51700		Payload Safety Policy and Requirements for the International Space Station
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
57237-NA-0003B		Baseline ICD AVMs for Kaber to Support VERITAS Submittals for SpX8
NASDA-ESPC-2903-B	B	JEM Payload Accommodation Handbook Vol. 6 Airlock/Payload Standard Interface Control Document
SSP 42004	K	Mobile Servicing System (MSS) to User (Generic) Interface Control Document Part 1
42004-NA-0123A		SPDM Power Requirements Updates for Active Payloads
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 Kaber Overview

This section is an overview of the NanoRacks Kaber Deployment System utilizing NanoRacks Separation System. It describes the various system interfaces and the operational elements of the payload lifecycle.

3.1 NanoRacks Kaber Deployment Structural Overview

The NanoRacks Kaber Deployment System (NRKDS) (see **Figure 3.1-1**) is a deployment system for small satellites staged from the International Space Station (ISS). Kaber utilizes the existing ISS Japanese Experiment Module (JEM) as a staging facility along with the CSA Special Purpose Dexterous Manipulator (SPDM) as a platform from which satellites are deployed. NRKDS refers to an integrated system consisting of the NanoRacks Kaber deployer and a NanoRacks Separation System (NRSS). The Kaber deployer is the power and data interface to the SPDM while the NRSS is the satellite separation system. Any other separation system would be covered under the payload unique Interface Control Agreement (ICA).

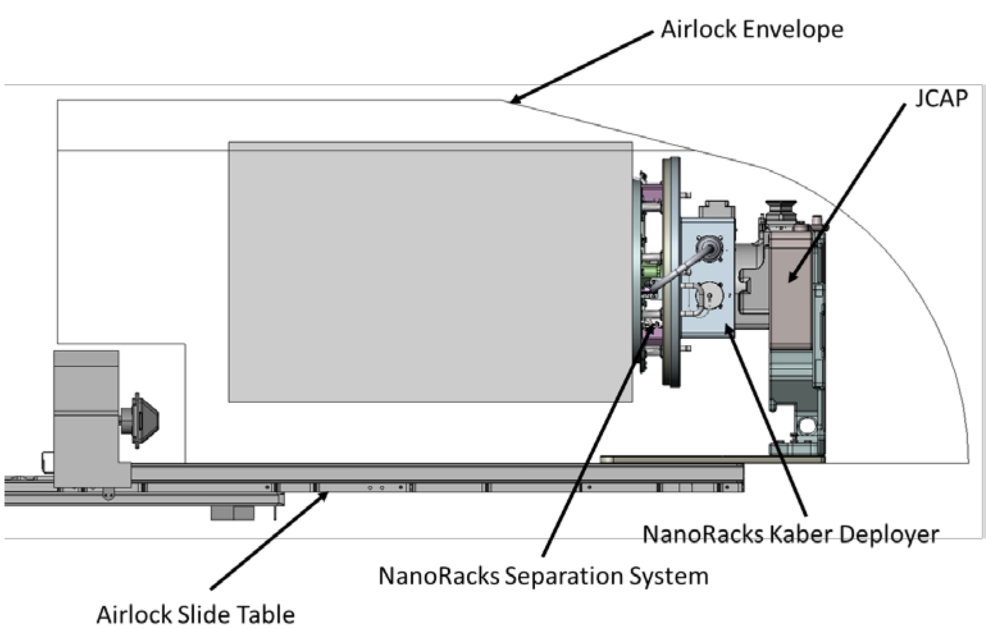

Figure 3.1-1: NanoRacks Kaber Deployment System

3.1.1 Kaber Deployer

The NanoRacks Kaber Deployer, or Kaber for short, shown in **Figure 3.1.1-1,** is a self-contained satellite deployer system that provides an interface between the SPDM and the satellite. Kaber also has an interface to the JEM Slide Table via the JEM CLPA Adaptor Plate (JCAP). The Kaber Deployer consists of the separation system mounting plate, the avionics housing, and the robotic interface to JCAP. An EVR Electrical Interface for the SPDM ORU Tool Changeout Mechanism (OTCM) is provided by an umbilical connector. A Micro-Fixture EVR Mechanical Interface is provided for the SPDM OTCM interface. The Kaber deployer is compatible with a range of separation system diameters and remains stowed in the ISS for reuse for each small satellite deployment mission.

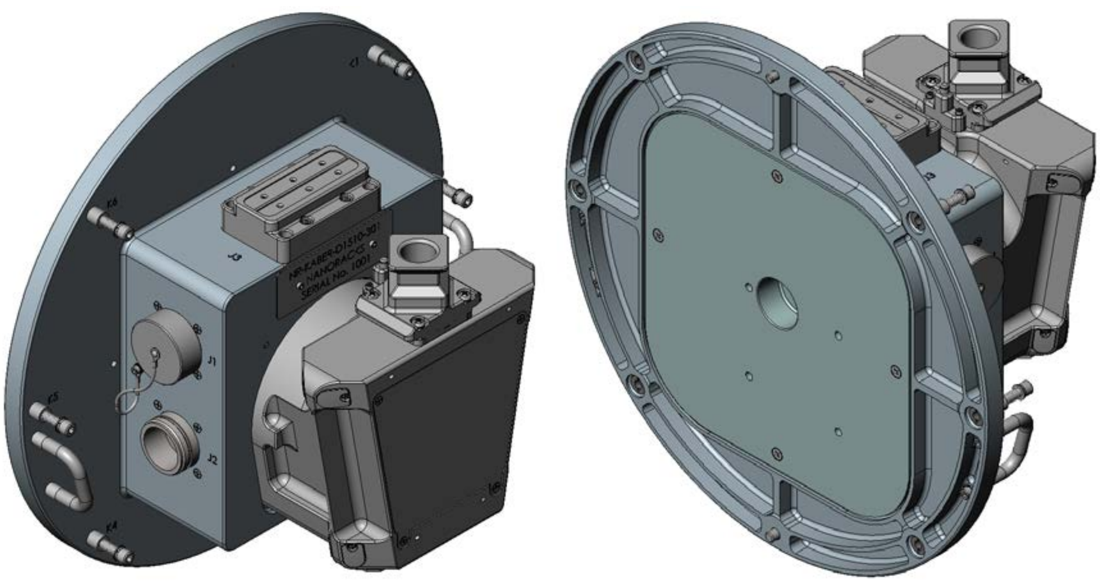

Figure 3.1.1-1: NanoRacks Kaber Deployer

3.1.2 NanoRacks Separation System (NRSS)

The NRSS (see **Figure 3.1.2-1**) attaches directly to the Kaber deployer via six (6) captive fasteners. The NRSS is a low-shock separation system designed for use in zero-g environment of ISS.

The NRSS consists of two major components- the “Fly-Away” and “Vestigial” sub-assemblies. The Fly-Away portion (**Figure 3.1.2-2**) is the mechanical interface for the satellite, and provides separation deployment switches. The Fly-Away portion remains attached to the satellite following separation. This baseline Fly-Away interface features an 11.732 inch diameter bolt circle. Additional sizes are available as a special accommodation.

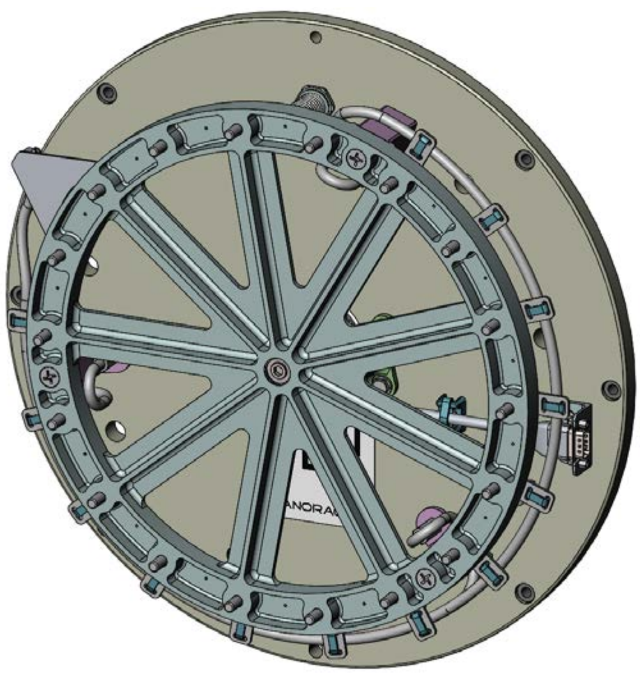

Figure 3.1.2-1: NanoRacks Separation System

The NRSS Vestigial portion (**Figure 3.1.2-3**) is the mechanical interface between the Fly-away portion and the NanoRacks Kaber deployer. The Vestigial portion contains the active release mechanism and springs, and remains attached to the Kaber following separation.

The NRSS design features pusher springs and spring shims that will be selected based on satellite mass, c.g., and tip off rate requirements. Coordination of the spring and shim configurations will be documented in the ICA.

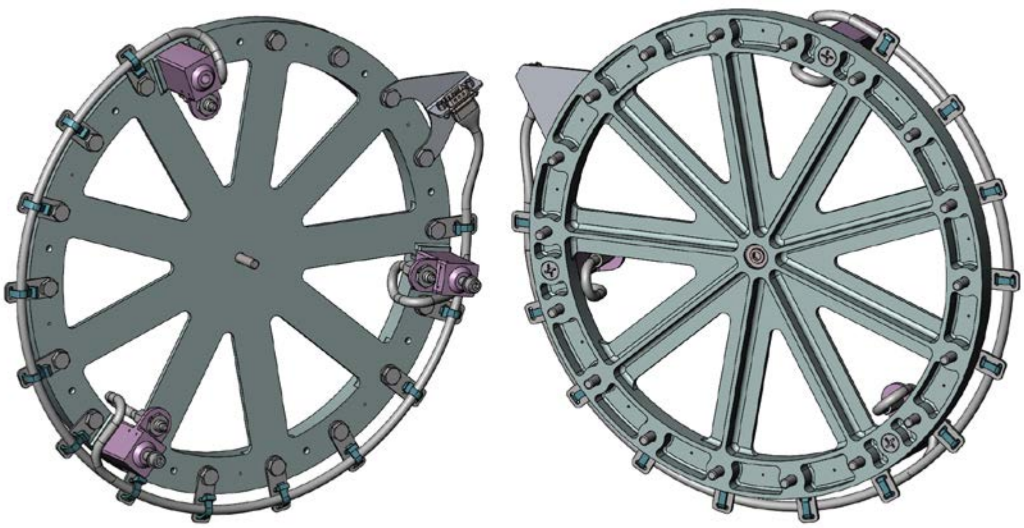

Figure 3.1.2-2: NRSS Fly-Away Sub-Assembly

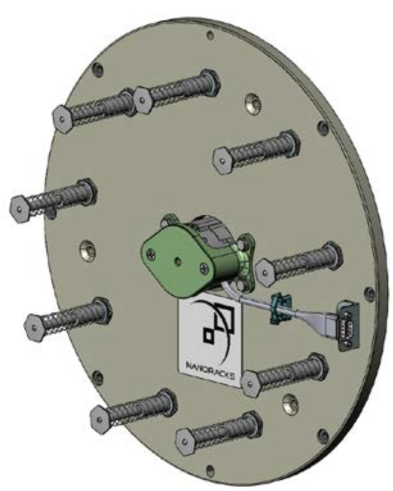

Figure 3.1.2-3: NRSS Vestigial Sub-Assembly

3.1.3 NanoRacks Kaber Deployer Coordinate System

The Kaber coordinate system (see **Figure 3.1.3-1**) is centered on the Kaber attach point of the separation system. The +Z-axis is normal to and originates from the Kaber interface plane. It points toward the satellite. The +Y-axis is in the plane of the Kaber interface and extends vertically away from the MLB and JEM airlock slide table. The +X-axis is defined by completing the right hand coordinate system with direction given by the cross product of the +Y and +Z-axes. Preferred satellite coordinate system clocking is expressed relative to Kaber coordinate system.

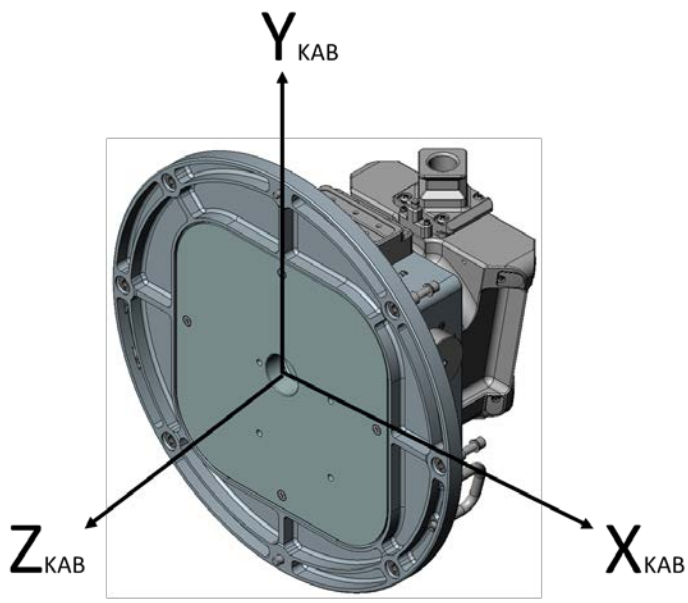

Figure 3.1.3-1: Kaber Coordinate System

3.2 NanoRacks Kaber Operations Overview

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)
Feasibility Study/Contract Signing	L – 14
Regulatory Compliance Start (Spectrum Coordination, Remote Sensing)	L – 14
NanoRacks/Customer Kickoff Meeting	L-13.5
Interface Control Agreement Start	L-13.5
NanoRacks/Customer Safety Data Call Start	L-13.5
NanoRacks Safety Initial Assessment Complete	L-12.5
Baseline Interface Control Agreement	L-12.5
Phase 0 Support Data from PLO complete (if required)	L-11.5
Phase 0 Safety Data Package Submittal to NASA (if required)	L-11
Phase 0 Safety Review (if required)	L – 10
TIM (NanoRacks-NASA)	L – 10.5
Phase 1 Support Data from PLO complete	L-10
Phase 1 Safety Data Package Submittal to NASA	L-9.5
Phase 1 Safety Review	L – 8.5
Phase 2 Support Data from PLO complete	L-8
Phase 2 Safety Data Package Submittal to NASA	L-7
Phase 2 Safety Review	L-6
Ground Safety Data Concept (if required)	L-6
Satellite-Separation System Fit Check	L-6
Payload Environmental Testing	L-5
ISS Program Required Flight Acceptance testing	L-5

Ground Safety Support Data from PLO complete (if required)	L-5.5
Ground Safety Data Package Data Submit (if required)	L-5
Phase 3 Support Data from PLO complete	L-5.5
Phase 3 Safety Data Package Submittal	L-5
Phase 3 Safety Review	L-4
Ground Safety Support Data from PLO complete (if required)	L-4
Payload Delivery to NanoRacks	L-3.5
Ground Safety Data Package Submit	L-3.5
NanoRacks Delivery to NASA	L-3

3.2.2 Ground Operations

3.2.2.1 Mechanical and Electrical Interface Checks

NanoRacks will coordinate to complete mechanical and electrical interface checks between the satellite and the NRSS fly-away component. Fit checks are conducted with the hardware intended for flight. Use of flight-like engineering qualification hardware in lieu of flight models must be coordinated with NanoRacks and documented in the ICA.

3.2.2.2 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, ESD sensitivity, etc., will be documented in the payload specific ICA.

3.2.2.3 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. NanoRacks will install the NanoRacks separation system (if necessary) that interfaces the payload to the Kaber deployer.

3.2.2.4 NanoRacks Data Gathering for Operations

NanoRacks will assess the combined payload assembly to develop products and procedures in support of crew interaction and on-orbit assembly. In order 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 the satellite.

3.2.2.5 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. Any special requirements will be documented in the payload specific ICA.

3.2.2.6 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, as long as these activities are part of the documented and verified payload design. No material or design chances are allowed at this phase of the processing. 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.

3.2.2.7 NanoRacks Packaging and Delivery

NanoRacks will deliver the completed payload assembly (see **Figure 3.2.2.7-1**) to the Cargo Mission Contracts area for incorporation into its final stowage configuration.

Figure 3.2.2.7-1: Sample Stowage Configuration for Launch

3.2.3 Launch

Cargo Missions Contract is responsible for delivering the final stowed configuration to the appropriate launch site facility and integration 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 packed configuration and placing it in the appropriate on-orbit stowage location until it is time to 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, assembling the satellite (if required) and installing the complete configuration onto the JEM slide table. The NanoRacks operations team will provide support to the crew in all aspects of the payload assembly in coordination with POIF. The JCAP (and STEP if needed) is installed on the JEM air lock slide table. The Kaber Deployer is then installed onto the JCAP. Finally, the Satellite/NRSS assembly is installed onto the Kaber Deployer and the NRSS-to-Kaber cable is connected.

3.2.4.3 JEM Operations

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

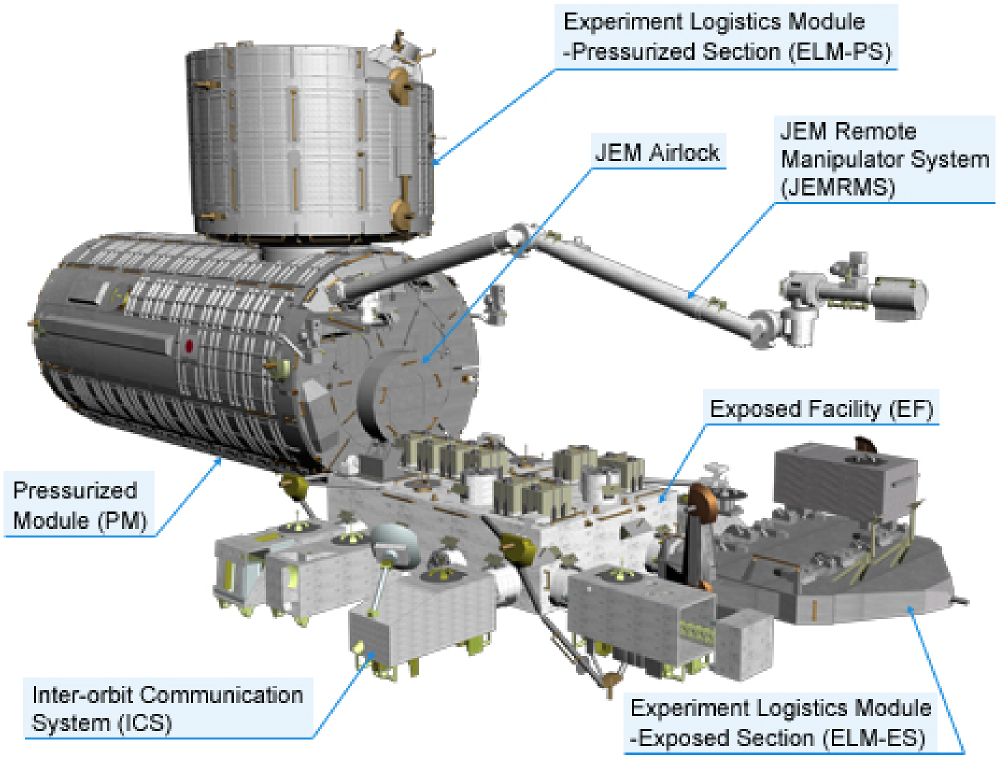

Figure 3.2.4.3-1: JEM Airlock View

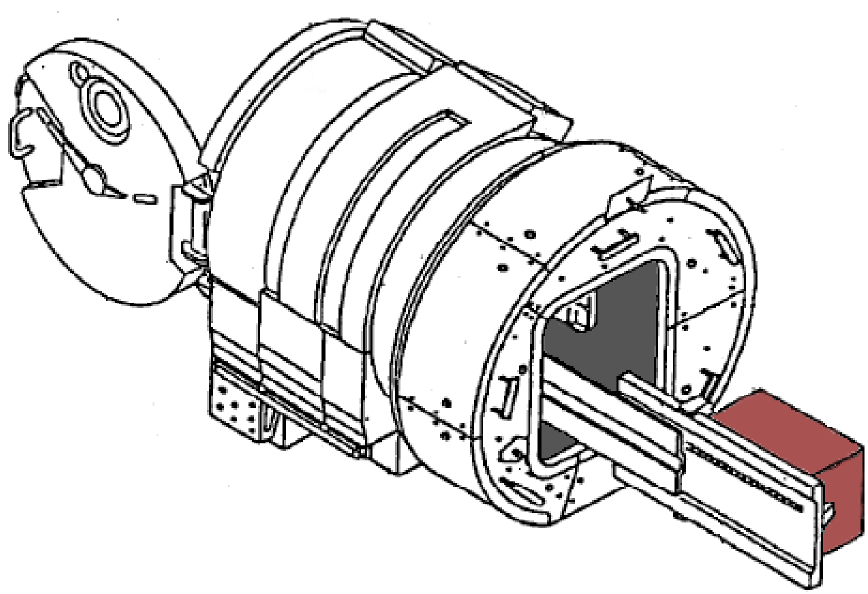

Figure 3.2.4.3-2: JEM Slide Table

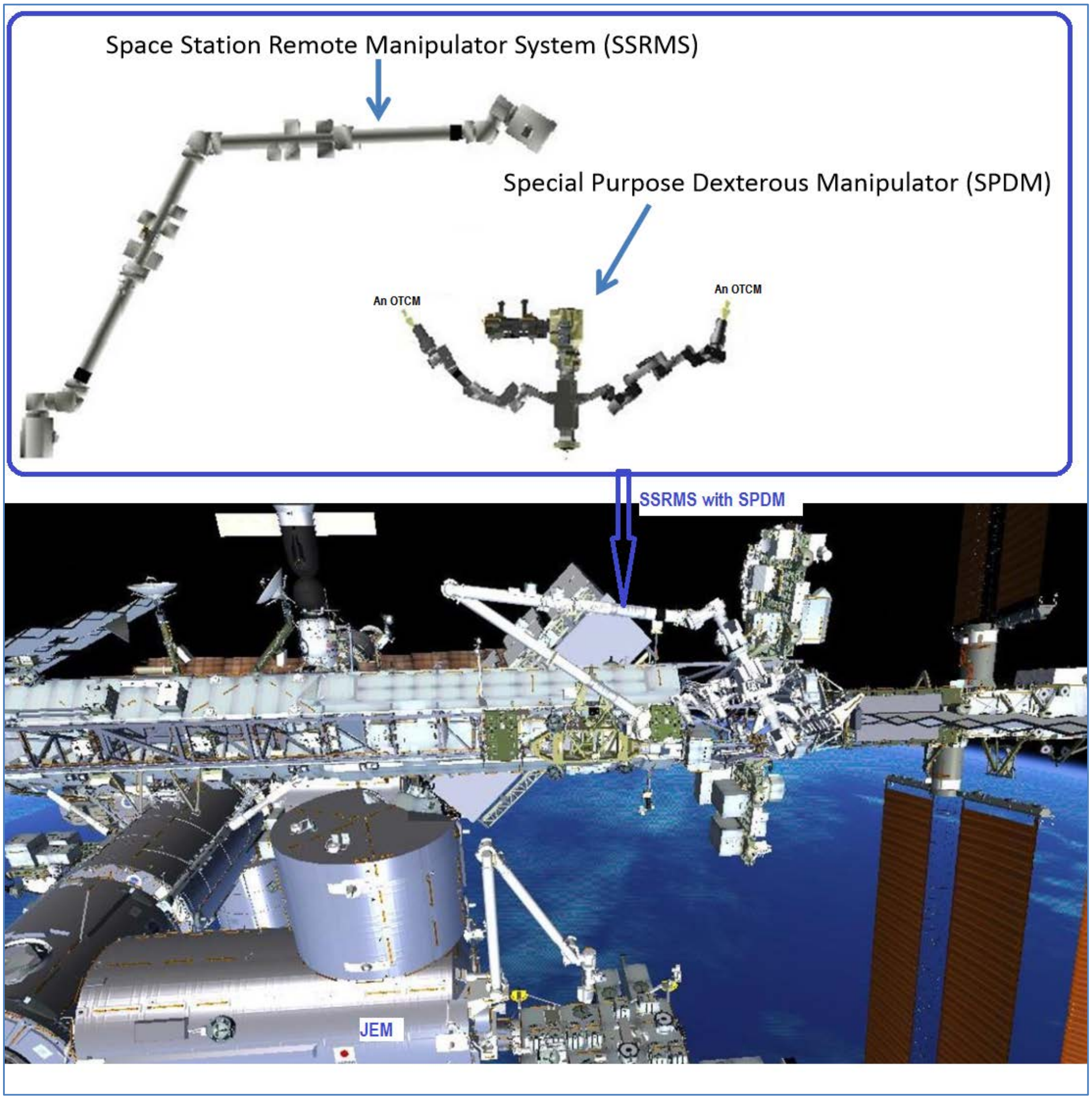

Figure 3.2.4.3-3: View of SRMS with SPDM OTCM in Relation to JEM

3.2.4.4 EVR Operations

The SSRMS SPDM OTCM grapples the NanoRacks Kaber Deployment System by the micro fixture and translates it to the pre-approved deployment position (pointed retrograde to the ISS). NASA controllers send the deployment command to the NRKDS via ISS CD&H backbone and then NRKDS deploys the satellite. Deployment of the satellite can be captured and recorded by ISS external cameras to verify good deployment.

3.3 NanoRacks Kaber Special Accommodations

The following sections list some optional accommodations that NanoRacks offers at additional cost. All special accommodations will be described in detail in the appropriate payload ICA.

3.3.1 NanoRacks Angled Frustum

The NRKDS may be customized to meet mission specific requirements. For example, satellites, which require the full linear distance within the JEM slide table envelope, are accommodated by an NRSS with an angled Kaber adapter plate built into the vestigial component as shown in **Figure 3.3.1-1**.

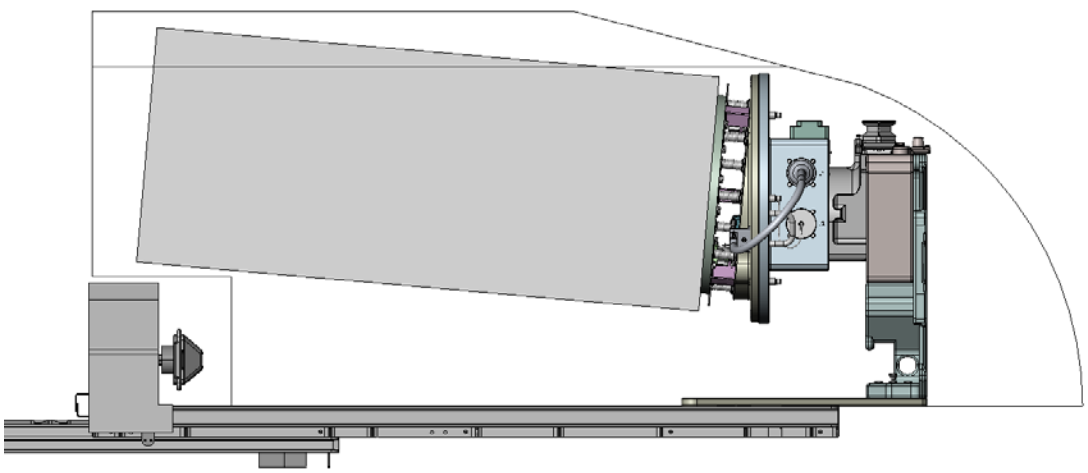

Figure 3.3.1-1: NRKDS with NRSS Angled Kaber Adapter Plate

3.3.2 NanoRacks Launch Container

The standard stowage configuration involves the satellite wrapped in bubble wrap and packed in a cargo bag. The NRKDS can be integrated with an optional NanoRacks provided mission specific Launch Container (see **Figure 3.3.2-1**) for satellites with special stowage requirements for transport on ISS visiting vehicles. The Launch Container in combination with an environmental and FOD control bag is utilized in lieu of removable protective covers over sensitive/frangible materials on the satellite exterior. The need for a NanoRacks Launch Container needs to be contractually documented in the ICA.

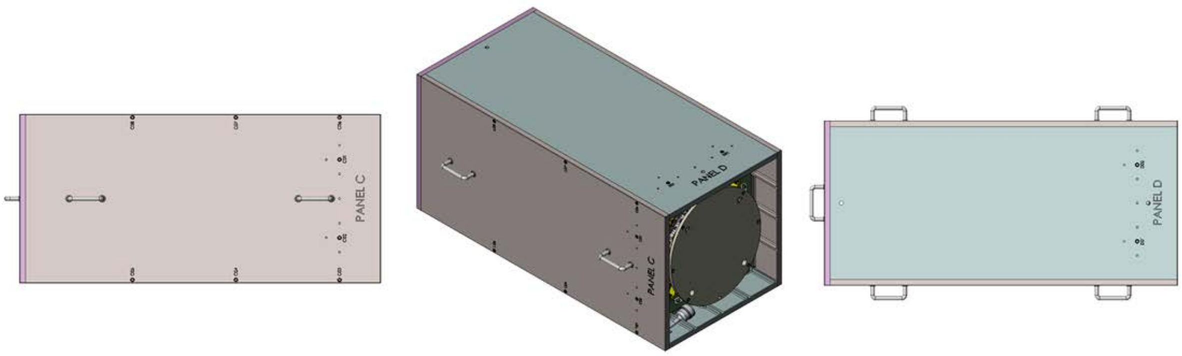

Figure 3.3.2-1: Satellite Payload with NRSS, in Launch Container

3.3.3 Alternative NRSS to Satellite Interfaces

The standard satellite interface is an 11.732 inch bolt circle comprised of eighteen ¼-28 bolts. Alternate bolt circle sizes and or NRSS to satellite attach methods will be defined in the payload unique ICA. Any unique electrical interfaces required by the payload will also be covered in the ICA.

4 Payload Interface Requirements

The requirements contained in this section will be complied with in order to certify a payload for integration into NRKDS as well as the ISS JEM module. This section is divided by the following disciplines: Structural and Mechanical, Electrical, Thermal Control, Environment, Materials and Processes, Human Factors.

4.1 Satellite Payload Physical Requirements

4.1.1 Mechanical Interface

The NRSS attaches to the satellite via an 11.732 inch bolt circle comprised of eighteen ¼-28 UNJF-3A bolts (**Figure 4.1.1-1**). The mating fasteners on the satellite should consist of ¼-28 nuts, nut plates, or threaded inserts that are thread locking and dry film lubricated. Alternate clocking can be considered and documented in the ICA.

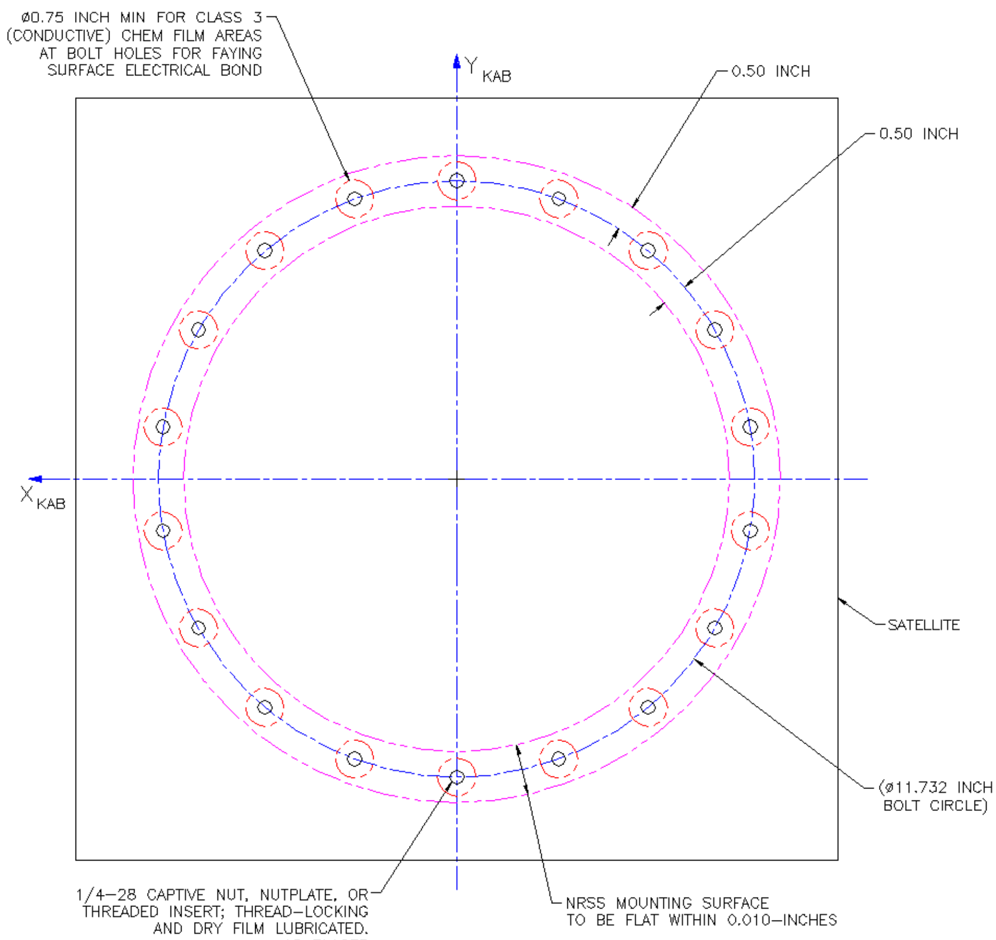

Figure 4.1.1-1: NRSS Bolt Hole Pattern Dimensions (view looking at base of satellite)

4.1.2 Mass Properties

The mass of the satellite, the separation system and the Kaber (26lb., 12.2kg) cannot exceed 220lb (100kg). Mass limits are further constrained by maximum ballistic number (BN) allowed for ISS deployed payloads. The maximum BN is dependent on separation velocity of the satellite summarized in **Table 4.1.2-1**. Exceeding overall mass or any combination of BN values requires approval by NanoRacks.

Table 42.1.2-1: Separation Velocity Relation to BN

Separation Velocity	BN (Kg/m^2)
≥ 0.5 m/sec	<= 120
< 0.5 m/sec	<= 100

Payload developers determine satellite BN using Equation 1:

$$BN = \frac{M}{C_d A_{avgp}}$$

Where M is satellite mass in Kg, C_d is the drag coefficient with value = 2 and A_{avgp} is the average projected area.

Average projected area is computed by Equation 2:

$$A_{avgp} = \frac{(A_1) + (A_2)}{2}$$

Where A_1 is area of the smallest face, and A_2 is area of the next smallest face.

4.1.3 Center of Gravity

The payload center of gravity is defined in **Figure 4.1.3-1**.

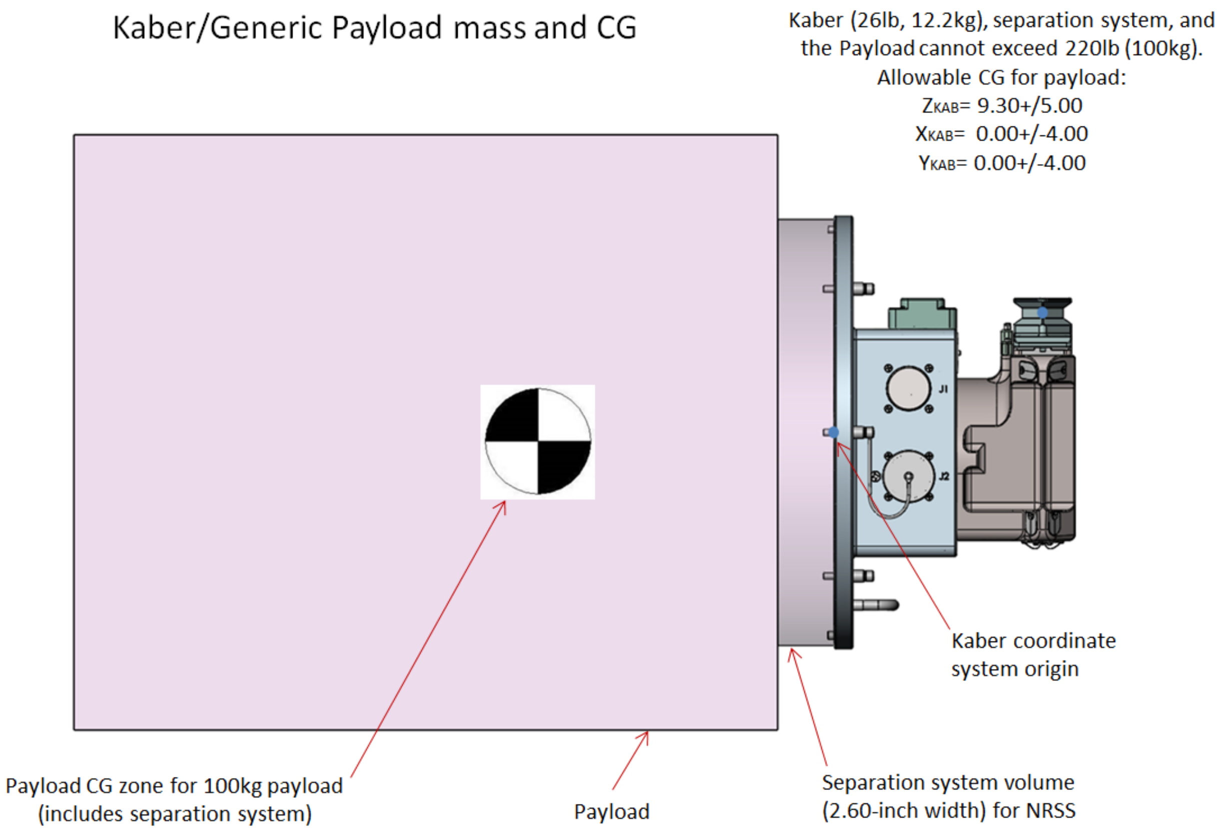

Figure 4.1.3-1: Kaber/Generic Payload CG

4.1.4 Allowed Envelope

Figure 4.1.4-1 and **4.1.4-2** show the dynamic envelope of the two slide table configurations as based on the dimensions and diagrams from NASDA-ESPC-2903-B. Note that these represent the maximum dynamic envelope. The payload should designed to be no closer than one inch from the maximum envelope dimensions shown. NanoRacks will perform the mission dynamic analysis to help verify the envelope requirements. .

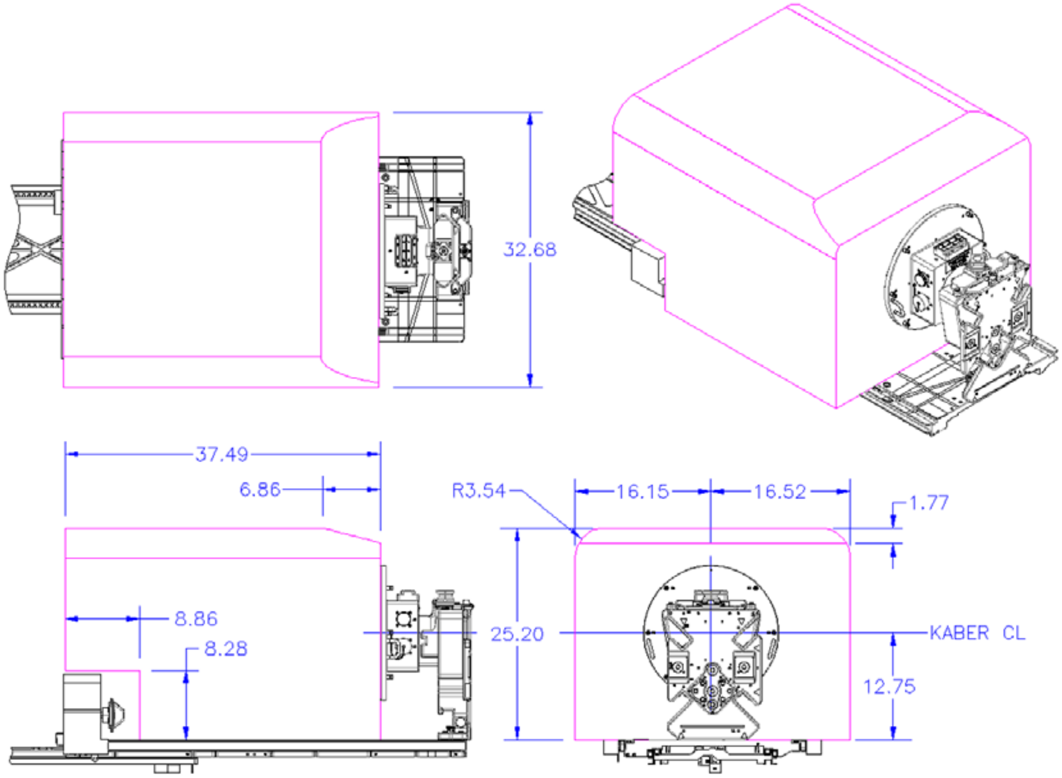

Figure 4.1.4-1: Kaber Payload Envelope with Standard JCAP (with units in inches)

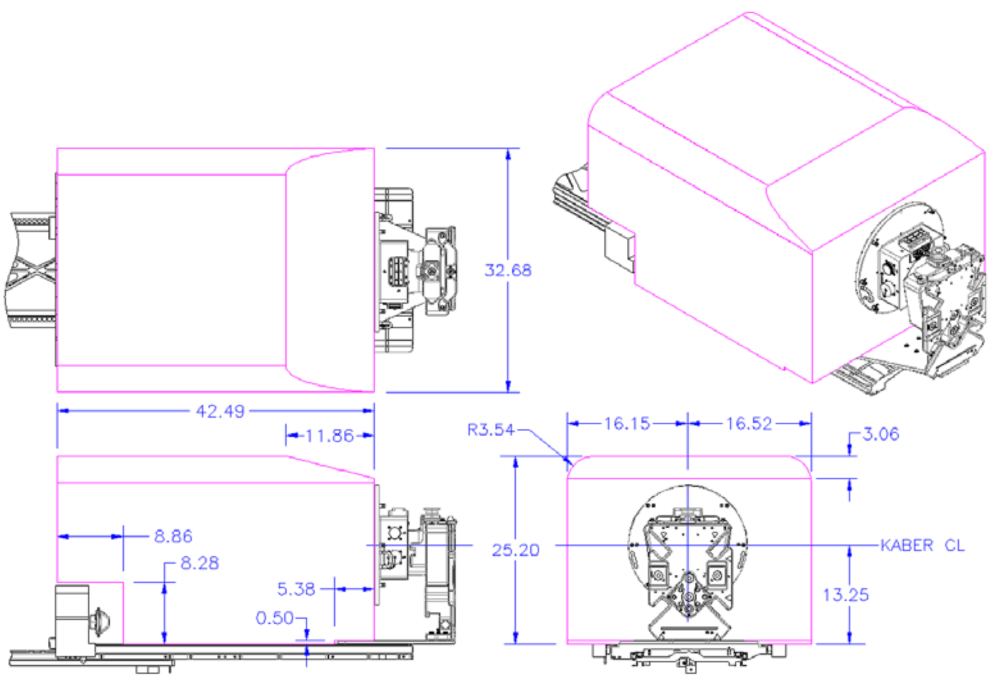

Figure 4.1.4-2: Kaber Payload Envelope with Slide Table Extension Plate (with units in inches)

4.1.5 Deployment Switches

The NRSS is equipped with three (3) mechanical deployment switches, for use by the satellite to signal that deployment has occurred. These switches are single pole double throw, and can be wired normally closed or normally open.

4.1.6 Deployment Compatibility

During deployment, the Satellites must be compatible with deployment velocities between 0.20 m/s to 1.5 m/s.

4.1.7 Tip Off Rates

Tip-off rates are mission-specific and the NRSS can be customized per customer requirements. Final system tip off rate is summation of contributions due to separation velocity, deployment platform stability (ISS MSS robotic SPDM), satellite deployment interface to separation system alignment, and separation system deployment vector off-set from satellite center of mass. This information will be documented in the ICA.

4.2 Satellite Electrical and Data Interfaces

4.2.1 Electrical System Design and Inhibits

All electrical power shall be internal to Satellites. Satellite electronics systems design shall adhere to the following requirements.

1) The Satellite operations shall not begin until a minimum of 30 minutes after deployment from the ISS. Only an onboard timer system may be operable during this 30-minute post deploy time frame.
2) The Satellite electrical system design shall incorporate a minimum of three (3) inhibit switches actuated by physical deployment switches as shown in Figure 4.2.1-1.
3) The Satellite electrical system design shall not permit the ground charge circuit to energize the satellite systems (load), including flight computer (see Figure 4.2.1-1). This restriction applies to all charging methods.
4) Remove Before Flight (RBF) pins are required. Arming switch or captive jumpers may be an acceptable alternative; contact NanoRacks.
5) The RBF pin shall preclude any power from any source operating any satellite functions with the exception of pre-integration battery charging.
6) RBF pins must be capable of remaining in place during integration with the NRSS.
7) All RBF pins, switches, or jumpers utilized as primary electrical system and RBF inhibits must be accessible for removal at the completion of flight integration with the NRSS.

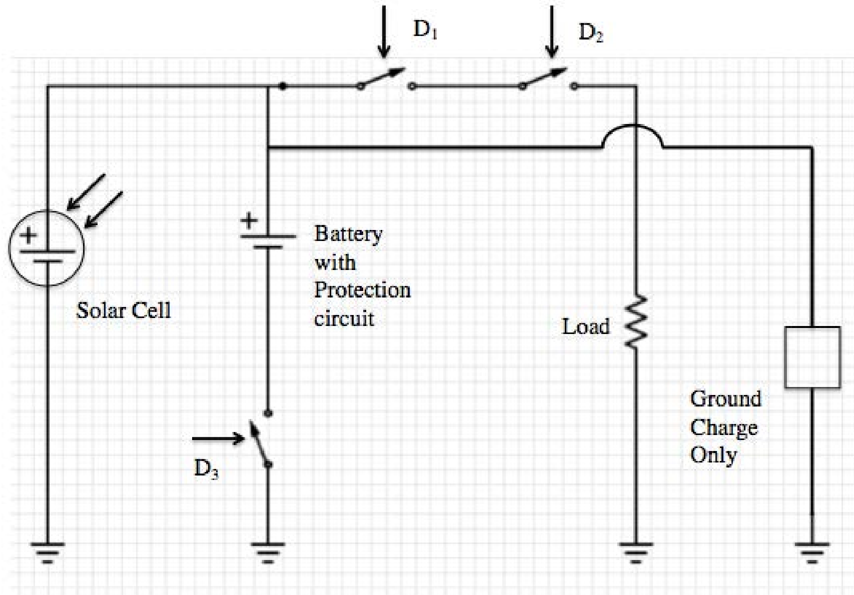

Figure 4.2.2: Satellite Electrical Subsystem Block Diagram (note: RBF pins not shown)

- Reference Example -

The Satellite electrical system design shall incorporate an appropriate number of inhibits dictated by hazard potential. See definitions above. For the purposes of this paragraph, an inhibit acts and power interrupt device and a control for an inhibit (electrical or software) cannot be counted as an inhibit or power interrupt device. Failure analysis may be required to determine the failure tolerance of systems where hazard potential exists.

4.2.1.1 Electrical System Interfaces

The electrical interface between the payload and the NRSS shall consist of electrical system inhibit wire leads connected to NanoRacks supplied separation switches as shown in **Figure 4.2.1.1-1**: **NRSS Electrical Separation Block Diagram**. Reference **Table 4.2.1.1-1** for the pin contacts' designated functions of the Fly-Away Plate J2 (D-Sub DE-9P style) Connector Jack mounted onto the "L-Bracket". The payload inhibit cable's mating P2 (D-Sub DE-9S Style) connecter plug shall be one of the following:

NASA/GSFC S-311-P-4/09 Specification Part Number: 311P409-1S-B-12 or

NASA/GSFC QVL/QVP = ITT Cannon Part Number: DEMA9SNMBK47FO or

NASA/GSFC QVL/QVP = TE Connectivity Part Number: 207253-2

The Socket Contacts' Designated Functions Table for the payload inhibits cable mating P2 D-Sub connector plug will be defined in the ICA.

Table 4.2.1.1-1: Fly-Away Plate J2 Connector Jack Pin Contact's Designated Functions

J2 D-Sub DE-9P Style Connector Jack NASA/GSFC S-311-P-4/09 Specification Part Number: 311P409-1P-B-12 or NASA/GSFC QVL/QVP = ITT Cannon Part Number: DEMA9PNMBK47FO or NASA/GSFC QVL/QVP = TE Connectivity Part Number: 207252-2		
Pin Contact #	**Designation**	**Function**
1	Limit Switch #1	Normally Closed (NC) Throw
2	Limit Switch #1	Pole
3	Limit Switch #1	Normally Open (NO) Throw
4	Limit Switch #2	Normally Closed (NC) Throw
5	Limit Switch #2	Pole
6	Limit Switch #2	Normally Open (NO) Throw
7	Limit Switch #3	Normally Closed (NC) Throw
8	Limit Switch #3	Pole
9	Limit Switch #3	Normally Open (NO) Throw

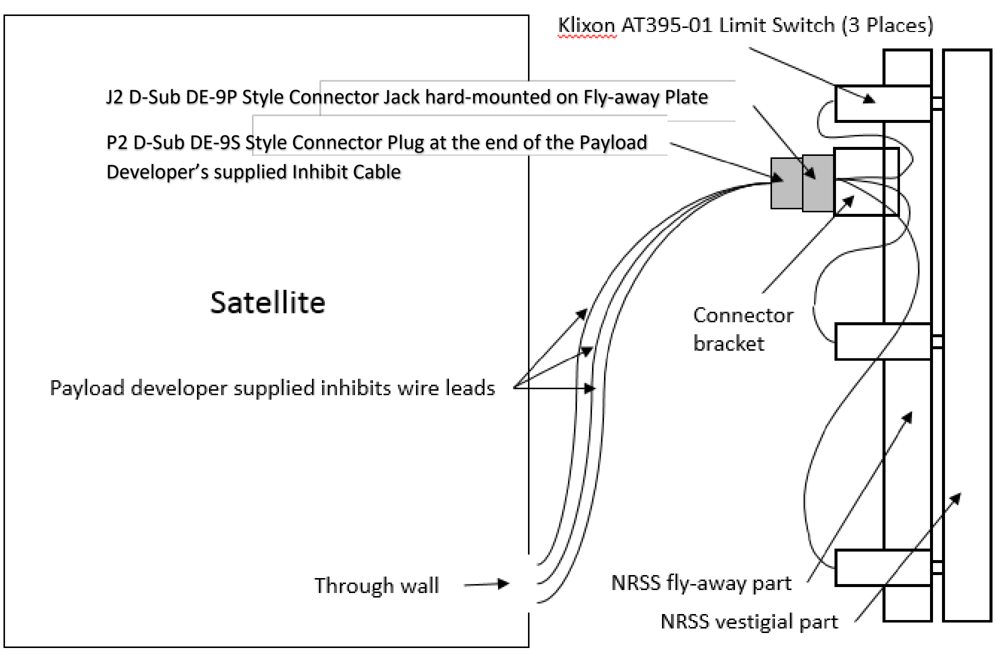

Figure 4.2.1.1-1: NRSS Electrical Separation Block Diagram

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.

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.

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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 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.

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, supporting 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 Deployment Loads Environment

Payloads utilizing the NanoRacks Separation System, shall withstand the deployment loads as defined in **Table 4.3.8-1**.

Due to damping effects, actual shock predicted for payloads is significantly less than shock generated at the Hold Down Release Mechanism retention bolt.

Table 4.3.8-1: NRSS Predicted Shock Values

Natural Frequency (Hz)	Peak Acceleration (g)
100	25
1,000	250
10,000	250

4.3.9 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.

Table 4.3.9-1: Expected Thermal Environments

Ref SSP 50835, Table E.2.10-1

Ground Transport (Customer facility to NanoRacks)	Determined for each payload
Ground Processing NanoRacks	Determined for each payload
Ground Processing NASA	10°C to 35°C (50°F to 95°F)
Dragon Pressurized Cargo	18.3°C to 29.4°C (65°F to 85°F)
Cygnus Pressurized Cargo	10°C to 46°C (50°F to 115°F)
On-orbit, Pre-deployment, U.S. and JEM Modules	16.7°C to 28.3°C (62°F to 83°F)
On-orbit, EVR deployment	To be analyzed by payload developer per ICA

4.3.10 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.

4.3.11 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 satellite design, unique requirements may be levied through the ICA between NanoRacks and the PD.

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.

Table 4.4.1-1: Requirements for Small Satellites Using the Kaber Service

#	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%	Inspection

Table 4.4.1-1: Requirements for Small Satellites Using the Kaber Service

	• >3.0 m at least each 0.5 meters	
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 closeout 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 tefzel (ETFE) or halar (EcTFE) with stainless steel locking device cable "zip" ties or cable clamps with teflon (PTFE) cushions 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 that 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 that 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 SSRMS use

SSP 51700 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 Space Station Remote Manipulator System (SSRMS).

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

- Structure Failure
    - Inability to sustain applied loads
    - Fracture
    - Stress corrosion
    - Mechanisms
    - Fastener integrity and secondary locking features
- Pressure System Failure
    - Explosion
    - Rupture
- Leakage of, or exposure to hazardous or toxic substances
- Propulsion system hazards
    - Including inadvertent operation
- Deployment of appendages
- RF system operation
- Battery Failure
- Flammable or toxic material usage
- Frangible material usage
- Electrical system failures causing shock or burn
    - Includes wiring, fusing, grounding
- EMI interference
- Magnetic field
- Collision with ISS including post deploy on subsequent orbits
    - Post deploy jettison policy
- Sharp edges, pinch points, and other touch hazards

    - IVA and EVA
    - Includes rotating equipment
- Operational procedures

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 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.

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.

4.5.3 Secondary Locking Feature

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.

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.

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.

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 actually manufactured. Cell/Battery testing associated with the verification of the safety compliance must be completed prior to safety certification of the spacecraft. To be compliant to the requirements herein, every battery design, along with its safety verification program, its ground and/or on-orbit usage plans, and its post-flight processing shall be evaluated and approved by the appropriate technical review panel in the given program or project.

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 maximizing 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 would 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 that 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 Propulsion System

The propulsion system will need to be assessed for hazard potential. NanoRacks will assist in the identification of hazards. Mechanical hazards may be related to pressure containment, flow containment, leakage, etc. Systems may also have hazard potential if inadvertent operation of the propulsion system in or around ISS could be catastrophic or critical. Depending on hazard potential, both mechanical and electrical fault tolerance may be required. Systems with toxic propellant may not be allowed onboard ISS but might be approvable if outside ISS. Propellants with explosive potential may not be approvable. Acceptable propellant type must be coordinated with NanoRacks and documented in the ICA.

4.5.10 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.

4.5.11 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.

4.5.12 Electrical Power

All electrical power shall be internal to Satellites. No provisions for battery charging are provided. Satellite systems must be safe without electrical services. Satellite electronics systems design shall adhere to the following requirements.

4.5.12.1 Hazardous Operations

The Satellite hazardous operations shall not begin until a minimum of 30 minutes after deployment from the ISS or until the hazardous operation is no longer in existence. Only an onboard timer system may be operable during this 30-minute post deploy time frame. Depending on the post deploy hazard potential, system failure tolerance may be required which might include fault tolerance in timer operations or post deploy sequencing.

4.5.12.2 Powered Operations

Following deployment, satellites shall not operate any system (including RF transmitters, deployment mechanisms or otherwise energize the main power system for a minimum of 30 minutes where hazard potential exists. Satellites shall must have a timer (set to a minimum of 30 minutes and require appropriate fault tolerance) before satellite operation or deployment of appendages where hazard potential exists. Satellite EPS inhibits must be utilized as hazard controls, and to initiate timer and other functions when a discrete separation signal is provided by the NRSS separation switches. Any timer operation initiated by satellite EPS inhibits must be automatically resetting should inadvertent separation switch operation occur.

4.5.12.3 Electrical Bonding

All spacecraft components shall be electrically bonded per SSP 30245 to ensure the spacecraft is free from electrical shock and static discharge hazards. Typically, spacecraft components may be bonded by either nickel plating or chemical film treated faying surfaces or dedicated bonding straps. A designated Single Point Ground shall be on the Payload's exterior conductive surface. NanoRacks will be authorized to access this Single Point Ground to perform electrical Bonding and Grounding tests after the mechanical and electrical mating/interfacing of the Fly-Away Plate to the Payload.

4.5.12.4 Solar Arrays

All solar arrays require the EPS design to use an inhibit to preclude flow of current from the solar arrays into the bus in the event they were illuminated at some point inside the ISS or prior to deploy where hazard potential is present.

4.5.12.5 Electrical System Inhibits

The Satellite electrical system design shall incorporate an appropriate number of inhibits dictated by hazard potential. See definitions above. For the purposes of this paragraph, an inhibit acts and power interrupt device and a control for an inhibit (electrical or software) cannot be counted as an inhibit or power interrupt device. Failure analysis may be required to determine the failure tolerance of systems where hazard potential exists.

4.6 Payload Jettison Requirements

NanoRacks will control (or have controlled) the deploy/jettison methods. However, payloads should be aware of the following criteria as a minimum. Special cases where post deploy collision controls necessitate other criteria are possible

4.6.1 Delta Velocity (Delta V)

Satellites with propulsion capability (including use for attitude control) require further assessment by NanoRacks. The full Delta V capability of the payload shall not raise the payload's apogee to less than 5 km DH relative to the ISS perigee. The payload developer shall submit an analytical analysis accounting for maximum theoretical Delta V capability using the equation below.

$\Delta v = -ISP*g*\ln(1 - m_p/m_0)$

Where ISP is the system highest specific impulse, m_p is the total propellant mass, m_o is satellite initial mass, and g = 9.8 m/sec.

4.7 Payload Document Deliverables

In addition to the payload specific ICA, payloads will be required to provide various documents and reports as described below. Due dates are No Later than dates for submittal to NASA for assessment. Dependent on satellite design, NanoRacks may impose earlier due dates to allow coordination with NASA Subject Matter Experts, and provide sufficient lead for the PLO in the event design changes are required.

Table 4.7-1: Deliverables

Item	Deliverable	Description	Date
1	Structural Verification Plan	NR to provide specific guidance but in general it is an outline of structural analysis, fracture control and structural testing requirements and those requirements will be verified.	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

Item	Deliverable	Description	Date
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
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	For safety inhibits part of the spacecraft EPS 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)	Typically no safety critical fasteners are part of payloads but will advise 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	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

Item	Deliverable	Description	Date
16	Final Satellite As-Measured Mass Properties	Weight, c.g., MOI and ballistic number	One Day prior to NanoRacks Delivery

5 Requirements Matrix

Table 5-1: Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1	**Physical Requirements**			**NVR**	
4.1.1	Mechanical Interface	The NRSS attaches to the satellite via an 11.732 inch bolt circle comprised of eighteen ¼-28 UNJF-3A bolts (**Figure 4.1.1-1**). The mating fasteners on the satellite should consist of ¼-28 nuts, nut plates, or threaded inserts that are thread locking and dry film lubricated. Alternate clocking can be considered and documented in the ICA.	A	I	Hardware Drawings
4.1.2	Mass Properties	The mass of the satellite, the separation system and the Kaber (26lb., 12.2kg) cannot exceed 220lb (100kg). Mass limits are further constrained by maximum ballistic number (BN) allowed for ISS deployed payloads. The maximum BN is dependent on separation velocity of the satellite summarized in **Table 4.1.2-1**. Exceeding overall mass or any combination of BN values requires approval by NanoRacks.	A	I	Table 4.6-1 #16
4.1.3	Center of Gravity	The payload center of gravity is defined in Figure 4.1.3-1.	A	A, I	Table 4.6-1 #16
4.1.4	Allowed Envelope	**Figure 4.1.4-1** and **4.1.4-2** show the dynamic envelope of the two slide table configurations as based on the dimensions and diagrams from NASDA-ESPC-2903-B. Note that these represent the maximum dynamic envelope. The payload	A	I	Hardware Drawings

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
		should designed to be no closer than one inch from the maximum envelope dimensions shown. NanoRacks will perform the mission dynamic analysis to help verify the envelope requirements.			
4.1.5	Deployment Switches	The NRSS is equipped with three (3) mechanical deployment switches, for use by the satellite to signal that deployment has occurred. These switches are single pole double throw, and can be wired normally closed or normally open.	A	I	Hardware Drawings
4.1.6	Deployment Compatibility	During deployment, the Satellites must be compatible with deployment velocities between 0.20 m/s to 1.5 m/s.	A	A	Table 4.6-1 #4
4.1.7	Tip-Off Rates	Tip-off rates are mission-specific and the NRSS can be customized per customer requirements. Final system tip off rate is summation of contributions due to separation velocity, deployment platform stability (ISS MSS robotic SPDM), satellite deployment interface to separation system alignment, and separation system deployment vector off-set from satellite center of mass. This information will be documented in the ICA	A	I	Table 4.6-1 #16
4.2	**Electrical and Data Interfaces**				
4.2.1	Electrical System Design	The electrical interface between the payload and the NRSS shall consist of electrical system inhibit wire leads connected to NanoRacks supplied separation switches (Figure 4.2.1.1-1). Reference Table 4.2.1.1-1 for the pin contacts' designated functions of the Fly-Away Plate J2 (D-Sub DE-9P style)	A	I	Dwg

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
		Connector Jack mounted onto the "L-Bracket". The payload inhibit cable's mating P2 (D-Sub DE-9S Style) connecter plug shall be one of the following: NASA/GSFC S-311-P-4/09 Specification Part Number: 311P409-1S-B-12 or NASA/GSFC QVL/QVP = ITT Cannon Part Number: DEMA9SNMBK47FO or NASA/GSFC QVL/QVP = TE Connectivity Part Number: 207253-2			
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	A	I	Table 4.6-1 #6

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
		in bubble wrap. Otherwise, test to the stowage requirements as set in the payload ICA.			
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	
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	A	A	Table 4.6-1 #4

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
		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.	A	A	Table 4.6-1 #4
4.3.8	Deployment Loads Environment	Payloads utilizing the NanoRacks Separation System, shall withstand the deployment loads as defined in **Table 4.3.8-1**. Due to damping effects actual shock predicted for payloads is significantly less than shock generated at the Hold Down Release Mechanism retention bolt.	A	A	Table 4.6-1 #4
4.3.9	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
4.3.10	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
4.3.11	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.	A	A, T	Table 4.6-1 #10, 11, 12

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
		Airlock Pressure: 0 to 104.8kPa Airlock pressure depressurization/re-pressurization rate: 1.0kPa/sec			
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

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
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

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
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	
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	A	T	Table 4.6-1 #14

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
		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 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
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	A	I	Hardware Drawings

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

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.9	Propulsion System	The propulsion system will need to be assessed for hazard potential. NanoRacks will assist in the identification of hazards. Mechanical hazards may be related to pressure containment, flow containment, leakage, etc. Systems may also have hazard potential if inadvertent operation of the propulsion system in or around ISS could be catastrophic or critical. Depending on hazard potential, both mechanical and electrical fault tolerance may be required. Systems with toxic propellant may not be allowed onboard ISS but might be approvable if outside ISS. Propellants with explosive potential may not be approvable. Acceptable propellant type must be coordinated with NanoRacks and documented in the ICA.	A	I	Hardware Drawings and Table 4.6-1 #2
4.5.10	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
4.5.11	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

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.12	Electrical Power			NVR	
4.5.12.1	Hazardous Operations	The Satellite hazardous operations shall not begin until a minimum of 30 minutes after deployment from the ISS or until the hazardous operation is no longer in existence. Only an onboard timer system may be operable during this 30-minute post deploy time frame. Depending on the post deploy hazard potential, system failure tolerance may be required which might include fault tolerance in timer operations or post deploy sequencing	A	I, T	Hardware Drawings and Table 4.6-1 #9
4.5.12.2	Powered Operations	Following deployment, satellites shall not operate any system (including RF transmitters, deployment mechanisms or otherwise energize the main power system for a minimum of 30 minutes where hazard potential exists. Satellites shall must have a timer (set to a minimum of 30 minutes and require appropriate fault tolerance) before satellite operation or deployment of appendages where hazard potential exists. Satellite EPS inhibits must be utilized as hazard controls, and to initiate timer and other functions when a discrete separation signal is provided by the NRSS separation switches. Any timer operation initiated by satellite EPS inhibits must be automatically resetting should inadvertent separation switch operation occur.	A	A	Hardware Drawings and Table 4.6-1 #9

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.5.12.3	Electrical Bonding	All spacecraft components shall be electrically bonded per SSP 30245 to ensure the spacecraft is free from electrical shock and static discharge hazards. Typically, spacecraft components may be bonded by either nickel plating or chemical film treated faying surfaces or dedicated bonding straps. A designated Single Point Ground shall be on the Payload's exterior conductive surface. NanoRacks will be authorized to access this Single Point Ground to perform electrical Bonding and Grounding tests after the mechanical and electrical mating/interfacing of the Fly-Away Plate to the Payload.	A	I, T	Hardware Drawings and Table 4.6-1 #9
4.5.12.4	Solar Arrays	All solar arrays require the EPS design to use an inhibit to preclude flow of current from the solar arrays into the bus in the event they were illuminated at some point inside the ISS or prior to deploy where hazard potential is present	A	I, T	Hardware Drawings and Table 4.6-1 #9
4.5.12.5	Electrical System Inhibits	The Satellite electrical system design shall incorporate an appropriate number of inhibits dictated by hazard potential. See definitions above. For the purposes of this paragraph, an inhibit acts and power interrupt device and a control for an inhibit (electrical or software) cannot be counted as an inhibit or power interrupt device. Failure analysis may be required to determine the failure tolerance of systems where hazard potential exists	A	I, T	Hardware Drawings and Table 4.6-1 #9
4.6	**Jettison Requirements**				

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.6.1	Delta Velocity	Satellites with propulsion capability (including use for attitude control) require further assessment by NanoRacks. The full Delta V capability of the payload shall not raise the payload's apogee to less than 5 km DH relative to the ISS perigee. The payload developer shall submit an analytical analysis accounting for maximum theoretical Delta V capability using the equation below. $\Delta v = -ISP*g*\ln(1 - m_p/m_0)$ Where ISP is the system highest specific impulse, m_p is the total propellant mass, m_o is satellite initial mass , and g = 9.8 m/sec.	A	A	Hardware Drawings and Table 4.6-1 #15