
NanoRacks External CubeSat Deployer (NRCSD-E) Interface Definition Document (IDD) 08/31/2018



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1 Introduction

1.1 Purpose

This Interface Definition Document (IDD) provides the minimum requirement set to verify compatibility of a small satellite with the NanoRacks External CubeSat Deployer system (NRCSD-E). This IDD includes all applicable International Space Station (ISS) and Cygnus flight safety and interface requirements for payload use of the NRCSD-E. NanoRacks verifies compliance to all applicable requirements directly to the ISS Program on behalf of the Payload Developer (PD) based on incremental data requests.

1.1.1 Scope

This IDD is the sole requirements document for end users of the NRCSD-E (the PD or the Customer). The physical, functional, and environmental design requirements associated with payload safety and interface compatibility for flight with the NRCSD-E are included herein. The requirements defined in this document apply to all phases of the mission leading up to the deployment of the payload from the NRCSD-E. In some circumstances, the design requirements outlined in this document also may govern the operational, post-deployment mission phase of the payload. The interface requirements defined herein primarily address the Payload to NRCSD-E interface, but also include requirements derived from ISS Program safety documentation and interface requirements documentation with Northrop Grumman.

1.2 Usage

This document levies design interface and verification requirements on PDs (i.e., NRCSD-E satellite customers). These requirements are allocated to a payload through the unique payload Interface Control Agreement (ICA). The unique payload ICA documents the payload compliance with the requirements defined in this IDD. The ICA is utilized as the documentation tool to capture requirements verification approaches, data submittals, schedule updates, and any required exceptions.

1.3 Exceptions

“Exception” shall be 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 the ICA and evaluated to ensure that the stated condition is controlled and acceptable. The ICA is revised throughout the payload design verification process and documents 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
BN	Ballistic Number
BoM	Bill of Materials
CD&H	Command Data & Handling
CMC	Cargo Mission Contract
CM	Center of Mass
CoC	Certificate of Compliance
COTS	Commercial Off-the-Shelf
CVCM	Collected Volatile Condensable Material
CTB	Cargo Transfer Bag
DFMR	Designed for Minimum Risk
DOT	Department of Transportation
EF	Exposed Facility
EPS	Electrical Power System
ESD	Electrostatic Discharge
ETFE	Ethylene tetrafluoroethylene
EVR	Extravehicular Robotics
FCC	Federal Communications Commission
FOD	Foreign Object Debris
GSE	Ground Support Equipment
HFIT	Human Factors Implementation Team
ICA	Interface Control Agreement
IDD	Interface Definition Document
I/F	Interface
ISS	International Space Station
ITU	International Telecommunication Union
JEM	Japanese Experiment Module
JEMRMS	Japanese Experiment Module Remote Manipulator System
JSC	Johnson Space Center
LCM	Launch Command Multiplexer
MLI	Multi-Layer Insulation
MEFL	Maximum Expected Flight Level



Acronym	Definition
MIUL	Materials Identification Usage List
MPEP	Multi-Purpose Experiment Platform
MSWG	Mechanical Systems Working Group
MWL	Minimum Workmanship Level
NASA	National Aeronautics and Space Administration
NLT	No Later Than
NOAA	National Oceanic and Atmospheric Administration
NRCSD	NanoRacks CubeSat Deployer
NRCSD-E	NanoRacks External CubeSat Deployer
NRDD	NanoRacks DoubleWide Deployer
NTIA	National Telecommunications and Information Administration
ODAR	Orbital Debris Assessment Report
OLR	Outgoing Longwave Radiation
PCM	Pressurized Cargo Module
PD	Payload Developer
POIF	Payload Operations Integration Function
PTC	Positive Temperature Coefficient
PTFE	Polytetrafluoroethylene
PSRP	Payload Safety Review Panel
RBF	Remove Before Flight
RH	Relative Humidity
RSS	Root Sum Square
RTC	Real-Time Clock
SDP	Safety Data Package
SE&I	Systems Engineering & Integration
SMA	Shape Memory Alloy
TIM	Technical Interchange Meeting
TML	Total Mass Loss
US	United States

Table 2-2: Applicable Documents

Doc No.	Rev	Title
JSC TA-92-038		Protection of Payload Electrical Power Circuits
JSC 20793	C	Crewed Space Vehicle Battery Safety Requirements
MSFC-SPEC-522	B	DESIGN CRITERIA FOR CONTROLLING STRESS CORROSION CRACKING
NASA-STD-8719.14A		NASA Technical Standard Process for Limiting Orbital Debris
NASDA-ESPC-2903-B	B	JEM Payload Accommodation Handbook Vol. 6 Airlock/Payload Standard Interface Control Document
SSP 30233	H	Space Station Requirements for Materials and Processes
SSP 30245	P	Space Station Electrical Bonding Requirements
SSP 42004	K	Mobile Servicing System (MSS) to User (Generic) Interface Control Document Part 1
SSP 50835	D	ISS Pressurized Volume Hardware Common 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 57000	R	Pressurized Payloads Interface Requirements Document
SSP 57003	L	External Payload Interface Requirements Document

3 NanoRacks External CubeSat Deployer System Overview

This section is an overview of the NanoRacks External CubeSat Deployer (NRCSD-E) system and describes the various system interfaces and the operational elements of the payload lifecycle. The payload interface requirements are captured in Section 4.

3.1 NRCSD-E Overview and Payload Capacity

The NRCSD-E (see Figure 3.1-1) is a self-contained CubeSat deployer system for small satellites staged from the Northrop Grumman Cygnus vehicle. The NRCSD-E is hard-mounted to the Cygnus vehicle on Panel 5 of the Service Module.

After performing resupply services to the ISS, the Cygnus vehicle ascends to a higher altitude and performs CubeSat deployment. Specific deployment altitude varies and is driven by propulsion budget requirements of the Cygnus program, and by conjunction analysis of the selected orbital altitude. Nominally, the altitude is around 450km.

The NRCSD-E is integrated with payloads on the ground at a NanoRacks facility prior to flight, and mechanically and electrically isolates CubeSats from the cargo resupply vehicles and the ISS. The NRCSD-E has six CubeSat silos, each capable of deploying 6U of volume, for a total of 36U.



Figure 3.1-1: NanoRacks External CubeSat Deployer (NRCSD-E)

3.2 NRCSD-E Coordinate System

The NRCSD-E coordinate system is defined in Figure 3.2-1 (location of origin not considered).



Figure 3.2-1: NRCSD-E Coordinate System

3.3 NRCSD-E Design Features

The NRCSD-E is composed of a rectangular dispenser, a Launch Control Multiplexer (LCM), and a circular adapter plate. Four (4) vertical rows and three (3) horizontal layers of anodized aluminum plates separate the dispenser into six (6) deployment “silos.” Each silo utilizes a base plate assembly combined with a pusher plate assembly and ejection spring (see Figure 3.3-1 and Figure 3.3-2). The three (3) deployer doors are located on the forward end (+Z face), the base plate assemblies are located on the aft end (-Z face), and the four (4) access panels are on the LCM side of the dispenser (-X face).

Each silo has eight (8) rails that interface with the payloads and constrain them in the X and Y axes. The inside walls of each silo are smooth bore design to minimize and/or preclude hang-up or jamming of CubeSat appendages during deployment should they be released prematurely. The LCM is attached to the -X face of the dispenser, and the adapter plate is attached to the -Y face.

The deployer doors of the NRCSD-E are held in place by five (5) non-explosive separation nut Hold-Down Release Mechanisms (HDRM). The middle door is held down by three (3) HDRM assemblies, while the side doors are each held by one (1). Electrical current is provided from the Cygnus to the LCM, which then individually energizes the HDRMs to release the door bolts. The middle door cannot open until all three separation nuts are energized.

On the -Z face, each silo of the NRCSD-E has a jack screw and jam nut assembly that allows the integrated payload subsystem to be preloaded and secured in the Z axis for flight. The NRCSD-E has access panels on the -X face that are removed on the ground for additional access during the payload fit-check and integration process. The access ports provide the only access for remove before flight (RBF) and apply before flight (ABF) features while the payloads are inside the NRCSD-E. The access panels are installed prior to handover for flight, and are never opened on-orbit by the ISS crew.

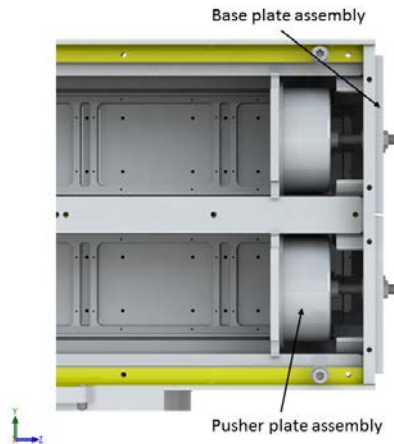


Figure 3.3-1: NanoRacks External CubeSat Deployer Design Features (Internal)

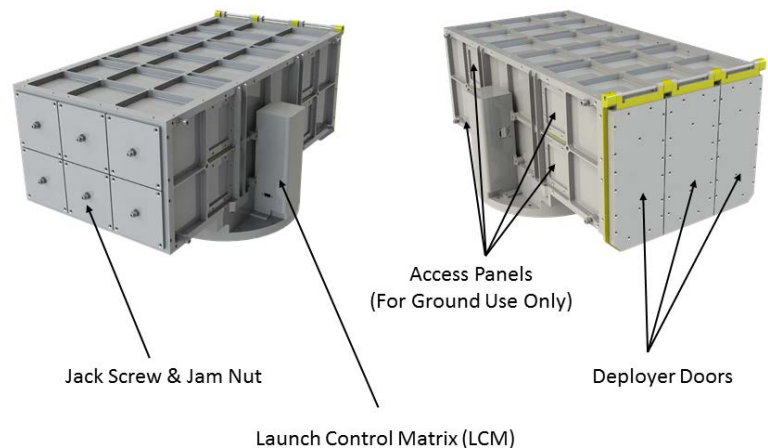


Figure 3.3-2: NanoRacks External CubeSat Deployer Design Features (External)

3.4 NRCSD-E Operations Overview

3.4.1 Schedule

Table 3.4.1-1 is a template schedule outlining the major safety and hardware milestones for payload developers (PDs). The majority of the schedule milestones are related to the phased ISS safety review process with the Payload Safety Review Panel (PSRP) and the associated data milestones. The detailed payload schedule is coordinated between NanoRacks and the PD and documented in the unique payload ICA.

Table 3.4.1-1: Template Milestone Schedule

Milestone/Activity	Launch-minus Dates (Months)
Feasibility Study/Contract Signing	L-12
Regulatory Compliance Initiation by PD (Spectrum Coordination, Remote Sensing)	L-12
NanoRacks/PD Kickoff Meeting	L-12
Interface Control Agreement (ICA) Initiation	L-12
NanoRacks/PD Safety Data Call Initiation	L-12
Baseline ICA	L-11
Phase 0/I Support Data from PD Complete	L-11
Phase 0/I Safety Data Package (SDP) Submittal to PSRP	L-10
NanoRacks/ISS Program Kickoff Meeting	L-9.5
Phase 0/I Safety Review	L-9
Phase 2 Support Data from PD Complete	L-8
Phase 2 SDP Submittal to PSRP	L-7
Phase 2 Safety Review	L-6
ICA Signed by PD and NanoRacks	L-6
CubeSat Fit-Check	L-5
Payload Environmental Testing	L-5
ISS Program Required Flight Acceptance Testing	L-5
Phase 3 Support Data from PD Complete	L-4.5
Phase 3 SDP Submittal to PSRP	L-4
Phase 3 Safety Review	L-3.5
Regulatory Licensing in Place	L-3.5
Payload Delivery to NanoRacks	L-31 Days
ENRSCD Installation on Cygnus	L-17 Days

3.4.2 Ground Operations

3.4.2.1 Mechanical Fit-Check

NanoRacks coordinates complete mechanical interface checks between the satellite and the NRCSD-E prior to final integration of the payload. Fit-checks are conducted with the hardware intended for flight. Use of flight-like hardware, such as an engineering model, in lieu of flight models must be coordinated with NanoRacks and documented in the ICA.

3.4.2.2 Delivery to NanoRacks

The PD delivers the complete payload to the NanoRacks Houston facility, or another facility as documented in the ICA, by the dates listed in the schedule for installation into the deployer. NanoRacks does not endorse any specific method to get the satellite to the integration site, but these are a few methods teams have used in the past: FedEx White Glove, buying an airline seat for the satellite, bringing the satellite as a carry-on, or driving the satellite.

Any special requirements, such as ground support equipment (GSE), special handling instructions, cleanliness requirements, humidity requirements, ESD sensitivity, etc., shall be documented in the payload-specific ICA. The PD is able, and encouraged, to oversee final integration of their CubeSat into the NRCSD-E.

3.4.2.3 NanoRacks Inspection

NanoRacks performs inspections of the payload to verify it meets the required safety and mechanical design requirements outlined in this IDD and the ICA. Typically, these requirements include, but are not limited to, mass properties and critical mechanical dimensions. This inspection takes place at the point of the fit-check and is repeated at the point that the payload is handed over to NanoRacks prior to final integration with the NRCSD-E. Note that any requirements that cannot be verified through inspection, measurement, and fit-check with the NRCSD-E must be verified via documentation and data submittals in advance of final payload delivery to NanoRacks.

3.4.2.4 Payload Developer Ground Servicing

The PD may perform payload activities at the NanoRacks facilities prior to final installation into the deployer, based on the agreements in the ICA, as long as these activities are within the scope of the documented and verified payload design. These payload activities may include post-shipment functional tests, battery charging, etc. Typically, these activities are completed prior to installation of the payload into the NRCSD-E.

Note that the only access to the payload after the installation is complete is via the NRCSD-E access ports on the -X face of the dispenser. No material or design changes shall be implemented at this phase of the processing. Once the payload has integrated into the NRCSD-E, no further payload servicing is permitted. The time between payload handover to NanoRacks and delivery to Wallops Flight Facility is nominally around 1-2 weeks. Any post-delivery payload activities besides standard post-shipment receive and inspect procedures must be coordinated in advance and documented in the payload-specific ICA.

3.4.2.5 NanoRacks Testing

Although not normally required for CubeSats, NanoRacks may perform testing of the CubeSat based on the agreements made in the unique payload ICA. This may include, but is not limited to, support of vibration tests utilizing NanoRacks GSE, final charging of the payloads, visual and mechanical inspections, etc.

3.4.2.6 NanoRacks Packaging and Delivery

Once the payloads are integrated into the NRCSD-E, NanoRacks delivers the completed NRCSD-E payload assembly to Wallops Flight Facility. The NRCSD-E is packaged with foam and bubble wrap inside a hard pelican case. The NRCSD-E is driven to WFF via a custom critical shipment inside a dedicated delivery vehicle. Upon arriving at WFF, the NRCSD-E is mounted directly onto panel 5 of the Cygnus service module. It remains in this configuration throughout the duration of the Cygnus mission. Installation onto the Cygnus nominally occurs 1-2 weeks after the satellites are integrated into the NRCSD-E, and about 30 days before launch. Any specific packing requirements or orientation constraints of payloads shall be captured in the unique payload ICA.

3.4.2.7 Delivery to Launch Site

NanoRacks is responsible for delivering the final stowed configuration to Wallops Flight Facility and for integrating the cargo onto the ISS visiting vehicle.

3.4.3 On-Orbit Environments, Interfaces, and Operations

3.4.3.1 NRCSD-E On-Orbit Environments

The NRCSD-E remains mounted to the Cygnus vehicle outside the ISS prior to deployment operation. As such, CubeSats should be designed to withstand exposure to extreme heat and cold cycling, vacuum, atomic oxygen, and high energy radiation. To avoid contaminating the ISS space environment, PDs should be very cognizant of their materials selection. See Section 4.4.9 for more information on materials selection.

3.4.3.2 NRCSD-E On-Orbit Interfaces

Externally mounted to the Cygnus vehicle, the NRCSD-E is exposed to the extra-vehicular environment of the ISS. The CubeSats are electrically isolated from the Cygnus, and only interface mechanically with the NRCSD-E. An example of the externally mounted NRCSD-E on-orbit interface is displayed below in Figure 3.4.3.2-1.

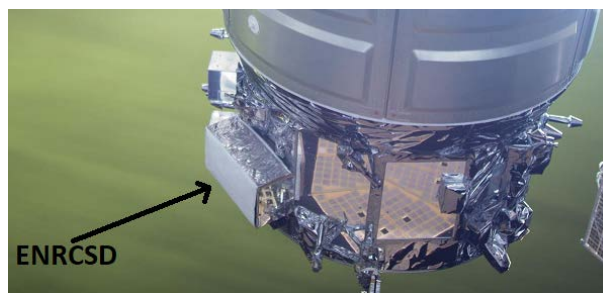
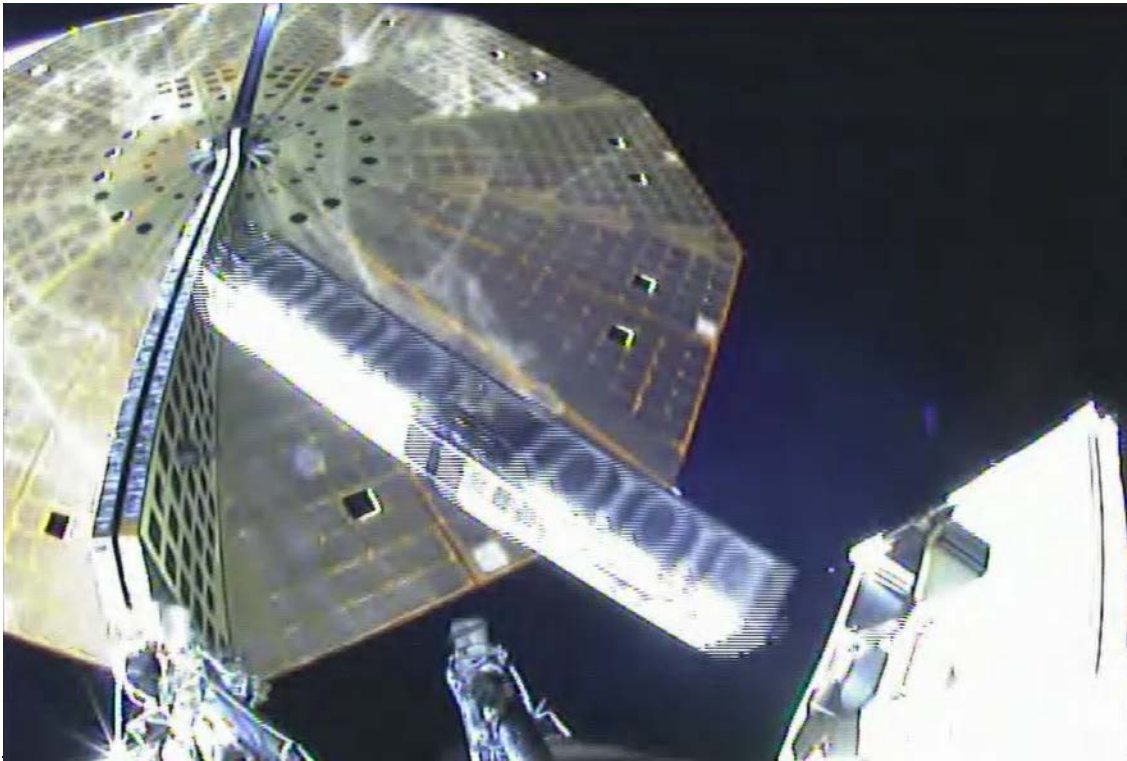


Figure 3.4.3.2-1: NRCSD-E On-Orbit

3.4.3.3 Deployment from Cygnus

After performing resupply and station keeping operations, the Cygnus vehicle un-berths from the International Space Station. CubeSat deployment from the NRCSD-E occurs prior to the destructive reentry of the Cygnus vehicle at an altitude above the ISS (specific altitude determined by Northrop Grumman pending programmatic decisions). Nominally, this new altitude is around 450km, but can range from 445km to 500km depending on Cygnus fuel capacity and conjunction analysis.

Cygnus operations are managed by Northrop Grumman ground controllers. Once a CubeSat deployment window has been established, ground controllers send the deployment command to the NRCSD-E. This deployment command electrically activates the three HRDMs restraining the middle door and deploys CubeSats from the two middle silos. There may be more than one CubeSat in a single silo, depending on the form factor and mission complement. Deployment of the satellite(s) is captured by Cygnus external cameras to verify good deployment (see Figure 3.4.3.3-2). After deploying the middle silos, ground controllers wait three hours before opening the next door, and so forth.



**Figure 3.4.3.3-2: NRCSD-E Deployment of Two (2) CubeSats from Cygnus
(Photo Credit: Northrop Grumman)**

4 Payload Interface Requirements

Compliance to the requirements contained in this section is necessary to certify the payload for integration into the NRCSD-E, launch, and stowage outside an ISS Cargo resupply vehicle. The requirements are presented in the following categories: Structural and Mechanical Systems, Electrical, Environmental, Safety, Jettison, and Documentation. In the event a requirement cannot be adhered to, exceptions are often possible depending on the nature of the noncompliance. All required exceptions and associated acceptance rationale shall be captured in the unique payload ICA.

4.1 Structural and Mechanical Systems Interface Requirements

The NRCSD-E is designed to house 6U of payloads in each of its six silos, for a total volume of 36U. It can accommodate any combination of CubeSats from 1U to 6U in length, up to a maximum volume of 6U in the 1x6x1U form factor. The only dimensional requirement that vary between the form factors is the total length (Z-axis dimension), which is specifically noted in the requirements herein. This section captures all mechanical and dimensional requirements to ensure the payloads interface correctly with the NRCSD-E and adjacent CubeSats.

4.1.1 CubeSat Mechanical Specification

- 1) The CubeSat shall have four (4) rails along the Z axis, one per corner of the payload envelope, which allow the payload to slide along the rail interface of the NRCSD as outlined in Figure 4.1.1-1.
- 2) The CubeSat rails and envelope shall adhere to the dimensional specification outlined in Figure 4.1.1-1.

Note: Any dimension followed by 'MIN' shall be considered a minimum dimensional requirement for that feature and any dimension followed by 'MAX' shall be considered a maximum dimensional requirement for that feature. Any dimension that has a required tolerance is specified in Figure 4.1.1-2. The optional cylindrical payload envelope (the "tuna can") must be approved for use by NanoRacks and special accommodations may be required if utilizing this feature.

- 3) Each CubeSat rail shall have a minimum width (X and Y faces) of 6mm.
- 4) The edges of the CubeSat rails shall have a radius of 0.5mm +/- 0.1mm.
- 5) The CubeSat +Z rail ends shall be completely bare and have a minimum surface area of 6mm x 6mm.

Note: This is to ensure that CubeSat +Z rail ends can serve as the mechanical interface for adjacent CubeSat deployment switches and springs.

- 6) The CubeSat rail ends (+/-Z) shall be coplanar with the other rail ends within +/- 0.1mm.
- 7) The CubeSat rail length (Z axis) shall be the following (+/- 0.1mm):
 - a. 1U rail length: 113.50mm
 - b. 2U rail length: 227.00mm



- c. 3U rail length: 340.50mm
- d. 4U rail length: 454.00mm
- e. 5U rail length: 567.5mm
- f. 6U rail length: 681 to 740.00mm

Note: Non-standard payload lengths may be considered. Any rail length differing from the above dimensions must be approved by NanoRacks and recorded in the payload unique ICA.

- 8) The CubeSat rails shall be continuous. No gaps, holes, fasteners, or any other features may be present along the length of the rails (Z-axis) in regions that contact the NRCSD-E rails.

Note: This does not apply to roller switches located within the rails. However, the roller switches must not impede the smooth motion of the rails across surfaces (NRCSD-E guide rails, fit gauge, etc.).

- 9) The *minimum* extension of the +/-Z CubeSat rails from the +/-Z CubeSat faces shall be 2mm.

Note: This means that the plane of the +/-Z rails shall have no less than 2mm clearance from any external feature on the +/-Z faces of the CubeSat (including solar panels, antennas, etc.).

- 10) The CubeSat rails shall be the only mechanical interface to the NRCSD-E in all axes (X, Y, and Z axes).

Note: For clarification, this means that if the satellite is moved in any direction while inside the NRCSD, the only contact points of the payload shall be on the rails or rail ends. *No appendages or any part of the satellite shall contact the walls of the deployer.*

- 11) The CubeSat rail surfaces that contact the NRCSD-E guide rails shall have a hardness equal to or greater than hard-anodized aluminum (Rockwell C 65-70).

Note: NanoRacks recommends a hard-anodized aluminum surface.

- 12) The CubeSat rails and all load points shall have a surface roughness of less than or equal to 1.6 μm (ISO Grade N7).

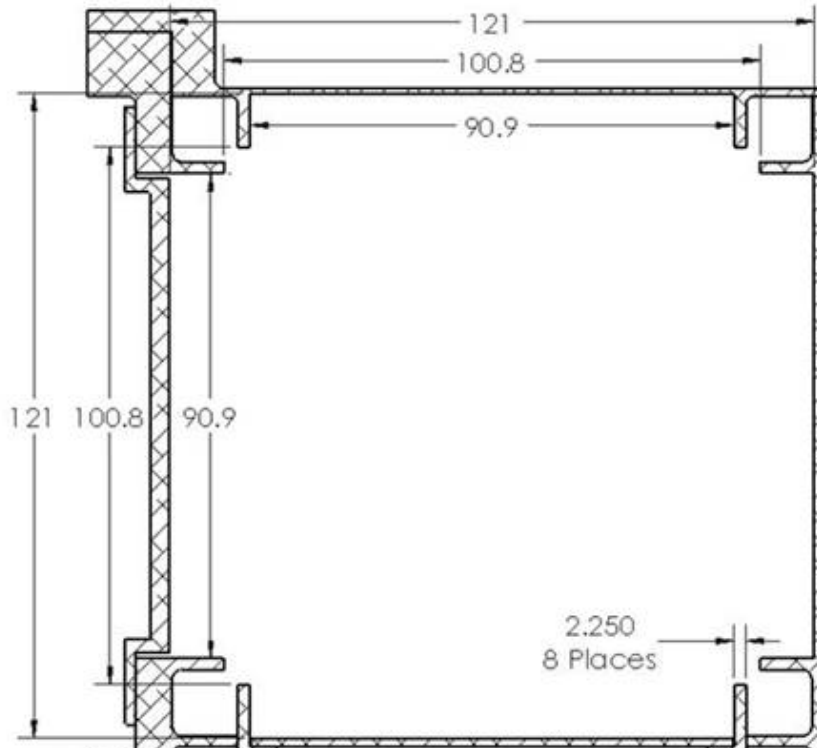


Figure 4.1.1-1: NRCSD-E Payload Mechanical Interface (Dimensions in mm)

CubeSat Z-axis Rail-to-Rail Maximum Dimensions

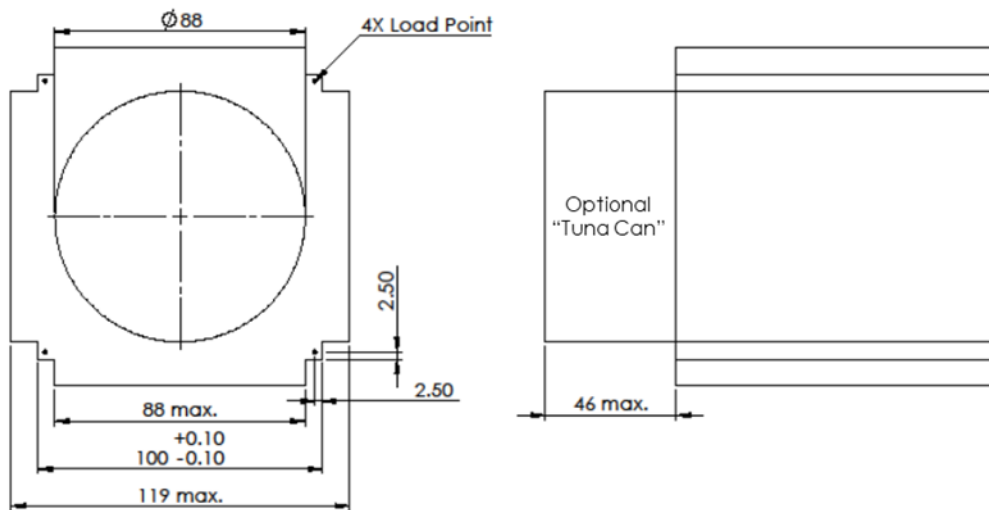
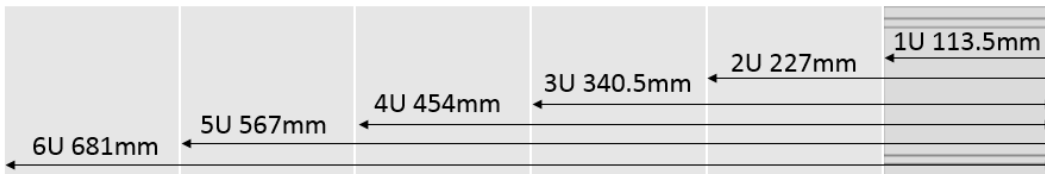


Figure 4.1.1-2: NRCSD-E Payload Envelope Specification (Dimensions in mm)

4.1.2 CubeSat Mass Properties

- 1) The CubeSat mass shall be less than the maximum allowable mass for each respective payload form factor per Table 4.1.2-1.

Note: The requirement driver for the CubeSat mass is the ballistic number (BN), which is dependent on the projected surface area of the payload on-orbit. The mass values in Table 4.1.2-1 assume no active or passive attitude control of the payload once deployed. If the CubeSat has attitude control capabilities or design features, then the operational ballistic number (BN) drives the mass requirement. If applicable, this shall be captured in the unique payload ICA.

Table 4.1.2-1: CubeSat Mass Limits

Form Factor	Maximum Mass (kg)
1U	2.40
2U	3.60
3U	4.80
4U	6.00
5U	7.20
6U	8.40

- 2) The CubeSat center of mass (CM) shall be located within the following range relative to the geometric center of the payload:
 - a. X-axis: (+/- 2cm)
 - b. Y-axis: (+/- 2cm)
 - c. Z-axis:
 - i. 1U: (+/- 2cm)
 - ii. 2U (+/- 4cm)
 - iii. 3U (+/- 6cm)
 - iv. 4U (+/- 8cm)
 - v. 5U (+/- 10cm)
 - vi. 6U (+/- 12cm)

4.1.3 RBF/ABF Access

- 1) The CubeSat shall have a remove before flight (RBF) feature that prevents the CubeSat from powering on when the inhibit switches are not depressed. The NRCSD-E has access ports only on the -X face of the dispenser. CubeSats in silos without the access panels should have timers implemented post RBF removal to prevent powering on of the spacecraft. The access port dimensions are defined in Figure 4.1.3-1.

Note: There is no physical access to the payload after integration into the NRCSD-E besides what can be accessed from the access ports.

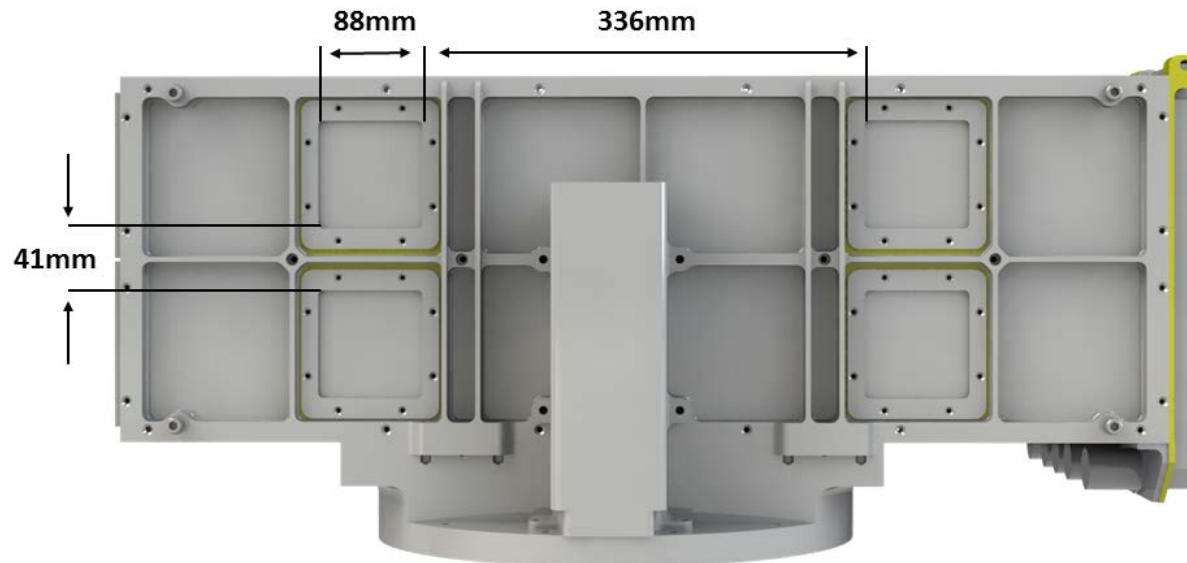


Figure 4.1.3-1: Payload Access Port Dimensions

4.1.4 Deployment Switches

- 1) The CubeSat shall have a minimum of three (3) deployment switches that correspond to independent electrical inhibits on the main power system (see section on electrical interfaces).
- 2) Deployment switches of the pusher/plunger variety shall be located on the rail end faces of the CubeSat's -Z face.
- 3) Deployment switches of the roller/lever variety shall be embedded in the CubeSat rails (+/- X or Y faces).
- 4) Roller/slider switches shall maintain a minimum of 75% surface area contact with the NRCSD-E rails (ratio of switch contact to NRCSD-E guide rail width) along the entire Z axis.
- 5) The CubeSat deployment switches shall reset the payload to the pre-launch state if cycled at any time within the first 30 minutes after the switches close (including but not limited to radio frequency transmission and deployable system timers).
- 6) The CubeSat deployment switches shall be captive.
- 7) The force exerted by the deployment switches shall not exceed 3N.
- 8) The total force of all CubeSat deployment switches shall not exceed 9N.

4.1.5 Deployable Systems and Integration Constraints

- 1) CubeSat deployable systems (such as solar arrays, antennas, payload booms, etc.) shall have independent restraint mechanisms that do not rely on the NRCSD-E dispenser.

Note: Passive deployables that release upon ejection of the CubeSat from the NRCSD are considered on a case-by-case basis.

- 2) The CubeSat shall be capable of being integrated forwards and backwards inside of the NRCSD (such that the +/-Z face could be deployed first without issue).

Note: In general, the deployables should be hinged towards the front of the deployer to mitigate risk of a hang-fire should the deployables be released prematurely while the CubeSat is still inside the NRCSD.

4.1.6 Deployment Velocity and Tip-Off Rate Compatibility

- 1) The CubeSat shall be capable of withstanding a deployment velocity of 0.5 to 2.5 m/s at ejection from the NRCSD-E.
- 2) The CubeSat shall be capable of withstanding up to 5 deg/sec/axis tipoff rate.

Note: The target tipoff rate of the NRCSD-E is less than 5 deg/sec/axis. Additional testing and analysis are being completed by NanoRacks to refine and verify this value. If a payload has specific tipoff rate requirements, these should be captured in the unique payload ICA.

4.2 Electrical System Interface Requirements

CubeSat electronic system designs shall adhere to the following requirements.

4.2.1 Electrical System Design and Inhibits

- 1) All electrical power storage devices shall be internal to the CubeSat.
- 2) To minimize hazard potential, the CubeSat shall not operate any system (including RF transmitters, deployment mechanisms or otherwise energize the main power system) for a minimum of 30 minutes after deployment. Satellites shall have a timer (set to a minimum of 30 minutes and requiring appropriate fault tolerance) before satellite operation or deployment of appendages.
- 3) The CubeSat electrical system design shall incorporate a minimum of three (3) independent inhibit switches actuated by physical deployment switches as shown in Figure 4.2.1-1. The satellite inhibit scheme shall include a ground leg inhibit (switch D3 in Figure 4.2.1-1) that disconnects the batteries along the power line from the negative terminal to ground.

Note: This requirement considers an inhibit as a power interrupt device, and a control for an inhibit (electrical or software) cannot be counted as an inhibit or power interrupt device. The requirement for three (3) inhibits is based on the worst-case assumption that the CubeSat contains a potential catastrophic hazard that exists in the event of an inadvertent power-up while inside the NRCSD-E. However, the electrical system design shall incorporate an appropriate number of inhibits dictated by the hazard potential of the payload. If this requirement cannot be met, a hazard assessment can be conducted by NanoRacks to determine if an exception can be granted and documented in the unique payload ICA.

- 4) The CubeSat 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.
- 5) The CubeSat shall have a remove before flight (RBF) feature or an apply before flight (ABF) feature that keeps the satellite in an unpowered state throughout the ground handling and integration process into the NRCSD-E.

Note: The RBF pin is required in addition to the three (3) inhibit switches. See Section 4.1.2 for details on mechanical access while the payload is inside the NRCSD-E.

- 6) The RBF/ABF feature shall preclude any power from any source operating any satellite functions with the exception of pre-integration battery charging.

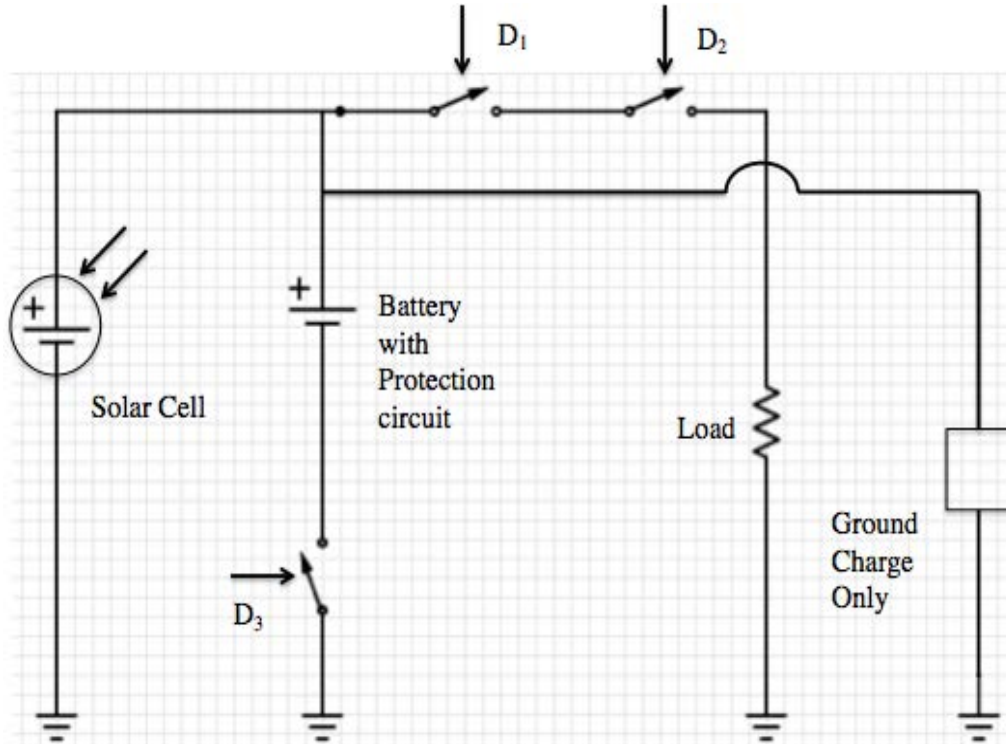


Figure 4.2.1-1: CubeSat Electrical Subsystem Block Diagram (Note: RBF pins not shown)

4.2.2 Electrical System Interfaces

- 1) There shall be no electrical or data interfaces between the CubeSat and the NRCSD-E. As outlined in Section 4.2, the CubeSat shall be completely inhibited while inside the NRCSD-E.

4.3 Environmental Interface Requirements

4.3.1 Acceleration Loads

- 1) 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.

Note: The acceleration values are applicable to both soft-stowed and hard-mounted hardware (Per SSP 57000, Section D.3.1.1). NanoRacks and the PD shall identify any safety critical structures in the unique payload ICA in order to determine what is required to verify this requirement. In general, all CubeSats structures are considered safety critical because failure of the CubeSat structure could produce untrackable space debris that could impact an ISS visiting vehicle (which is considered a catastrophic hazard by ISS Program).

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	+/- 7.0	+/- 4.0	+/- 4.0	+/- 13.5	+/- 13.5	+/- 13.5

Note: The RSS of Ny and Nz is +/- 1.8 g, which can be applied one axis at a time in combination with the Nx load.

4.3.2 Random Vibration Environment

- 1) The CubeSat shall be capable of withstanding the dynamic flight environment as outlined in Section 4.3.2.1.

Note: The test outlined below in Section 4.3.2.1 is based on the Cygnus to NanoRacks IRD '6354-GR5600'. Specific post-vibration test inspection records are required to verify all external components are properly installed and do not pose a hazard of coming loose. Additional post-test inspection records may be required depending on the hazard classification of the CubeSat. The verification plan and all required inspection records are documented in the unique payload ICA.

4.3.2.1 Random Vibration Test

The CubeSat shall be capable of withstanding the dynamic flight environment for the mission-applicable launch vehicle (shown in Table 4.3.2.1-1 through Table 4.3.2.1-4). Nominally, NRCSD-E missions are launched on the Antares rocket; however, Atlas V rockets have been utilized in the past.

Note: Test configuration is achieved by integrating the CubeSat into the NRCSD-E or a mechanically equivalent test fixture bolted directly to a vibration table.

Note: Launch loads vary based on launch vehicle. Contact NanoRacks to ensure these are the applicable loads for your mission.

Table 4.3.2.1-1: In-Plane Random Vibration Test Levels and Duration

Frequency (Hz)	ASD (g ² /Hz)
20	0.016
30	0.025
800	0.025
2000	0.016
grms	6.55
Duration	60

Table 4.3.2.1-2: Out-of-Plane Random Vibration Test Levels and Duration

Frequency (Hz)	ASD (g ² /Hz)
20	0.016
50	0.05
800	0.05
2000	0.016
grms	8.45
Duration	60

Table 4.3.2.1-3: In-Plane Sine Vibration Test Profiles

Frequency (Hz)	Levels (g's)
5	0.5 inch Double Amplitude (DA)
24	13.8
25	13.8
26	10.8
35	10.8
40	2.4
100	2.4
Sweep Rate	4 octave/minute

Table 4.3.2.1-4: Out-of-Plane Sine Vibration Profiles

Frequency (Hz)	ASD (g ² /Hz)
5	0.5 inch Double Amplitude (DA)
24	13.8
25	13.8
26	10.8
35	10.8
36	6.6
50	6.6
55	2.4
100	2.4
Sweep Rate	4 octave/minute

4.3.3 Launch Shock Environment

The CubeSat shall be capable of withstanding the shock environment shown in Table 4.3.3-1.

Table 4.3.3-1: Cygnus Shock Spectrum

CubeSat Deployer Shock Spectrum	
Frequency (Hz)	Protoflight Level (g)
100	40
500	494
1000	989
10000	989

Any mechanical or electrical components on the spacecraft that are highly sensitive to shock should be identified and assessed on a case-by-case basis as defined in the unique payload ICA.

4.3.4 Integrated Loads Environment

The CubeSat shall be capable of withstanding a force 1320N across all load points equally in the Z direction.

4.3.5 Thermal Environment

The CubeSat shall be capable of withstanding the expected thermal environments for all mission phases, which are enveloped by the on-orbit EVR phase prior to deployment. The expected thermal environments for all phases of the mission leading up to deployment are below in Table 4.3.5-1.

Note: The on-orbit temperature extremes for the EVR phase prior to deployment are considered worst-case extremes based on the results of the thermal analysis conducted for the NRCSD-E (see Figure 4.3.5-1). The thermal analysis was conducted based on worst-case atmospheric conditions that are expected to be exceeded no more than 0.5 percent of the time, with albedo and outgoing longwave radiation (OLR) adjusted to the top of the atmosphere (30 kilometer altitude) per SSP 41000 Table XXV.

Table 4.3.5-1: Expected Thermal Environments

Mission Phase	Temperature Extremes
Ground Transport (Customer facility to NanoRacks)	Determined for each payload
Ground Processing NanoRacks	Determined for each payload
Ground Processing NASA Envelope	10°C to 35°C
Pre-Deployment **extreme temperatures seen by the deployer**	-14°C to 44°C

Ref SSP 50835, Table E.2.10-1

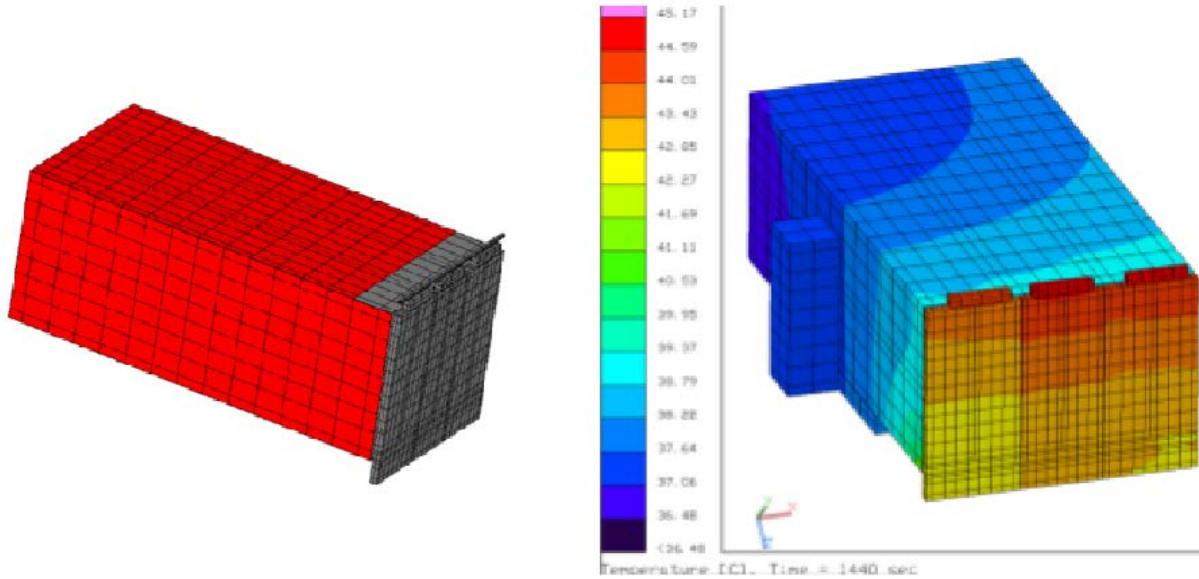


Figure 4.3.5-1: Thermal Analysis of NRCSD-E

During worst-case atmospheric conditions, the NRCSD-E sees temperature extremes at -14°C and +44°C. Analysis has not been conducted to determine what individual silos may experience. Any unique temperature requirements should be documented in the payload unique ICA.

4.4 Safety Requirements

CubeSats shall be designed to preclude or control all hazards present according to the requirements and guidelines outlined in this section. The following sections contain the specific safety requirements common to standard CubeSat designs. In many cases, though, the specific design requirements are dependent on the hazard classification of the CubeSat (particularly for CubeSats with non-standard design features). While NanoRacks is responsible for performing the hazard classification for all payloads (with ultimate concurrence from the ISS PSRP), the general guidelines of the process have been outlined below and should be considered background information for the PD.

In general, hazards are classified according to the following definitions:

1) Catastrophic Hazard Definition – Any condition that may result in the potential for:

- 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.

2) Critical Hazard Definition – Any condition that may result in:

- 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

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).

3) Marginal Hazard Definition – Any condition which may cause:

- Damage to an ISS element in a non-critical path
- Personal injury causing minor crew discomfort that does not require medical intervention from a second crewmember, and/or consultation with a Flight Surgeon

Some examples of CubeSat features/failures that are assessed for hazard potential are:

- 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 hazard to ISS hardware and crew
- Battery failure
- Flammable or toxic material usage
- Frangible material usage
- Electrical system failures causing shock or burn
 - Includes wiring, fusing, grounding
- Electromagnetic Interference (EMI)
- Magnetic field
- Collision with ISS or Visiting Vehicles post deploy on subsequent orbits
- Operational procedures

Control of hazards shall be appropriate for the hazard type and occurrence. Many CubeSat hazards are controlled by the deployer itself since the CubeSat is contained in the deployer while at ISS until deployment. Some examples of other controls are:

- Structural hazards
 - Application of factor of safety with positive margin
 - Supports design for minimum risk
 - Fault tolerance where applicable
 - Controlled by remaining elements not failing under resulting load
 - Redundant mechanisms
- Electrically operated systems
 - Inhibits to control inadvertent operations appropriate to the hazard level
 - Redundancy as necessary to perform required functions
 - Design controls

- Leakage of toxic substances
 - Fault tolerance in seals
 - Structural strength of containers
 - Multiple levels of containment
- Flammable materials
 - Elimination of flammable materials
 - Containment
 - Wire sizing and fusing
- Pressure systems
 - Factor of safety
 - Venting
- 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
 - Separation to prevent thermal runaway propagation
 - Screening and testing

4.4.1 Containment of Frangible Materials

The CubeSat design shall preclude the release or generation of any foreign object debris (FOD) for all mission phases. Integrity of these materials are verified during flight acceptance vibration testing of the satellite.

Note: The primary concern is exposed frangible materials on the satellite exterior (solar cell cover glass, optical lenses, etc.). For most frangible materials on CubeSats, a containment or protection method is not required (however all frangible materials shall be identified in the payload unique ICA for NanoRacks review).

4.4.2 Venting

The Maximum Effective Vent Ratio (MEVR) of the CubeSat structure and any enclosed containers internal to the CubeSat shall not exceed 5080cm.

The MEVR is calculated as follows:

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

Effective vent area shall be considered as the summation of the unobstructed surface area of any vent hole locations or cross-sectional regions that air could escape the CubeSat or subsystems.

4.4.3 Secondary Locking Feature

The CubeSat shall have an approved secondary locking feature for any and all fasteners or subcomponents external to the CubeSat chassis that would not be held captive by the spacecraft structure should it come loose.

Note: The measured and recorded fastener torque is considered the primary locking feature for fasteners. Mechanical or liquid locking compounds are approved. Mechanical secondary locking features are preferred and may be either a locking receptacle such as a locking helical insert or locknut. Approved thread locking compounds include Loctite® Threadlocker Red 271™ and Blue 242™. Contact NanoRacks to determine what other commonly used locking compounds have been approved for use and for appropriate application instructions. The secondary locking feature for all external fasteners and the application procedure of all liquid locking compounds shall be approved by NanoRacks and documented in the unique payload ICA.

4.4.4 Passivity

The CubeSat shall be passive and self-contained from the time of integration up to the time of deployment.

Note: No charging of batteries or support services are provided after final integration.

4.4.5 Pyrotechnics

The CubeSat shall not contain any pyrotechnics unless the design approach is approved by NanoRacks.

Note: Electrically operated melt-wire systems for deployables that are necessary controls for hazard potentials are permitted.

4.4.6 Space Debris Compliance

- 1) CubeSats shall not have detachable parts during launch or normal mission operations. Any exceptions are coordinated with NanoRacks and documented in the unique payload ICA.
- 2) CubeSats shall comply with NASA space debris mitigation guidelines as documented in NASA Technical Standard NASA-STD-8719.14A.

4.4.7 Batteries

All cells and batteries on the CubeSat shall adhere to the design and testing requirements for spacecraft flight onboard or near the ISS as derived from the NASA requirement document JSC 20793 Crewed Space Vehicle Battery Safety Requirements. Specific provisions for battery use are designed to ensure that a battery is safe for ground personnel and ISS crew members to handle and operate during all applicable mission phases, particularly in the enclosed environment of a crewed space vehicle. These NASA provisions also ensure 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. 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 ensure the necessary safety features are present to control the hazards associated with a particular battery design and to identify all necessary verifications and testing required (as documented in the unique payload ICA). Redesign efforts greatly impact the PD both in cost and schedule. Consult with NanoRacks before hardware is manufactured. Cell/battery testing associated with the verification of the safety compliance shall be completed as part of the safety certification of the spacecraft. To comply with 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 and captured in the unique payload ICA.

4.4.7.1 Battery Hazards

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

Potential battery hazards:

- Fire/explosion/flammability
- Venting/burst of battery enclosure
- Overcharge failure/over-discharge failure
- External short circuit
- Internal short circuit failure
- Thermal runaway propagation/extreme temperature hazards
- Chemical exposure hazards

4.4.7.2 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 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 require coordination with NanoRacks.

4.4.7.3 *Required Battery Flight Acceptance Testing*

All flight cells and battery packs shall be subjected to an approved set of acceptance screening tests to ensure the cells are able to perform in the required load and environment without leakage or failure. While the specific test procedures vary depending on the type of battery, the majority of lithium ion or lithium polymer cells or batteries used in CubeSats can be tested to a standard statement of work issued by NanoRacks (NR-SRD-139). Some generic battery design requirements are outlined below.

Note: The battery test plan and verification approach shall be captured in the payload unique ICA. No testing shall be performed without the approval of NanoRacks.

4.4.7.4 *Internal Short*

Protection circuitry and safety features shall be implemented at the cell level to prevent an internal short circuit.

- Application of all cells shall be reviewed by NanoRacks.
- Charger circuit and protection circuit schematics shall be reviewed and evaluated for required fault tolerance.

4.4.7.5 *External Short*

Protection circuitry and safety features shall be implemented at the cell level to prevent an external short circuit.

- Circuit interrupters that are rated well below the battery's peak current source capability shall be installed in the battery power circuit. Interrupters may be fuses, circuit breakers, thermal switches, positive temperature coefficient (PTC) thermistors, or other effective devices. Circuit interrupters other than fuses shall be rated at a value 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 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 allows, maximizing the zone of protection.
- All inner surfaces of metal battery enclosures should be anodized and/or coated with a non-electrically conductive electrolyte-resistant paint to prevent a subsequent short circuit hazard (if applicable).
- The surfaces of battery terminals on the outside of the battery case should be protected from accidental bridging.
- Battery terminals that pass through metal battery enclosures should be insulated from the case by an insulating collar or other effective means.

- Wires inside the battery case should 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.

4.4.7.6 Overvoltage and Undervoltage Protection

Protection circuitry and safety features shall be implemented at the cell level to prevent overvoltage or undervoltage conditions of the cell.

4.4.7.7 Battery Charging

It should be verified that the battery charging equipment (if not the dedicated charger) has at least two levels of control that prevent it from causing a hazardous condition on the battery being charged.

Note: This does not apply if the CubeSat will not be charged at NanoRacks.

4.4.7.8 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.

Note: Any system over 80 Wh requires additional design scrutiny and testing (likely including destructive thermal runaway testing). It is possible that this additional testing may be avoided by implementing design features in the system, such as splitting up the cells into distinct battery packs less than 80 Wh and physically isolating them at opposite ends of the CubeSat (so that thermal runaway cannot propagate between packs). Other methods such as reducing the state of charge of the batteries at the time of delivery can be explored with the JSC Battery Safety team to reduce the risk of a thermal runaway event.

4.4.7.9 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.

4.4.7.10 Button Cells

Button cell or coin cell batteries often are used in COTS components to power real-time clocks (RTCs), watch-dog circuits, or secondary systems for navigation, communication, or attitude control. These batteries shall be clearly identified by part number and UL listed or equivalent.

Note: Flight acceptance screening testing of these cells typically is not required; only a functional test of the system needs to be reported. NanoRacks confirms requirements upon documentation of all coin cell part numbers in the unique payload ICA.

4.4.7.11 Capacitors Used as Energy Storage Devices

Capacitors are used throughout today's modern electronics. Capacitors used as energy storage devices are treated and reviewed like batteries. Hazards associated with leaking electrolyte can be avoided by using solid-state capacitors. Any wet capacitors that utilize liquid electrolyte must be reported to NASA. The capacitor part number and electrolyte must be identified, along with details of how the capacitor is used and any associated schematics.

Note: NanoRacks will advise on any required flight acceptance screening testing once the information has been captured in the payload unique ICA.

4.4.7.12 Pressure Vessels

A pressure vessel is defined by SSP 52005 as any sealed container with an internal pressure greater than 100 psia. A pressure vessel may be made acceptable for flight safety with proper controls for any hazard potential both for inside ISS and outside ISS. If a satellite has a pressure vessel, the PD shall provide documentation with respect to the materials used, tank history (including cycles and life time assessment) and control measures taken to ensure 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 certified by the Department of Transportation (DOT) or have a DOT-issued waiver for transportation across the US. Use of non-DOT certified pressure vessels generally is not permitted. Exceptions must be coordinated with NanoRacks during the pre-contract signing phase. Systems must demonstrate via test that required factors of safety are present for tanks, lines, and fittings that can be exposed to pressure with one or two failures depending on hazard potential.

Pressure vessels and components procured from third-party vendors must have proper certification records or the PD must develop the appropriate records to ensure that the systems are safe by meeting NASA requirements. NanoRacks assists in negotiating with NASA to define the work and analysis necessary to meet the NASA requirements.

4.4.8 Propulsion System

The propulsion system must be assessed for hazard potential. NanoRacks assists in the identification of hazards. Mechanical hazards may be related to pressure containment, flow containment, leakage, etc. Systems also may 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.

Propellants with explosive potential may not be approvable. Acceptable propellant type must be coordinated with NanoRacks and documented in the ICA.

4.4.9 Materials

4.4.9.1 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.

4.4.9.2 Hazardous Materials

Satellites shall comply with NASA guidelines for hazardous materials. Beryllium, cadmium, mercury, silver and other materials prohibited by SSP-30233 shall not be used.

4.4.9.3 Outgassing/External Contamination

Satellites shall comply with NASA guidelines for selecting all non-metallic materials based on available outgassing data. Satellites shall not utilize any non-metallic materials with a Total Mass Loss (TML) greater than 1.0 percent or a Collected Volatile Condensable Material (CVCM) value of greater than 0.1 percent.

Since the satellite will be in close proximity to the ISS for anywhere from 21-90 days, a more thorough outgassing analysis is performed. This outgassing analysis, performed by the ISS Space Environments group, uses ASTM 1559 data to characterize any potential material issues.

Note: A Bill of Materials (BoM) must be provided to NanoRacks to verify all materials requirements are met. The BoM shall be provided in the template specified by NanoRacks, and must include the vacuum-exposed surface areas of all non-metals. The ISS Space Environments Team screens the BoMs to ensure there are no external contamination concerns due to high-outgassing components. A bake-out is not required.

The NASA website linked below is a useful source for obtaining outgassing data for materials.

<https://outgassing.nasa.gov/>

4.4.9.4 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.

4.5 Jettison Requirements

The insertion parameters of the CubeSat are dictated by the NRCSD-E, and therefore the jettison approval process is coordinated by NanoRacks based on inputs provided by the PD. However, payloads should be aware of the following criteria as a minimum. Special cases where post deploy collision controls necessitate other criteria are possible.

Each satellite deployed from the Cygnus spacecraft needs to receive jettison approval before deployment. Additionally, customers seeking FCC licenses may need jettison approval before the FCC will grant the PD a license to transmit.

4.5.1 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 5km DH relative to the ISS perigee. The PD shall submit an 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_0 is satellite initial mass,
and $g = 9.8m/sec$.

Note: The information above is just so that NanoRacks can characterize the capabilities of any propulsion system. All propulsion systems are subject to a compatibility assessment with the ISS Program prior to manifesting for flight.

4.5.2 Re-Entry Survivability

- 1) CubeSats over 5kg shall provide an Orbital Debris Assessment Report (ODAR) that verifies compliance with NASA-STD-8719.14.
- 2) CubeSats that are designed to survive re-entry or have components that are designed to survive re-entry shall provide an ODAR that verifies compliance with NASA-STD-8719.14.

Note: Any payload that is designed to survive re-entry may require additional data submittals or justification that are handled on a case-by-case basis and documented in the payload unique ICA.

4.6 Documentation Requirements

4.6.1 Regulatory Compliance

The CubeSat developer shall submit evidence of all regulatory compliance for spectrum utilization and remote sensing platforms prior to handover of the payload. This evidence shall come in the form of the authorization or license grant issued directly from the governing body or agency (which is dependent on the country where the CubeSat originates).

Note: NanoRacks is not responsible for facilitating the licensure effort for spectrum and remote sensing authorization, but is required to provide ISS Program with proof of compliance prior to delivering the payload for launch.

For United States (US) CubeSats, the governing body for spectrum authorization is the Federal Communications Commission (FCC) unless the payload is government owned and operated, in which case the regulatory body is the National Telecommunications and Information Administration (NTIA). The governing body for US CubeSats with remote sensing platforms is the National Oceanic and Atmospheric Administration (NOAA), which is not required if the payload is government owned and operated.

For non-US CubeSats, proof of regulatory compliance with appropriate domestic agencies and the International Telecommunication Union (ITU) coordination details shall be provided.

NanoRacks is not responsible for facilitating the licensure effort, but is required to provide ISS Program with proof of compliance prior to delivering the payload for launch.

4.6.2 Documentation

In addition to the payload unique ICA, payload providers are required to provide various documents and reports to progress through the flight safety and verification process. Table 4.6.2-1 captures the major documents that are required. Note that the deliverables outlined below may not apply to all payloads and in turn additional documentation required at the discretion of NanoRacks. The required documentation for verification shall be captured in the unique payload ICA.

Table 4.6.2-1: Data Deliverables

Item	Deliverable	Description
1	Safety Data Template	Summary of Satellite Design. Requires filling in NanoRacks template with basic satellite design information appropriate for processing the satellite through the Safety Review Process.
2	Structural Analysis	NR provides specific guidance on what is required depending on the hazard classification of the payload.
3	Bill of Materials	Utilized for external outgassing contamination assessment and formation of Materials Identification Usage List (MIUL).
4	Vibration Test Report	Integrated test report outlining test set-up, as-run accelerometer response plots, and post-vibration functional and inspection results.
5	Inspection Reports for fracture critical parts	If any parts are determined to be fracture critical.
6	Inspection Reports for stress corrosion parts	If any parts are determined to be stress corrosion sensitive.
7	Power System Functional Test Report for EPS inhibits verification	For safety inhibits part of the spacecraft EPS system.
8	Pressure System Qualification Test Report (if Qual Test is performed)	If Pressure Systems are onboard the payload.
9	Provide Pressure System Acceptance Test Report	If Pressure Systems are onboard the payload.
10	Materials Compatibility Report for Pressure System	If Pressure Systems are onboard the payload.
11	Battery Test Report	Test report shows compliance with work instruction provide by NanoRacks.
12	Final Satellite As-Measured Mass Properties	Mass and CM (Mass Measured, CM Calculated).
13	Investigation Summary Form	Template provided by NanoRacks documenting the science objectives of the payload for use on public NASA webpage.

5 Requirements Matrix

Table 5-1: NR-NRCSD-E-S0004 NanoRacks External CubeSat Deployer IDD Requirements Matrix

Paragraph	IDD Title	Requirement Text	Verification Method
4.1.1-1	Rail Specification	The CubeSat shall have four (4) rails along the Z axis, one per corner of the payload envelope, which allow the payload to slide along the rail interface of the NRCSD-E as outlined in Figure 4.1.1-1.	Inspection, Testing
4.1.1-2	Rail Dimensions and CubeSat Envelope	The CubeSat rails and envelope shall adhere to the dimensional specification outlined in Figure 4.1.1-1.	Inspection, Testing
4.1.1-3	CubeSat Load Points	Each CubeSat rail shall have a minimum width (X and Y faces) of 6mm.	Inspection
4.1.1-4	Rail Outer Radius	The edges of the CubeSat rails shall have a radius of 0.5mm +/- 0.1mm.	Inspection
4.1.1-5	Rail End Surface Area	The CubeSat +Z rail ends shall be completely bare and have a minimum surface area of 6mm x 6mm.	Inspection
4.1.1-6	Rail End Plane	The CubeSat rail ends (+/-Z) shall be coplanar with the other rail ends within +/- 0.1mm.	Inspection
4.1.1-7	Rail Length	The CubeSat rail length (Z axis) shall be the following (+/- 0.1mm): a. 1U rail length: 113.50mm b. 2U rail length: 227.00mm c. 3U rail length: 340.50mm d. 4U rail length: 454.00mm e. 5U rail length: 567.5mm f. 6U rail length: 681 to 740.00mm	Inspection
4.1.1-8	Rail Continuity	The CubeSat rails shall be continuous. No gaps, holes, fasteners, or any other features may be present along the length of the rails (Z-axis) in regions that contact the NRCSD-E rails. Note: This does not apply to roller switches located within the rails. However, the roller switches must not impede the smooth motion of the rails across surfaces (NRCSD-E guide rails, fit gauge, etc.).	Inspection
4.1.1-9	Rail Extension	The minimum extension of the +/-Z CubeSat rails from the +/-Z CubeSat faces shall be 2mm. Note: This means that the plane of the +/-Z rails shall have no less than 2mm clearance from any external feature on the +/-Z faces of the CubeSat (including solar panels, antennas, etc.).	Inspection

Paragraph	IDD Title	Requirement Text	Verification Method
4.1.1-10	NRCSD-E Mechanical Interface	The CubeSat rails shall be the only mechanical interface to the NRCSD-E in all axes (X, Y, and Z axes).	Inspection, Testing
4.1.1-11	Rail Hardness	The CubeSat rails and all load points shall have a hardness equal to or greater than hard-anodized aluminum (Rockwell C 65-70).	Inspection
4.1.1-12	Rail Surface Roughness	The CubeSat rails and all load points shall have a surface roughness of less than or equal to 1.6 μm .	Inspection
4.1.2-1	Mass Limits	The CubeSat mass shall be less than the maximum allowable mass for each respective payload form factor per Table 4.1.2-1.	Testing
4.1.2-2	Center of Mass	The CubeSat center of mass (CM) shall be located within the following range relative to the geometric center of the payload: a. X-axis: (+/- 2cm) b. Y-axis: (+/- 2cm) c. Z-axis: i. 1U: (+/- 2cm) ii. 2U (+/- 4cm) iii. 3U (+/- 6cm) iv. 4U (+/- 8cm) v. 5U (+/- 10cm) vi. 6U (+/- 12cm)	Inspection
4.1.3-1	RBF/ABF Access	The CubeSat shall have a remove before flight (RBF) feature that is either accessible via NRCSD-E access ports on the +/-Y face of the dispenser, or has a timer in place to prevent powering on of the spacecraft.	Inspection, Testing
4.1.4-1	Deployment Switch	The CubeSat shall have a minimum of three (3) deployment switches that correspond to independent electrical inhibits on the main power system (see section on electrical interfaces).	Inspection, Testing
4.1.4-2	Deployment Switch Location	Deployment switches of the pusher/plunger variety shall be located on the rail end faces of the CubeSat's -Z face. Deployment switches of the roller/lever variety shall be embedded in the CubeSat rails (+/- X or Y faces).	Inspection
4.1.4-3	Deployment Switch Contact	Roller/slider switches shall maintain a minimum of 75% surface area contact with the NRCSD rails (ratio of switch contact to NRCSD guide rail width) along the entire Z axis.	Inspection

Paragraph	IDD Title	Requirement Text	Verification Method
4.1.4-5	Deployment Switch Reset	The CubeSat deployment switches shall reset the payload to the pre-launch state if cycled at any time within the first 30 minutes of the switches closing (including but not limited to radio frequency transmission and deployable system timers).	Testing
4.1.4-6	Deployment Switch Captivation	The CubeSat deployment switches shall be captive.	Inspection
4.1.4-7	Deployment Switch Force	The force exerted by the deployment switches shall not exceed 3N. The total force of all CubeSat deployment switches shall not exceed 9N.	Inspection, Testing
4.1.5-1	Deployable Restraint Mechanisms	CubeSat deployable systems (such as solar arrays, antennas, payload booms, etc.) shall have independent restraint mechanisms that do not rely on the NRCSD-E dispenser.	Inspection
4.1.6-1	Deployment Velocity	The CubeSat shall be capable of withstanding a deployment velocity of 0.5 to 2.5 m/s at ejection from the NRCSD-E.	No Verification Required
4.1.6-2	Tip-Off Rate	The CubeSat shall be capable of withstanding up to 5 deg/sec/axis tipoff rate.	No Verification Required
4.2.1-1	Power Storage Device Location	All electrical power storage devices shall be internal to the CubeSat.	Inspection
4.2.1-2	Post-Deployment Timer	The CubeSat shall not operate any system (including RF transmitters, deployment mechanisms or otherwise energize the main power system) for a minimum of 30 minutes after deployment where hazard potential exists. Satellites shall have a timer (set to a minimum of 30 minutes and requiring appropriate fault tolerance) before satellite operation or deployment of appendages where hazard potential exists.	Inspection, Testing
4.2.1-3	Electrical Inhibits	The CubeSat electrical system design shall incorporate a minimum of three (3) independent inhibit switches actuated by physical deployment switches as shown in Figure 4.2.1-1. The satellite inhibit scheme shall include a ground leg inhibit (switch D3 on Figure 4.2.1-1) that disconnects the batteries along the power line from the negative terminal to ground.	Inspection

Paragraph	IDD Title	Requirement Text	Verification Method
4.2.1-4	Ground Circuit	The CubeSat 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.	Inspection
4.2.1-5	RBF/ABF Location	The CubeSat shall have a remove before flight (RBF) feature or an apply before flight (ABF) feature that keeps the satellite in an unpowered state throughout the ground handling and integration process into the NRCSD-E.	Inspection
4.2.1-6	RBF/ABF Functionality	The RBF/ABF feature shall preclude any power from any source operating any satellite functions with the exception of pre-integration battery charging.	Inspection
4.2.2	Electrical Systems Interfaces	There shall be no electrical or data interfaces between the CubeSat and the NRCSD-E. As outlined in Section 4.2.1, the CubeSat shall be completely inhibited while inside the NRCSD-E.	No Verification Required
4.3.1-1	Acceleration Loads	Payload safety critical structures shall (and other payload structures <i>should</i>) 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.	Analysis
4.3.2-1	Random Vibration Environment	The CubeSat shall be capable of withstanding the random vibration environment for flight with appropriate safety margin as outlined in Section 4.3.2.1.	Testing
4.3.3	Launch Shock Environment	The CubeSat shall be capable of withstanding the shock environment shown in Table 4.3.3-1. Any mechanical or electrical components on the spacecraft that are highly sensitive to shock still should be identified and assessed on a case-by-case basis as defined in the unique payload ICA.	No Verification Required
4.3.4	Integrated Loads Environment	The CubeSat shall be capable of withstanding a force 1320N across all load points equally in the Z direction.	Analysis
4.3.5	Thermal Environment	The CubeSat shall be capable of withstanding the expected thermal environments for all mission phases, which are enveloped by the on-orbit EVR phase prior to deployment. The expected thermal environments for all phases of the mission leading up to deployment are in Table 4.3.5-1.	No Verification Required

Paragraph	IDD Title	Requirement Text	Verification Method
4.4.1	Containment of Frangible Materials	The CubeSat design shall preclude the release or generation of any foreign object debris (FOD) for all mission phases.	Testing
4.4.2	Venting	The Maximum Effective Vent Ratio (MEVR) of the CubeSat structure and any enclosed containers internal to the CubeSat shall not exceed 5080cm.	Analysis
4.4.3	Secondary Locking Feature	The CubeSat shall have an approved secondary locking feature for any and all fasteners or subcomponents external to the CubeSat chassis that would not be held captive by the spacecraft structure should it come loose.	Inspection, Testing
4.4.4	Passivity	The CubeSat shall be passive and self-contained from the time of integration up to the time of deployment.	No Verification Required
4.4.5	Pyrotechnics	The CubeSat shall not contain any pyrotechnics unless the design approach is approved by NanoRacks.	No Verification Required
4.4.6-1	CubeSat Sub-Deployables	CubeSats shall not have detachable parts during launch or normal mission operations. Any exceptions are coordinated with NanoRacks and documented in the unique payload ICA.	Inspection
4.4.6-2	Space Debris Compliance	CubeSats shall comply with NASA space debris mitigation guidelines as documented in NASA Technical Standard NASA-STD-8719.14A.	Analysis
4.4.7.3	Battery Testing	All flight cells and battery packs shall be subjected to an approved set of acceptance screening tests to ensure the cells are able to perform in the required load and environment without leakage or failure. While the specific test procedures vary depending on the type of battery, the majority of lithium ion or lithium polymer cells or batteries used in CubeSats can be tested to a standard statement of work issued by NanoRacks (NR-SRD-139).	Inspection, Testing
4.4.7.4	Internal Short Circuit	Protection circuitry and safety features shall be implemented at the cell level to prevent an internal short circuit.	Inspection
4.4.7.5	External Short Circuit	Protection circuitry and safety features shall be implemented at the cell level to prevent an external short circuit.	Inspection, Testing
4.4.7.6	Overvoltage and Undervoltage Protection	Protection circuitry and safety features shall be implemented at the cell level to prevent overvoltage or undervoltage conditions of the cell.	Inspection, Testing
4.4.7.7	Battery Charging	It should be verified that the battery charging equipment (if not the dedicated charger) has at least two levels of control that prevent it from causing a hazardous condition on the battery being charged.	Inspection

Paragraph	IDD Title	Requirement Text	Verification Method
4.4.7.8	Battery Energy Density	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.	Inspection, Testing
4.4.7.9	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.	Inspection
4.4.7.10	Button Cells	Button cell or coin cell batteries often are used in COTS components to power real-time clocks (RTCs), watch-dog circuits, or secondary systems for navigation, communication, or attitude control. These batteries shall be clearly identified by part number and UL listed or equivalent.	Inspection, Testing
4.4.7.11	Capacitors	Capacitors are used throughout today’s modern electronics. Capacitors used as energy storage devices are treated and reviewed like batteries. Hazards associated with leaking electrolyte can be avoided by using solid-state capacitors. Any wet capacitors that utilize liquid electrolyte must be reported to NASA. The capacitor part number and electrolyte must be identified, along with details of how the capacitor is used and any associated schematics.	Inspection, Testing

Paragraph	IDD Title	Requirement Text	Verification Method
4.4.8	Pressure Vessels	<p>A pressure vessel is defined by SSP 52005 as any sealed container with an internal pressure greater than 100 psia. A pressure vessel may be made acceptable for Flight Safety with proper controls for any hazard potential both for inside ISS and outside ISS. If a satellite has a pressure vessel, the PD shall provide documentation with respect to the materials used, tank history (including cycles and life time assessment) and control measures taken to ensure tank integrity (damage control plan), testing performed, fracture control measures planned, inspection process and methods, etc., wherever hazard potential is present.</p> <p>All pressure vessels shall be certified by the Department of Transportation (DOT) or have a DOT-issued waiver for transportation across the US. Use of non-DOT certified pressure vessels generally is not permitted. Exceptions must be coordinated with NanoRacks during the pre-contract signing phase.</p> <p>Systems must demonstrate via test that required factors of safety are present for tanks, lines, and fittings that can be exposed to pressure with one or two failures depending on hazard potential.</p> <p>Pressure vessels and components procured from third-party vendors must have proper certification records or the PD must develop the appropriate records to ensure that the systems are safe by meeting NASA requirements. NanoRacks assists in negotiating with NASA to define the work and analysis necessary to meet the NASA requirements.</p>	Inspection, Analysis, Testing

Paragraph	IDD Title	Requirement Text	Verification Method
4.4.9	Propulsion System	The propulsion system must be assessed for hazard potential. NanoRacks assists in the identification of hazards. Mechanical hazards may be related to pressure containment, flow containment, leakage, etc. Systems also may 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.	Inspection, Analysis, Testing
4.4.10.1	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.	Inspection
4.4.10.2	Hazardous Materials	Satellites shall comply with NASA guidelines for hazardous materials. Beryllium, cadmium, mercury, silver, and other materials prohibited by SSP-30233 shall not be used.	Inspection
4.4.10.3	Outgassing/ External Contamination	Satellites shall comply with NASA guidelines for selecting all non-metallic materials based on available outgassing data. Satellites shall not utilize any non-metallic materials with a Total Mass Loss (TML) greater than 1.0 percent, or a Collected Volatile Condensable Material (CVCM) value of greater than 0.1 percent.	Inspection
4.5.1	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 5km DH relative to the ISS perigee. The payload developer shall submit an analysis accounting for maximum theoretical Delta V capability using the equation in Section 4.5.1.	Inspection, Analysis
4.5.2-1	Re-Entry Survivability	CubeSats over 5kg shall provide an Orbital Debris Assessment Report (ODAR) that verifies compliance with NASA-STD-8719.14.	Analysis
4.5.2-2	Re-Entry Survivability - 2	CubeSats that are designed to survive re-entry or have components that are designed to survive re-entry shall provide an ODAR that verifies compliance with NASA-STD-8719.14.	Inspection, Analysis

Paragraph	IDD Title	Requirement Text	Verification Method
4.6.1	Regulatory Compliance	The CubeSat developer shall submit evidence of all regulatory compliance for spectrum utilization and remote sensing platforms prior to handover of the payload. This evidence shall come in the form of the authorization or license grant issued directly from the governing body or agency (which is dependent on the country the CubeSat originates).	Inspection