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Interface Definition Document (IDD)

Nanoracks Mainframe (Nanode)

Nanoracks

Doc No: NR-NANODE-S0001
Revision: A

List of Revisions

Revision	Revision Date	Revised By	Revision Description
-	2/24/2020	Michael Greer	Initial Release
A	8/31/20	Michael Greer	Added vertical module dimensional spec in Sect. 4.2.1.1 and Appendix B containing standard module interface information. Various other minor edits/additions.

Table of Contents

List of Tables and Figures

1 Introduction

1.1 Purpose

Nanoracks Mainframe (Nanode), or "Nanode" for short reference in this document, is the replacement for the Nanoracks Platform-2 (Frame 2B) facility. This Interface Definition Document (IDD) defines the interfaces, environments, and processes that are relevant to payload design and operation and defines the minimum requirements payloads must meet in order to successfully interface with Nanode and the International Space Station (ISS). Nanoracks verifies compliance on behalf of payload developers based on incremental data requests. An initial payload Interface Control Agreement (ICA) will be developed based on the available payload data. Subsequent iterations will follow that will fully define all payload applicable requirements, services, and interfaces.

1.2 Scope

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

1.3 Use

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

1.4 Exceptions

The Unique Payload ICA documents the payload implementation of the IDD requirements. The Unique ICA is used to determine if the hardware design remains within the interface design parameters defined by this document. Limits of the ICA are established in a conservative manner to minimize individual payload and mixed cargo analyses. Exception is the general term used to identify any payload-proposed departure from specified requirements or interfaces. Any exception to requirements, capabilities, or services defined in this IDD shall be documented in the derived ICA and evaluated to ensure that the stated condition is controlled. The ICA 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
CMC	Cargo Mission Contract
CoC	Certificate of Compliance
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EXPRESS	EXpediting the PRocessing of Experiments to the Space Station
GLACIER	General Laboratory Active Cryogenic ISS Experiment Refrigerator
HFIT	Human Factors Implementation Team
HMST	Hazardous Materials Summary Table
HTV	H-II Transfer Vehicle
ICA	Interface Control Agreement
IDD	Interface Definition Document
ISS	International Space Station
IVA	Intra-Vehicular Activity
JEM	Japanese Experiment Module
JSC	Johnson Space Center
MELFI	Minus Eighty-Degree Laboratory Freezer for ISS
MERLIN	Microgravity Experiment Research Locker/INcubator
NASA	National Aeronautics and Space Administration
PD	Payload Developer
RE	Radiated Emissions
RS	Radiated Susceptibility
SLPM	Standard Litre Per Minute
SRP	Safety Review Panel
USB	Universal Serial Bus
VC-S	Visibly Clean-Sensitive

Table 2-2: Applicable Documents

Doc No.	Rev	Title
SSP 57000	S	Pressurized Payloads 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 30237	T	Space Station Electromagnetic Emission and Susceptibility Requirements
JSC 20793	D	Crewed Space Vehicle Battery Safety Requirements
SSP 50835	D	ISS Pressurized Volume Hardware Common Interface Requirements Document

3 Nanoracks Nanode Overview

The Nanoracks Nanode interfaces between individual Nanolab Modules and the ISS, providing mechanical mounting points and electrical connections for power, data, and communication capabilities.

Each Nanode platform is installed in its own EXPRESS rack locker. The Nanoracks Nanode Assembly is shown in Figure 3-1, and in its ISS Locker installed configuration in Figure 3-2.

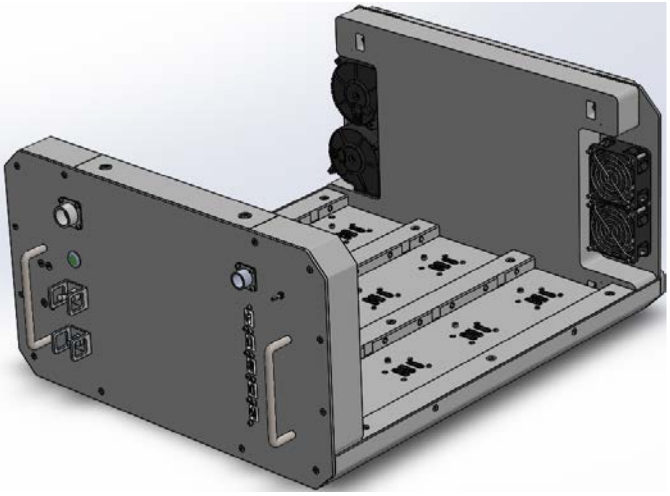


Figure 3-1: Nanoracks Nanode (Mainframe) Assembly

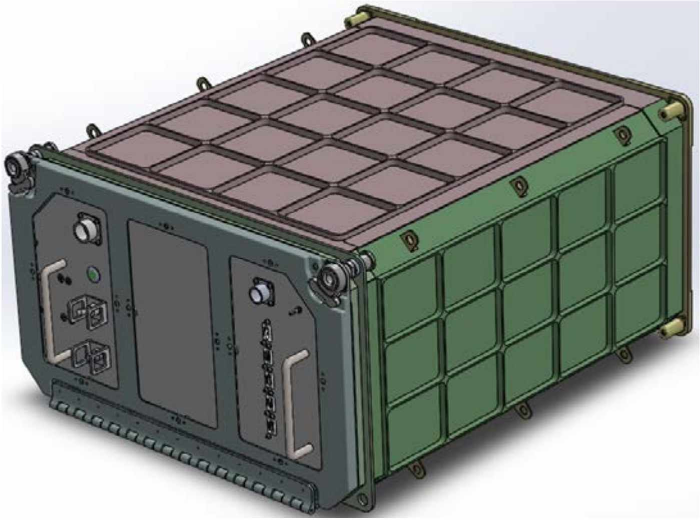


Figure 3-2: Nanoracks Nanode (Mainframe) Assembly Installed in ISS Locker

3.1 Nanode Structural Interface Overview

3.1.1 Nanode Payload Interface

Nanode interfaces with payloads via the Nanode "drawer" base in the Nanode payload volume. There are 12 4"x4" payload positions on the Nanode base; 4 per each of Nanode's 3 retention slots as shown in Fig. 3.1.1-1. Each payload position includes 3 Mill-Max 858 Series 5-pin female connectors. Each position also includes a key feature (head of a cap-screw) to ensure correct orientation of the connecting payload. Interface dimensions for a single payload position are shown in Fig. 3.1.1-2.

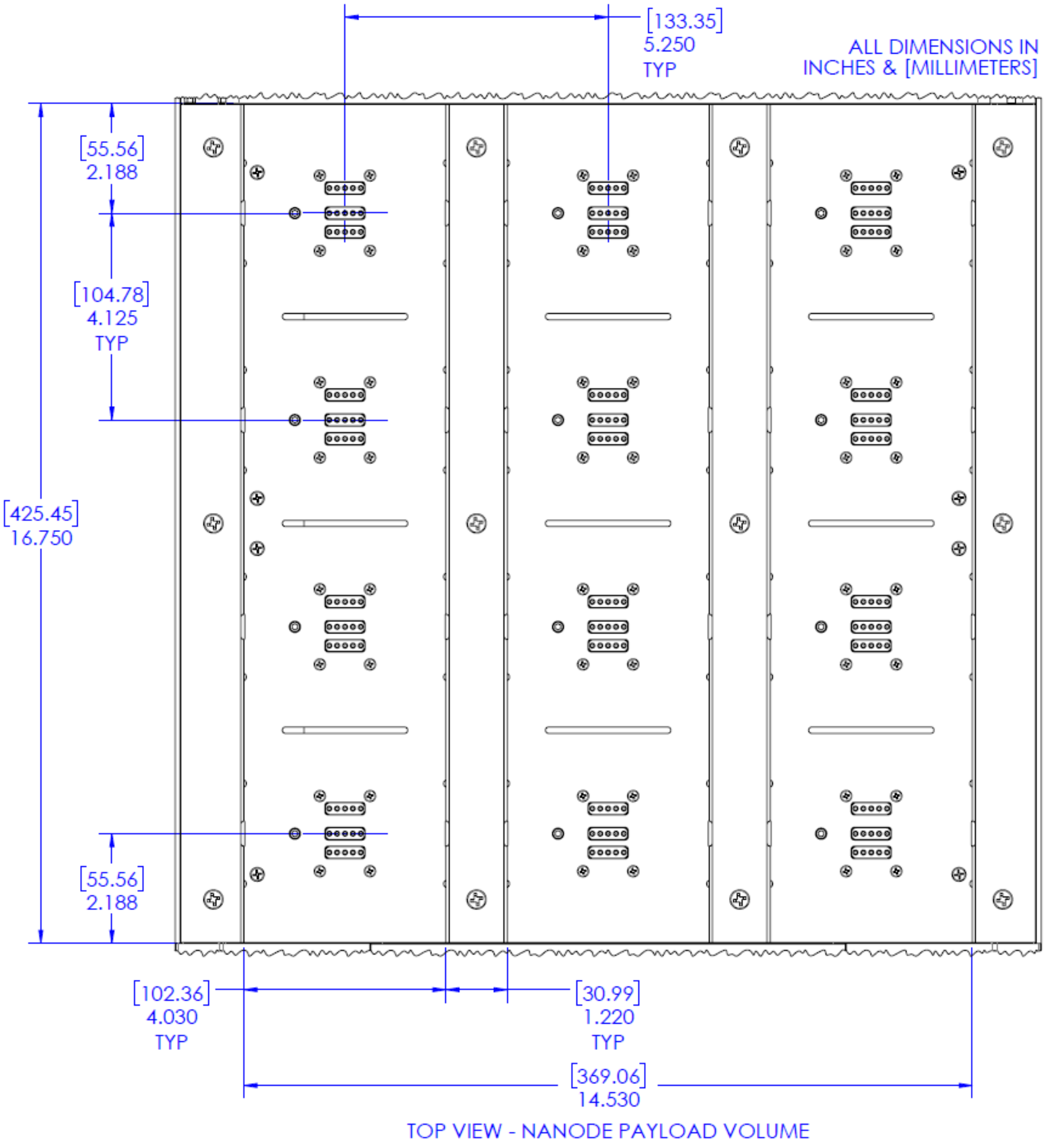


Figure 3.1.1-1: Nanode Payload Volume Dimensions

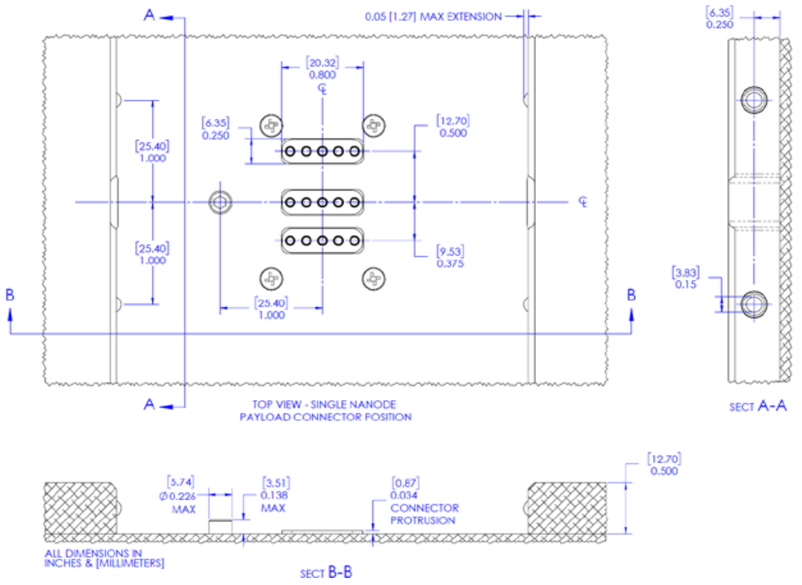


Figure 3.1.1-2: Single Payload Connector Position Dimensions

Payloads are retained by two opposing sets of two spring-ball-plungers embedded in the slot walls around each payload position. The ball plungers apply pressure to detents on either side of the payload to center and retain it. Figures 3.1.1-3 and 3.1.1-4 show how a standard Nanolab may interface with the payload retention system.

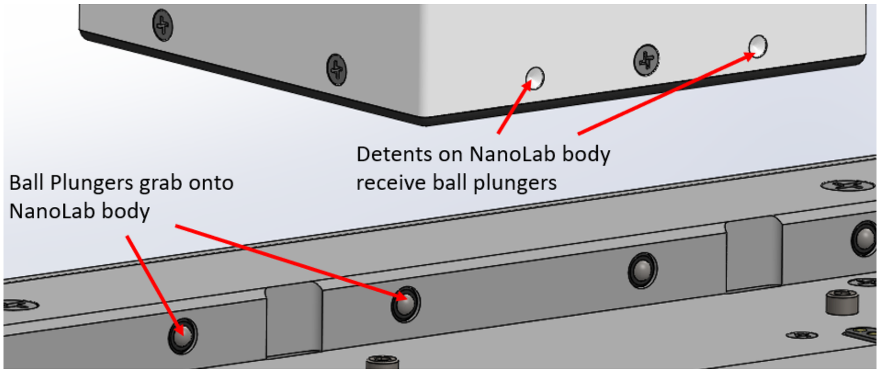


Figure 3.1.1-3: Nanolab Interface

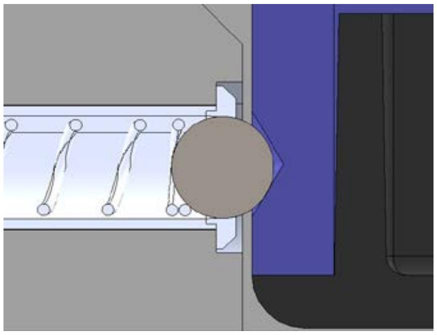


Figure 3.1.1-4: Ball Plunger Engagement

3.1.2 Payload Accommodations

The total payload volume of Nanode is approximately 4U (40 cm, Length) X 3.5U (35 cm, Width) X 2U (20 cm, Height). The Nanode payload interface is designed to accommodate up to 12 standard Nanolab Modules (more information on the standard Nanolab Module can be found in Appendix B). Nanolab modules longer than 2U (20 cm) and up to 4U (40 cm) in length can be accommodated, if contracted, by laying horizontally in a retention slot and covering multiple connector positions (as in Fig. 3.1.2-1). Other possible non-standard payload sizes can be assessed/considered for Nanode if they do not exceed the overall size of the payload volume. Any non-standard size will require additional evaluation and approval by Nanoracks, and special design considerations will need to be made for payload sizes that exceed the retention slot width. See section 4.2.1 for specific sizing requirements.

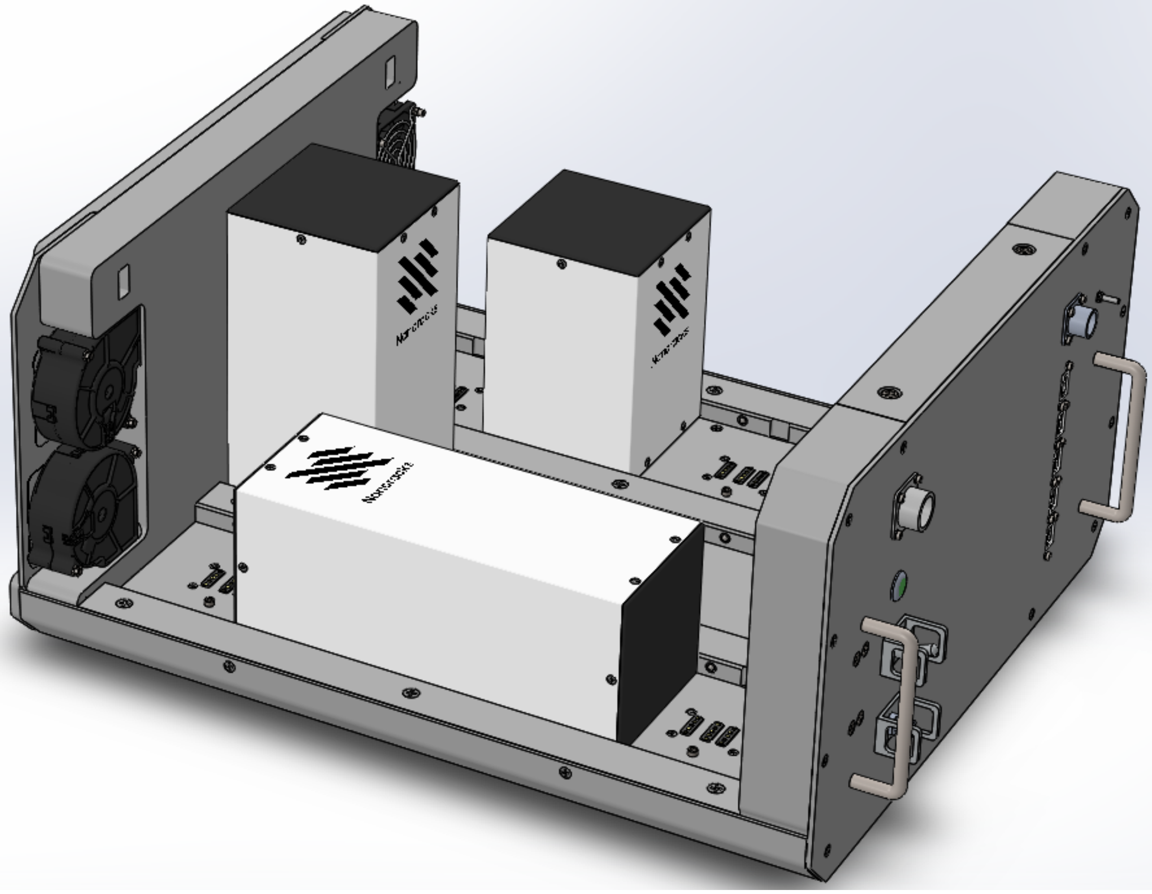


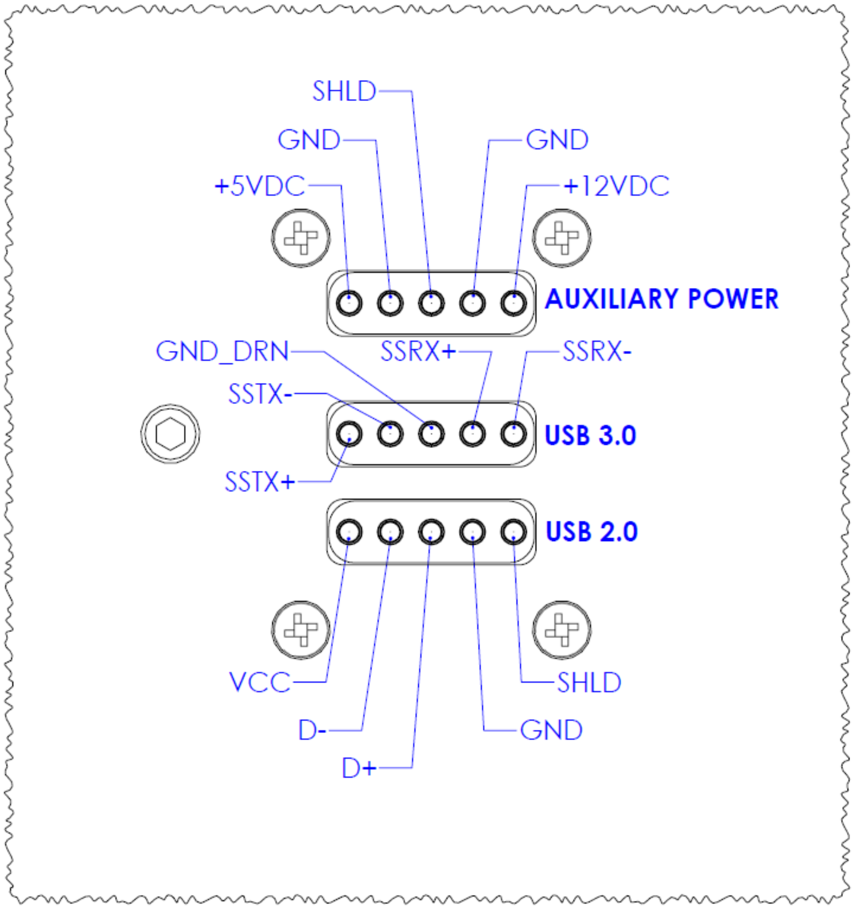
Figure 3.1.2-1: Example of Payload Accommodations

3.2 Nanode Electrical Overview

The primary electrical interfaces for payloads on Nanode are the twelve (12) internal connector positions consisting of:

- One USB 2.0 capable 5-pin connector with 5 VDC @ 2A power.
- One USB 3.0 data pair 5-pin connector.
- One Auxiliary Power 5-pin connector that can provide 5 VDC @ 5 A and 12 VDC @ 3 A.

Power for each internal payload connector position can be controlled individually (switched on/off without powering down the Nanode or other modules). Payloads using this capability are non-standard and details must be documented in the payload specific ICA.



TOP VIEW - NANODE CONNECTOR PIN-OUT

Figure 3.2-1: Pin Layout of the 3 Nanode Connectors

The front panel has three (3) USB 2.0 Type A Female ports, which are not intended for Payload Provider use. Use of the front panel USB ports requires additional evaluation, coordination, and approval by Nanoracks.

All power requirements are to be documented in the payload specific ICA.

3.3 Nanode Environments Overview

3.3.1 Load Environments

Payloads interfacing with Nanode will be exposed to launch vehicle loads during launch. Payloads returning to the ground will additionally be exposed to vehicle landing loads. Specific requirements pertaining to launch/landing loads can be found in section 4.2.3.

Once on orbit, payloads will be exposed to various IVA loads, including station re-boost loads and crew induced loads. Specific requirements pertaining to IVA loads can be found in section 4.2.4.

3.3.2 Thermal Environments

Expected thermal environments for all phases of payload integration are summarized in Table 3.3.2-1.

Table 3.3.2-1: Expected Thermal Environments

Ref SSP 50835, Rev D, Table E.2.10-1 & SSP 57000, Rev S, Table 3.9.3-1

Ground Transport (Payload Provider facility to Nanoracks)	Determined for each payload
Ground Processing at Nanoracks/NASA facilities	10°C to 35°C (50°F to 95°F)
Dragon Pressurized Cargo (All flight phases)	18.3°C to 29.4°C (65°F to 85°F)
Cygnus Pressurized Cargo (All flight phases)	10°C to 46°C (50°F to 115°F)
On-orbit, Pre-deployment, U.S. and JEM Modules	18.3°C to 26.7°C (65°F to 80°F)

3.3.2.1 Conditioned Stowage Environments

Payloads with special thermal constraints should coordinate with Nanoracks and document them in the payload specific ICA. Arrangements for thermal controls in transport and/or on-orbit can be arranged as needed, including incubation options if required. Please note that Nanolab operations while on Nanode are subject to ISS thermal environments as shown in Table 3.3.2-1 above; conditioned stowage options are only available before or after the planned on-orbit operations. The following thermal controls in transport and on-orbit to ISS are offered:

- **Launch:**
    - -95 to +4°C using POLAR or GLACIER facilities
    - +4 to +40°C using MERLIN facility on Dragon (i.e. SpaceX flight)
    - -32°C, -26°C, +4°C, +22°C, +27°C, or +37°C using Ice Bricks in a Cold Bag
- **On-orbit:**
    - -160 to +4°C per GLACIER facility
    - -95 to +4°C using POLAR (-80°C nominally)
    - -20 to +48.5°C using MERLIN facility
    - -95°C, -35°C, or +2°C using MELFI

3.3.3 Humidity

The average relative humidity in Houston, TX (where the Nanoracks and NASA CMC facilities are located) is 75%. However, the relative humidity can easily reach 90% or higher in the Houston area.

The relative humidity will be 25% to 75% for ascent and on-orbit phases of flight.

Payloads with special humidity control constraints should coordinate with Nanoracks and document the constraints in the payload specific ICA.

3.4 Nanode Operations Overview

The launch, on-orbit installation, and operation duration for Nanode service is defined in the individual ICA. The payload representative will be notified of the status of their hardware. The timeframe for payload activation will be documented in the ICA to ensure Payload Provider support for flight operations.

3.4.1 Ground Processing

3.4.1.1 Delivery to Nanoracks

The Payload Provider will deliver the integrated Nanolab to the Nanoracks Houston facility, or another facility as specified in the ICA, by the deadline listed in the schedule. Any special requirements such as ground handling hardware, special handling instructions, etc., will be documented in the payload specific ICA. If the payload contains biological or chemical contents, a Certificate of Compliance (CoC) for all seals/containment levels and for sanitization of the overall payload is required from the Payload Provider prior to turnover to Nanoracks. Nanoracks will not accept payloads containing biological or chemical contents without a CoC due to the potential contamination hazard. Hardware is to be turned over to Nanoracks in sealed clear bagging to allow for inspection for any containment breach.

3.4.1.2 Nanoracks Testing and Inspection

Many requirements need testing or inspection for verification. During payload integration activities, Nanoracks will perform the standard tests and inspections listed in Table 3.4.1.2-1 for all payloads. Additional testing may be required based on the design and function of the payload. Table 3.4.1.2-2 outlines the additional testing and the driving factors for the testing. If applicable, Nanoracks may perform the required additional testing for Payload Providers if negotiated in the ICA. Otherwise, Payload Providers are responsible for completing the applicable testing in Table 3.4.1.2-2 and should consult with Nanoracks on acceptable methods to complete these tests.

Table 3.4.1.2-1: Standard Testing/Inspections Completed by Nanoracks

Test Name	**Test Objectives**	**Requirement Number**
Grounding/Bonding Test	Verify payload is properly grounded and bonded. This test will be performed prior to powering the payload to ensure electrical hazards do not exist.	4.4.4
Interface Compatibility Testing	Verify payload physically interfaces with Nanode.	4.2.1
Functional Testing	Verify payload concept of operations, successful USB communication between the payload and Nanode, that the Command & Data Handling requirements are met, and to conduct a subset of required on-orbit operations such as file transfers and recovery from power interruptions.	4.5
HFIT Inspection	Verify that the payload is designed according to the Human Factors requirements.	4.6

Table 3.4.1.2-2: Additional Testing Required for Applicable Requirements

Test Name	**Test Objective**	**Rationale for Test**	**Requirement Number**
Induced Vibration Testing	Verify that the payload does not exceed induced vibration limits.	Payload contains rotating parts (motors, fans, etc.).	4.2.4.3
Vibration Testing	Verify that the payload is designed to have positive margins of safety when exposed to the launch vibration environment.	Failure of the payload structure could result in a hazard (contains hazardous materials, high voltage, etc.).	4.2.3.2
Thermal Testing	Verify that the payload meets touch temperature requirements.	Payload consumes a large amount of power and may exceed touch temperature limits.	4.2.5
Acoustic Testing	Verify that the payload does not generate noise that exceeds continuous or intermittent noise limits.	Payload contains fans, vibration motors, servos, or other devices that may produce audible noise.	4.3
EMC Testing	Verify that the payload meets electromagnetic compatibility requirements.	Payload contains switch mode power supplies, generates high voltages, or contains any RF transmitters. Payload contains safety critical circuits.	4.4.2
Static Magnetic Field Testing	Verify that the payload meets static magnetic field requirements.	Payload contains motors, electromagnets, or permanent magnetic devices.	4.4.3
Joint Station LAN (JSL) Testing	Verify compatibility with the ISS JSL. JSL testing can only be done at the NASA JSL facility.	Payload has complex data handling functions.	4.5
Leak Check Testing	Verify integrity of payload levels of containment.	Payload contains hazardous materials.	4.1.4.1.1

3.4.1.3 Nanoracks Data Gathering for Operations

Nanoracks will assess the payload to develop data products and procedures in support of crew interaction and on-orbit operations. In order to efficiently 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 procedures for crew to assemble and install the payload, develop support products, and ensure successful deployment of the Payload.

3.4.1.4 Payload Provider Ground Servicing

The Payload Provider, if previously agreed in the ICA, may perform late load payload activities at Nanoracks facility (or alternate agreed upon delivery site) prior to final flight packaging. These late load activities may include preparation of limited life science samples, applications of seals for each level of containment, etc. note that no modifications to the payload may be conducted once the payload has been through functional testing. Once the payload has been accepted to be turned over to Nanoracks, no further payload servicing will be allowed, except as allowed for defined scrub turnaround scenarios. Any special requirements will be documented in the payload-specific ICA.

3.4.1.5 Nanoracks Packaging and Delivery

Nanoracks will deliver the completed payload assembly to the Cargo Mission Contract (CMC) team or Cold-Stow Group (depending on transport configuration) for flight packing. Any special packing requirements (e.g. humidity, thermal, venting, or orientation) are to be listed in the payload specific ICA.

3.4.2 Launch

CMC and Cold Stow Group are responsible for delivering the final stowed configuration to the launch vehicle team for final integration into the ISS visiting vehicle.

3.4.2.1 Launch Scrub

If agreed in the contract the Payload Provider can be on-hand at the launch site prep location to prepare an identical replacement payload for swap out if a launch scrub scenario occurs. The Payload Provider needs to specify in the ICA if a swap-out replacement will be available, the steps for scrub replacement, as well as how long a scrub timeframe can be tolerated by the payload before loss of science.

3.4.3 On-Orbit Operations

3.4.3.1 Payload Stowage

Once the launch vehicle is on orbit and berthed/docked, the crew is responsible for transferring the payload and placing it in the appropriate on-orbit stowage location until it is time to complete next steps for the payload.

3.4.3.2 Payload Installation

Once NASA schedules the payload installation window (subject to various constraints such as crew time, berthing schedule, payload priority, etc.) the on-orbit crew is responsible for unpacking the payload and installing it into the Nanode platform. When possible, video of the crew installation of the payload into Nanode may be recorded and made available to the Payload Provider.

3.4.3.3 Experiment Operations

During experiment operations, the Payload Provider will be able to update their experiment via file uplink; as well as downlink experiment data on a semi-frequent basis. The Nanoracks Operations team will be responsible for performing the necessary commanding, file uplinks, and data downlinks as required by the Payload Provider. The standard service for commanding to the payload and uplink/downlink of data is as follows:

- 30 days of on-orbit payload operations support – NTE 1 hour every business day
- File downlink limited to 2 GB per day
- Total file downlink per week limited to 10 GB

The exact timing and frequency of payload operations support will have to be coordinated with the Nanoracks Operations team and documented in the ICA. If the payload requires more interactions on-orbit or larger size file downlinks, it will have to be negotiated and agreed to with the Nanoracks Operations team and documented in the ICA. The following operational specifications must be defined in the ICA for assessment with Nanoracks to be assured the requirements can be met by the current Nanode performance and ISS environment:

- Frequency and lead-time for updates and data downlink;
- Data format and size;
- Whether the payload needs to be returned to the ground;
- Thermal constraints pre/post operations (refer to previous sub-section on Thermal Constraints which provides information for on-orbit as well as for transport).
- Thermal or humidity constraints/limits for the science while operating.

3.4.3.3.1 Ground to Payload Communication

Communications to/from Nanode is accomplished through NASA managed Ku-band Internet Protocol (Ku-IP) at the Nanoracks BRIDGE in Houston. Ku-IP provides the Nanoracks Operations team with a Linux Virtual Network Computing graphical interface to Nanode and any connected modules. File transfer rates are dependent on many different factors. Payload required file sizes and downlink frequency will be documented in the ICA. All communications with the Nanolab while on orbit are conducted by Nanoracks Operations team only.

3.5 Schedule and Deliverables

3.5.1 Schedule

Table 3.5.1-1 is a standard template schedule. The detailed payload schedule and deliverables will be coordinated through the individual ICA between Nanoracks and the Payload provider.

Table 3.5.1-1: Milestone Schedule

Milestone/Activity	**Launch-minus Dates**	
Contract Signing	L – 9M	
Start of the Interface Control Agreement (ICA) and the Nanoracks/ISS Safety process	L – 8.5M	
Start of the Interface Verification Process	L – 8M	
Phase I Safety Data Package Submittal	L – 8M	
Phase I Safety Review	L-7M	
Phase II Safety Data Package Submittal	L-6M	
Phase II Safety Review	L-5M	
NOTE:	Nominal Turn-Over[1] Payload	Late Load [1] Turn-Over Payload
Hardware Testing Complete	L – 5M	L-4M
Phase III SDP submit & Stage Interface Verification	L – 4.5M	L-3.5M
Hardware Fit-check and Functional Test	L – 4.5M	L-3M
Phase III Safety Review and Final Approval	L – 3.5M	L-2M
Turnover to Nanoracks for final inspections, prep, and final verification close-outs.	SpaceX: NLT L-11.5w Cygnus: NLT L-14w HTV[4]	SpaceX: L-24d to NLT L-34hrs[3] Cygnus: L-30d to NLT L-34hrs[3] HTV[4]: L-14w
Turnover to NASA[4]	SpaceX: L-9.5w Cygnus: L-12w HTV[4]	SpaceX: L-24 d to NLT L-32hrs[3] Cygnus: L-30d to NLT L-32hrs[3] HTV[4]: L-10w

Legend: M=Months; w=weeks; d=days

NOTES:

1. Payloads with limited life experiments and/or cold-stow needs can be delivered later than it typical for hardware handover. This is called "late-load.". Late load accommodation is negotiated on a case-by-case basis, must be requested in the ICA, and must be approved by Nanoracks and NASA. Approval depends upon rationale for need and schedule capability with other shipments for the same flight.
2. Turn-over to Nanoracks prior to turn-over to NASA depends on preparation needs and workload for other payloads on the same flight. This is to be negotiated and documented as part of the ICA.
3. Even with approval from Nanoracks for late load, the late load date depends on negotiations with NASA based on priority/viability ranking in comparison with other late loads.
4. HTV nominal delivery is L-6.5M beyond the above standard expedited Nanolab payload template. If a payload is to be nominally delivered for HTV then all previous milestones need to be shifted 5M earlier. For HTV nominal or late delivery an export database milestone must be added and is due at L-6M.

3.5.2 Deliverables

Table 3.5.2-1 describes the list of potential Payload Provider deliverables required to certify the payload for flight. More detailed information will be provided in the payload ICA.

Table 3.5.2-1: Deliverables

Item	Deliverable	Description	Date
1	ICA & Safety Data	Payload Description & Constraints and initial Safety Data.	L-8.5M
2	Bill of Materials	Complete BOM required; if complete with amounts and accurate with material/vendor data – out-gas testing is generally met by Program assessment rather than testing.	NLT L-7.5M
3	Data for Tox/Bio Hazard Evaluation		NLT L-7.5M
4	Safety Data Update	Updated Safety Data (based of final design)	NLT L-7M
4	SDSs for each substance	Safety Data Sheet published or updated less than 5 year before mission completion.	NLT L-5M
5	Confirmed data for Tox/Bio Hazard Evaluation	At this point no additions or modifications will be allowed. Only removal or reduction or materials.	NLT L-5M
6	Cold Stowage Test Report	If payload uses cold stowage assets.	L-1M
7	Final mass and dimension report		NLT H/W Turn-over
8	Containment Level & Cleanliness Certification	CoC for Containment Levels and Sanitized Surface required for turn-over/handling acceptance or leak and vibration testing (if required)	NLT H/W Turn-over
9	Final as loaded data for Tox/Bio Hazard	Certification of final materials	NLT H/W Turn-over
10	Quality Assurance Certification	CoC stating that the hardware was built, assembled, and meets the ICA.	Hardware Delivery

4 Payload Interface Requirements

A payload's compliance with the requirements contained in this section ensure proper integration with Nanode. This section is divided by the following disciplines: Safety, Structural, Electrical, Environmental, Human Factors.

4.1 Payload Safety Requirements

All payloads must complete the NASA Safety Review Process conducted by the ISS Safety Review Panel (ISRP). The Nanoracks safety group interfaces directly with the ISRP to complete this process for each payload. The following sections contain requirements that must be met for Nanoracks to get your payload approved to fly by NASA Safety.

4.1.1 Safety Criticality Definitions

The ISRP makes the following determinations on safety criticality for payload structures and circuitry. These levels of safety criticality may trigger additional requirements and verification efforts.

1. **Safety Critical Structures:** Levied on payloads containing hazardous or shatterable materials and requires additional evaluation and verification to ensure that structural failure resulting in a hazardous condition does not occur.
2. **Vibration Sensitive Safety Critical Structures:** Levied on payloads without adequate levels of containment for hazardous materials, or where the launch vibration environment could otherwise result in a structural failure and hazard to the crew. The vibration sensitive determination may trigger the need to conduct additional vibration testing.
3. **Safety Critical Circuits:** Levied on payloads containing circuitry that controls a hazard and requires additional evaluation and verification to ensure that circuit failure resulting in a hazardous condition does not occur.

*note that for payloads determined to fall into one of these categories any additional required testing or analysis triggered will be the responsibility of the Payload provider unless otherwise coordinated and agreed in the ICA.

4.1.2 Debris and Shatterable Materials

Payloads **shall not** generate debris during launch or normal mission operations.

4.1.2.1 Shatterable Materials

If the hardware contains shatterable materials, the hardware **shall** provide containment to ensure that no particles 50-micron or larger are liberated.

Any shatterable materials used in the payload design must be defined in the payload ICA and any hardware containing shatterable materials must be packed in a clear sealed bag for transport to ISS. This will allow the crew to conduct a visual inspection for fracture/debris before the payload is deployed for operations. This is the minimum constraint for which the Payload Provider must accept risk to prevent a debris/frangible hazard.

If the Payload Provider wants to reduce risk of hardware damage during transport to the ISS due to the load environments shown in Section 4.1.1, the Payload Provider should specify additional packing constraints in the ICA. Packing options may consist of bubble wrap, custom cut foam padding, or even custom fabricated hard enclosures.

4.1.2.2 Rotating Equipment

To further prevent debris risk, any threaded fasteners for retaining a rotating part/device **shall** be safety cabled or cotter pinned as a means of positive locking. Safety wire can ONLY be used if on-orbit removal of the fastener is not required. For any fasteners intended to be removed on-orbit (for a unique payload scenario), the fastener should also be made captive with built-in self-locking features. Any redundant threaded fasteners (non-fracture critical) *should* employ self-locking threaded devices, such as by using built-in self-locking features or approved thread-locking compounds.

4.1.3 Pressure Systems

Nanolabs do not typically employ pressurized gas systems as this introduces further Safety and Interface Verification and risk. However, if required by the experiment, any such system requires additional evaluation and coordination for approval, and if approved will likely extend the integration schedule. Use of pressure systems must be agreed in advance and defined in the contract and ICA.

Payloads with pressurized gas systems which have a total expanded gas volume exceeding 400 liters at Standard Conditions **shall** limit the gas flow after a single failure to less than 240 SLPM after 400 liters at Standard Conditions has been released to the cabin air. This applies to payloads for both on-orbit and transport time periods.

4.1.4 Hazardous Materials

4.1.4.1 Toxicology and Microbiology

Payloads **shall** pass a JSC Toxicology and Microbiology Review. The assessment by the two groups is established as the Hazardous Materials Summary Table (HMST) product that must receive further approval through the Payload Safety Review Panel. The product must also be re-verified to have been met once all substances are loaded into your payload to verify the final flight product. NOTE: the payload is NOT allowed to exceed or add substances or concentrations from the Safety Reviewed version, only decreases can be made. The final sign-off to the HMST is called the "V-2". The Payload Provider will need to provide their final load values and sign-off. Nanoracks will forward the "V-1" (version from Safety Review) for mark-up ahead of flight loading.

The following are generic guidelines on what CANNOT be transported:

- No bio (health) hazard material rated higher than 2M
- No radioactive material
- No material/substance rated higher than a Toxicity Hazard Level 2
- No explosive gases/reactive mixes

NOTE: Payload Providers need to check that any chosen substance, or combination of substance, is compatible with the container material.

If you need help with checking any material for the above concerns, please send your questions to your Nanoracks point-of-contact.

4.1.4.1.1 Levels of Containment for Hazardous Chemicals and Biological Materials

Payloads containing materials that have been deemed hazardous by the JSC Toxicology and Microbiology group **shall** provide adequate levels of containment for the materials in question. Depending on the hazard level of the material documented in the payload HMST, the payload may need to use up to three independent levels of containment. Details on the levels of containment used are to be documented in the payload ICA.

The Payload Provider must provide a Certificate of Compliance for all seals/containment levels and sanitization of the payload by the time the hardware is turned over to Nanoracks. The payload is to be turned over to Nanoracks in a sealed clear bag to allow for a visual inspection for a potential containment breach.

4.1.4.2 Flammability and Off-Gassing

Payloads **shall** submit a Bill of Materials (BOM) to Nanoracks for assessment of structural materials for off-gassing and flammability.

4.1.5 Sharp Edges

Payloads **shall not** have any exposed sharp edges or corners. Payloads using a standard vertical Nanolab Module provided by Nanoracks already meet this requirement. Payloads with custom enclosures or that require crew-access should reference Tables 4.1.5-1 and 4.1.5-2 for the minimum requirements for rounding exposed edges and corners.

Table 4.1.5-1: Minimum Bend Radii for Exposed Edges
Ref SSP 57000, Rev S, Table 3.12.8.2-1

Edge Thickness (T)	**Bend Radius**
T ≥ 0.25 inch (6.4 mm)	0.12 inch (3.0 mm)
0.12 inch (3.0 mm) ≤ T < 0.25 inch (6.4 mm)	0.06 inch (1.5 mm)
0.02 inch (0.5 mm) ≤ T < 0.12 inch (3.0 mm)	Full radius
T < 0.02 inch (0.5 mm)	Rolled or curled edge

Table 4.1.5-2: Minimum Bend Radii for Exposed Corners
Ref SSP 57000, Rev S, Table 3.12.8.2-2

Material Thickness (T)	**Bend Radius**
T ≤ 1.0 inch (25.0 mm)	0.5 inch (13.0 mm)
T > 1.0 inch (25.0 mm)	0.5 inch (13.0 mm)

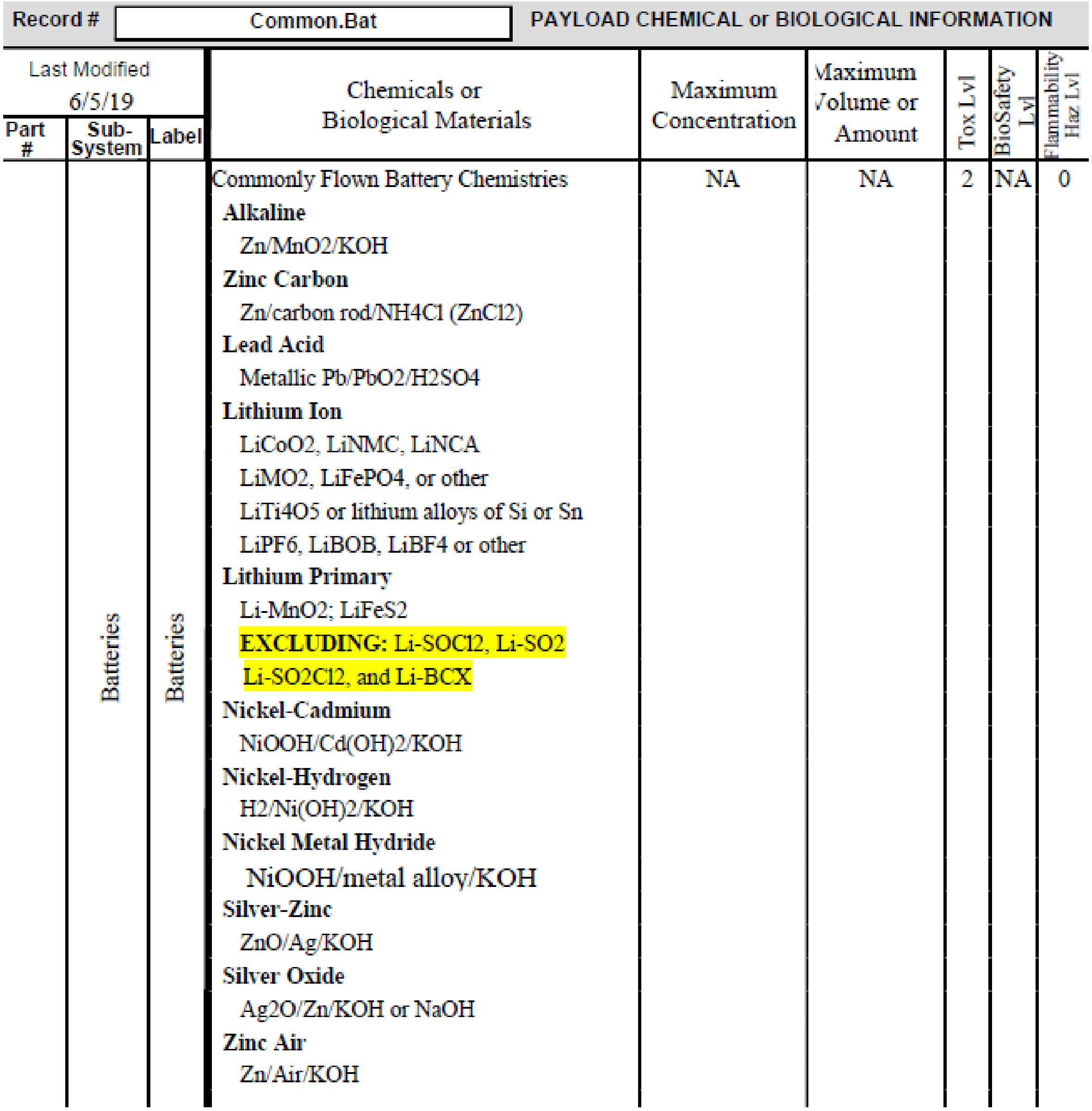
Alternatively, covers can be considered for sharp edges or corners that cannot be rounded.

4.1.6 Batteries

Payloads containing batteries **shall** comply with the requirements outlined in JSC 20739, Crewed Space Vehicle Battery Safety Requirements. Due to the unique nature of hazards presented by batteries and battery-powered payloads, detailed information about the battery power system design, cell chemistry, voltage, capacity, cell arrangement, and charge/discharge cycling must be provided to Nanoracks early in the development process.

Approval of a battery system is dependent upon hazard controls, design evaluation, testing, and verification. Evaluation of the battery system must be complete prior to certification for flight and ground operations. Due to the high risk of rejection for battery control system designs, Payload Providers are strongly encouraged to seek feedback from Nanoracks prior to committing to a battery system design and before manufacturing any battery system hardware. Consulting with Nanoracks prior to system development can save substantial cost and prevent schedule delays by ensuring a compliant design in the first iteration.

It is highly recommended that Payload Providers use one of the common battery chemistries listed in Figure 4.1.6-1.



Record #	Common.Bat	PAYLOAD CHEMICAL or BIOLOGICAL INFORMATION						
Last Modified 6/5/19								
Part #	Sub-System	Label	Chemicals or Biological Materials	Maximum Concentration	Maximum Volume or Amount	Tox Lvl	BioSafety Lvl	Flammability Haz Lvl
	Batteries	Batteries	Commonly Flown Battery Chemistries **Alkaline** Zn/MnO2/KOH **Zinc Carbon** Zn/carbon rod/NH4Cl (ZnCl2) **Lead Acid** Metallic Pb/PbO2/H2SO4 **Lithium Ion** LiCoO2, LiNMC, LiNCA LiMO2, LiFePO4, or other LiTi4O5 or lithium alloys of Si or Sn LiPF6, LiBOB, LiBF4 or other **Lithium Primary** Li-MnO2; LiFeS2 **EXCLUDING:** Li-SOCl2, Li-SO2 Li-SO2Cl2, and Li-BCX **Nickel-Cadmium** NiOOH/Cd(OH)2/KOH **Nickel-Hydrogen** H2/Ni(OH)2/KOH **Nickel Metal Hydride** NiOOH/metal alloy/KOH **Silver-Zinc** ZnO/Ag/KOH **Silver Oxide** Ag2O/Zn/KOH or NaOH **Zinc Air** Zn/Air/KOH	NA	NA	2	NA	0

Figure 4.1.6-1: Common Battery Chemistries Used on ISS

4.2 Payload Structural Requirements

4.2.1 Payload Dimensions

4.2.1.1 Vertical Nanolab Modules

Vertical Nanolab Module dimensions **shall** adhere to the dimensional specification detailed in Figure 4.2.1.1-1. Vertical modules must be designed to interface with a single Nanode connector position (detailed in Section 3.1.1) through its end cap.

Figure 4.2.1.1-1 outlines the dimensional envelope for vertical modules, along with detailed dimensions for the implementation of the module retention and connector design. Any dimensions 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 4.2.1.1-1.

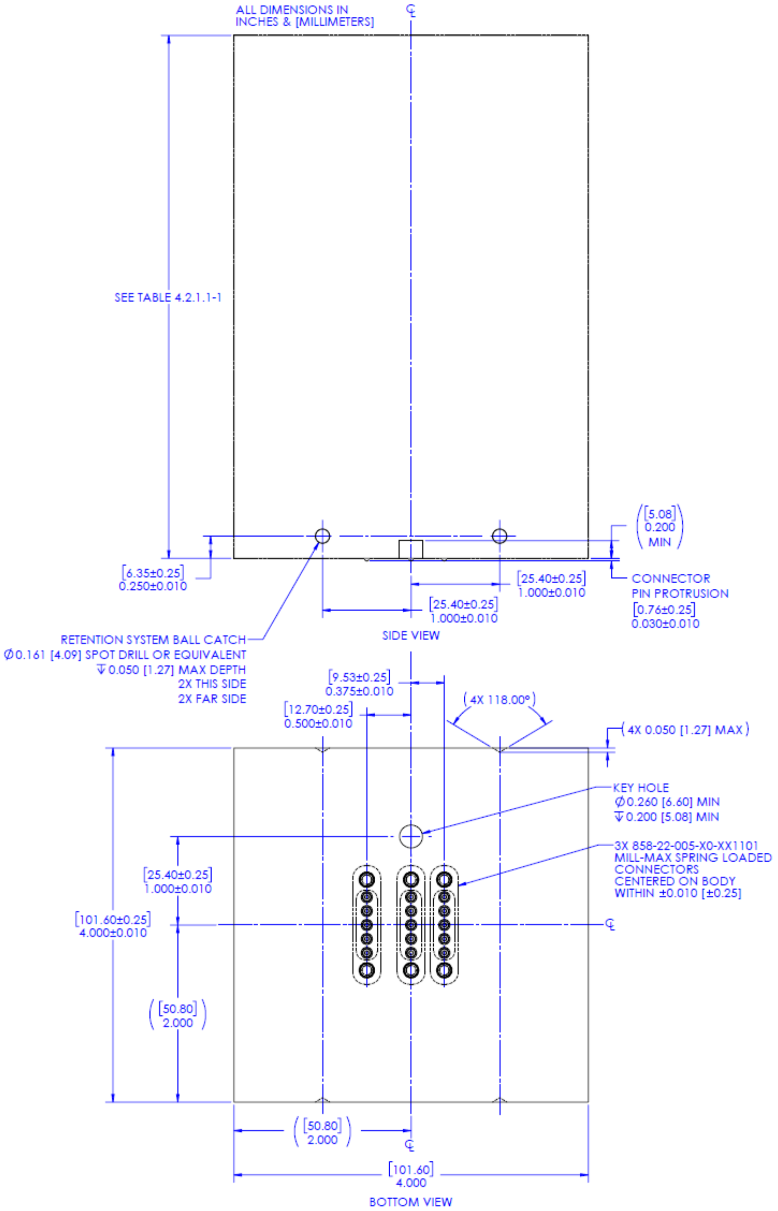


Figure 4.2.1.1-1: Dimensional Specification for Vertical Nanolab Modules

Table 4.2.1.1-1: Table of Standard Vertical Nanolab Sizes

Form Factor	Nanolab Height
1U	3.937 in (100 mm)
1.5U	5.906 in (150 mm)
2U	7.874 in (200 mm)

The standard Nanoracks-provided Nanolab Module already meets this requirement. More information and additional interface requirements on the standard Nanolab Module can be found in Appendix B.

4.2.1.2 Horizontal Nanolab Modules

Module sizes longer than 2U (20cm) can be accommodated in Nanode by laying horizontally in one of the base retention slots. A single retention slot can support up to a 4U (40cm) module laying horizontally. Because a horizontal Nanolab module will cover multiple connector positions, some unique requirements apply.

Horizontal Nanolab Modules **shall** be designed to interface with multiple Nanode connector positions at once. The number of connector positions covered is dependent on the length of the horizontal module. The module will interface electrically with at least one position but will need to include cut-outs/insets to allow clearance for any unused connectors and keys.

Additionally, horizontal Nanolabs **shall** be designed to interface with multiple positions of the Nanode retention system.

Horizontal payload interface designs must be coordinated with Nanoracks to ensure proper retention of the payload and clearance of unused Nanode connectors/keys.

4.2.1.3 Non-Standard Modules

In general, non-standard Nanolab Modules **shall** not exceed the dimensions of the Nanode payload volume given in section 3.1.1.

Any Nanolab module that does not fall into the two categories from sections 4.1.1.1 and 4.1.1.2 is considered non-standard and must be coordinated with Nanoracks and documented in the payload ICA. Large payloads that exceed the width of the Nanode retention slot may be required to use adapters to stand the payload off from the Nanode base.

4.2.2 Mass Properties

The Nanolab module mass properties **shall** follow the specifications outlined in Table 4.1.1-1.

Table 4.2.2-1: Nanolab Module Mass

Form Factor	Maximum Mass (g)
1U	1000
1.5U	1500
2U	2000
3U	3000
4U	4000

Table 4.2.2-1 applies to standard Nanolab Modules. In general, maximum mass is 1 kg for every 1U unit size. All non-standard modules must be assessed/negotiated with Nanoracks and documented in the payload ICA.

4.2.3 Structural Analysis Factor of Safety (FOS)

Structural analysis performed to verify the requirements in the following sections **shall** apply a FOS of 1.25 (yield) and 2.0 (ultimate) and result in a positive margin of safety (>0.00).

The margin of safety must be calculated using the following formula:

Safety Margin = (Ultimate Tensile Strength / (FOS * Maximum Principle Stress)) – 1

4.2.4 Transportation Loads

4.2.4.1 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 4.4.1-1 at the center of gravity of the item, with all six degrees of freedom acting simultaneously. The acceleration values are applicable to both soft stowed and hard mounted hardware.

Table 4.2.4.1-1: Launch/Landing Load Factors Envelope
Ref SSP 57000, Rev S, Table D.3.1.1-1

	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**
Landing	**+/- 9.2**	**+/- 9.3***	**+/- 9.3***	**N/A**	**N/A**	**N/A**

**Note: The RSS of Ny and Nz is +/- 9.3 g, which can be applied one axis at a time in combination with the Nx load.*

4.2.4.2 Random Vibration Loads

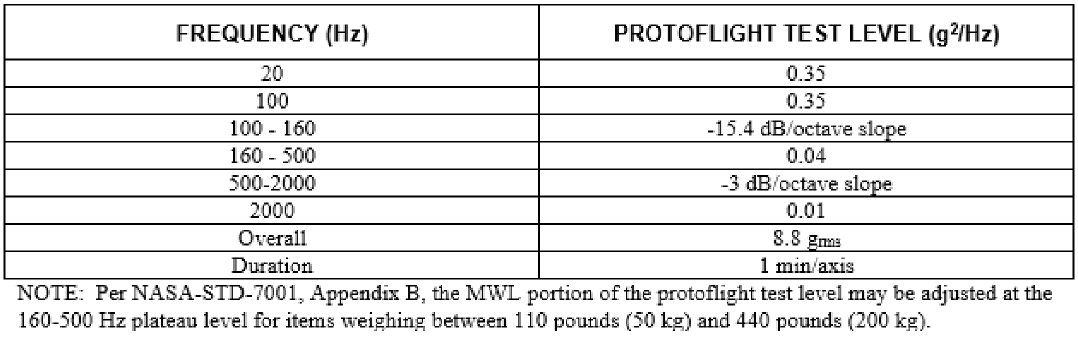
Payload vibration sensitive safety-critical structures that are packed in foam or bubble wrap and either soft stowed in bags or enclosed in hard containers such as lockers, boxes, or similar structures **shall** meet the specified performance requirements when exposed to the maximum flight random vibration environments defined in Table 4.4.2-1. If using a standard Aluminum Nanoracks Nanolab Module for typical operations with Nanode and the payload does not have biological/liquid/toxicology containment requirements, then this requirement for the Module is already completed.

Even so, the acceptance of the Module does not guarantee survival of internal components for mission success. If testing is desired for mission success reasons, or necessary for containment levels, contact Nanoracks for the proper vibration test or alternate testing.

Random vibration testing may not be required; coordination with the Safety and Interface verification groups may allow this to be reduced to the leak testing already required of any containment level(s). If considering the testing, the standard stowage configuration is the payload wrapped in bubble wrap. Otherwise, test to the stowage requirements as set in the payload ICA.

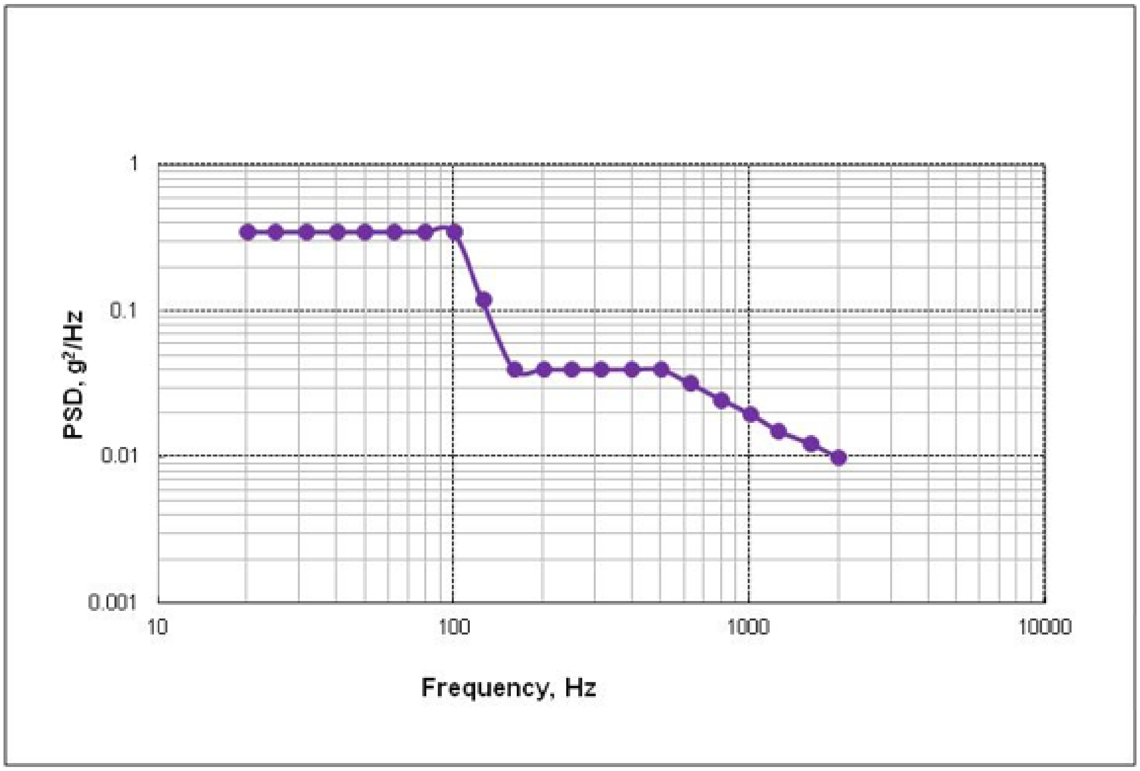
Table 4.2.4.2-1: Random Vibration Environment

Ref. SSP 57000, Rev S, Table D.3.1.2-1



FREQUENCY (Hz)	PROTOFLIGHT TEST LEVEL (g^2/Hz)
20	0.35
100	0.35
100 - 160	-15.4 dB/octave slope
160 - 500	0.04
500-2000	-3 dB/octave slope
2000	0.01
Overall	8.8 g_{rms}
Duration	1 min/axis

NOTE: Per NASA-STD-7001, Appendix B, the MWL portion of the protoflight test level may be adjusted at the 160-500 Hz plateau level for items weighing between 110 pounds (50 kg) and 440 pounds (200 kg).



NOTE: Per NASA-STD-7001, Appendix B, the MWL portion of the protoflight test level may be adjusted at the 160-500 Hz plateau level for items weighing between 110 pounds (50 kg) and 440 pounds (200 kg).

Figure 4.2.3.2-1: Random Vibration Protoflight Test Level
Ref SSP 57000, Rev S, Figure D.3.1.2-1

4.2.4.3 Shock Loads

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. If the payload uniquely has any mechanical or electrical components that are highly sensitive to shock, these should be assessed on a case-by-case basis as defined in the payload ICA.

4.2.5 IVA Loads

4.2.5.1 Crew Induced Loads

Generally, all payloads should be designed to provide positive margins of safety when exposed to the crew induced loads defined in Table 4.2.5.1-1. However, as a hand-held item to be placed in Nanode, Nanolab Module structures are usually exempt from this requirement.

Table 4.2.5.1-1 Crew-Induced Loads
Ref SSP 57000, Rev S, Table 3.1.1.1.2-1

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

4.2.5.2 Station Re-Boost Loads

Payloads **shall** be designed to have positive margins of safety for on–orbit loads of 0.2 g acting in any direction for nominal on-orbit operations. If using a standard Aluminum Nanoracks Nanolab Module for typical operations with Nanode, the analysis for this requirement is already completed based on the known Module structure.

4.2.5.3 Microgravity Disturbance Requirements

All Nanolab Modules **shall** limit the force and vibrations they induce onto Nanode to prevent exceeding the limits of the EXPRESS Rack. If the payload uses a motor, the motor must be assessed. If a singular source (one motor) is used and manufacturer data is available to verify the payload is within limits, that data may suffice, otherwise testing needs to be completed to verify compliance with the limits shown in Figure 4.2.4.2-1. Transient forces are limited to an impulse of no greater than 10 lb·s (44.5 N·s) for a ten-second period.

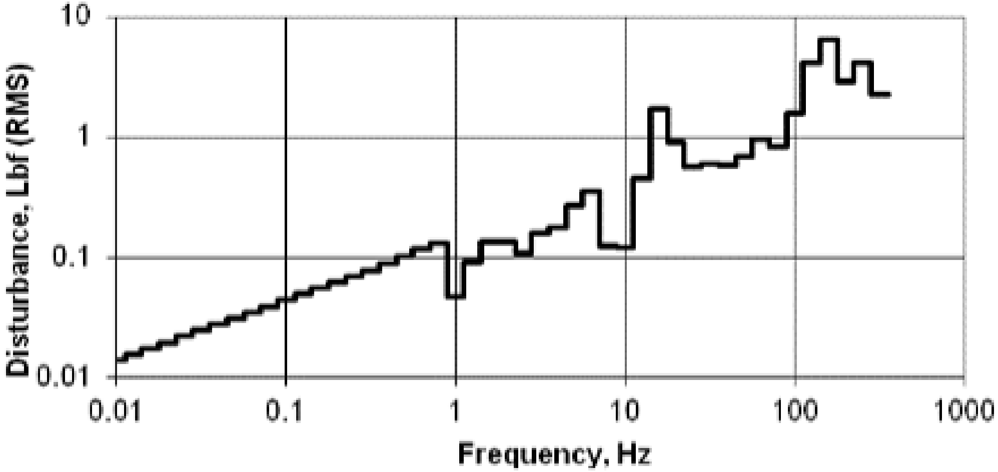


Figure 4.2.5.3-1: Express Rack Subrack Payload Vibratory Disturbances Allowable
Ref SSP 57000, Rev S, Figure F.3.1.3.2-1

4.2.6 Thermal Requirements

4.2.6.1 Touch Temperature

Payloads **shall** be designed such that the outer surface does not exceed 45°C, so that the payload does not pose a touch temperature hazard to the crew.

4.2.7 Protrusions

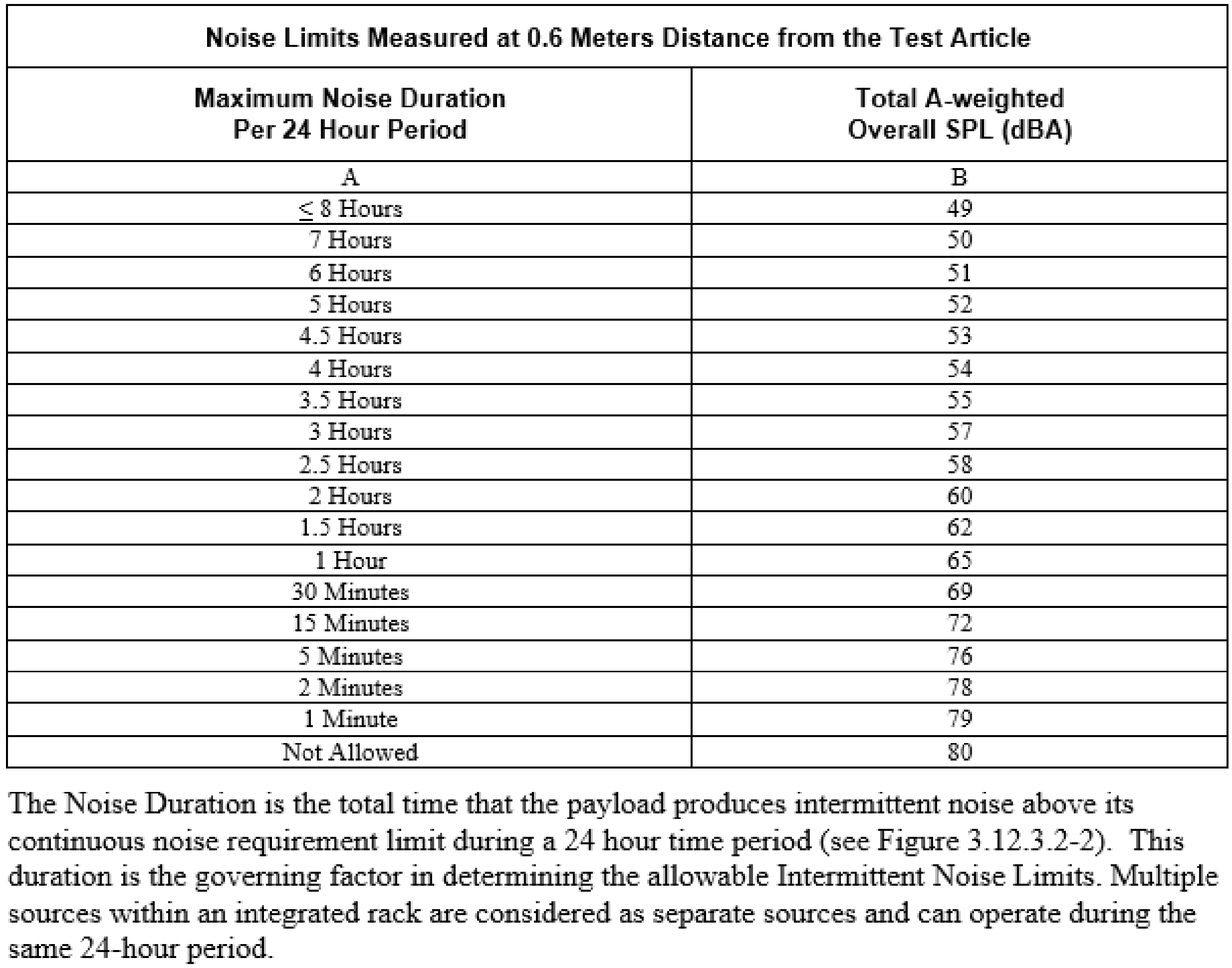
Nanolab modules **shall not** have any objects protruding from the external module surfaces, with the exception of the connector pins which protrude by the small amount defined in Figure 4.2.1.1-1. Any deviation from this requires prior approval from Nanoracks and must be documented in the payload ICA.

4.3 Acoustic Requirements

Any module with a motor or device that can create acoustic noise **shall** be tested to meet acoustic limits that were set by the Program to both protect the crew and prevent negative impact to other payloads/equipment.

If the payload's source of noise exists for a cumulative total of more than eight hours in any 24-hour period, it is considered a continuous noise, but must also meet the intermittent noise limits. If less, only the intermittent noise needs to be evaluated. Therefore, the noise duration is to be specified in the ICA. The payload should be designed as not to exceed the intermittent and continuous acoustic limits shown in Table 4.3-1 and Table 4.3-2.

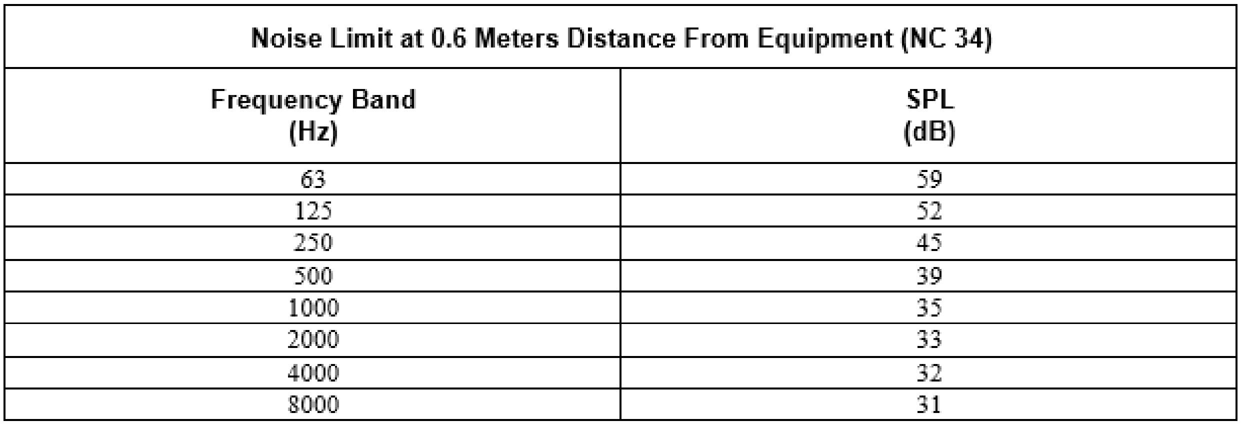
Table 4.3-1: Intermittent Noise Limits
Ref SSP 57000, Rev S, Table 3.12.3.2-1



Noise Limits Measured at 0.6 Meters Distance from the Test Article	
Maximum Noise Duration Per 24 Hour Period	**Total A-weighted Overall SPL (dBA)**
A	B
≤ 8 Hours	49
7 Hours	50
6 Hours	51
5 Hours	52
4.5 Hours	53
4 Hours	54
3.5 Hours	55
3 Hours	57
2.5 Hours	58
2 Hours	60
1.5 Hours	62
1 Hour	65
30 Minutes	69
15 Minutes	72
5 Minutes	76
2 Minutes	78
1 Minute	79
Not Allowed	80

The Noise Duration is the total time that the payload produces intermittent noise above its continuous noise requirement limit during a 24 hour time period (see Figure 3.12.3.2-2). This duration is the governing factor in determining the allowable Intermittent Noise Limits. Multiple sources within an integrated rack are considered as separate sources and can operate during the same 24-hour period.

Table 4.3-2: Continuous Noise Limits
Ref SSP 57000, Rev S, Table G.3.12.1-1



Noise Limit at 0.6 Meters Distance From Equipment (NC 34)	
Frequency Band (Hz)	**SPL (dB)**
63	59
125	52
250	45
500	39
1000	35
2000	33
4000	32
8000	31

4.4 Payload Electrical Interface Requirements

4.4.1 Electrical Interface

4.4.1.1 Electrical Connectors

Payloads **shall** use Mill-Max 858-22-005-X0-XX1101 Spring Loaded Pin Connectors to connect to the Nanode payload platform. Connectors must be arranged according to the dimensional specification of Section 4.2.1.1, and must be configured to match the Nanode-side connector pin-out detailed in Figure 3.2-1.

4.4.1.2 Standard Power & Data Connection

Standard payloads shall be designed to utilize the Nanode USB 2.0 Power and Data connection specified in Section 3.2, and have a maximum nominal power usage of 7.5 W (5 VDC @ 1.5 A). Payloads using the additional connections and their expanded power/data capabilities are non-standard and shall be documented in the payload specific ICA.

4.4.2 Electromagnetic Compatibility (EMC)

Payloads operated within the Nanode payload volume and electrically connected to Nanode are generally exempted from EMC testing due to the isolation and shielding provided by Nanode. However, all payloads are assessed on a case by case basis, and payloads containing transmitters, high voltage boost converters, or with safety critical circuits may be subject to EMC testing requirements. These requirements are levied by NASA as the payload progresses through the review process and may be levied at any time.

Payload subjected to EMC testing requirements **shall** comply with the electromagnetic compatibility limits outlined in SSP 30237. Verification of compliance will be by test at a certified EMI/EMC test facility and the verification will be closed with a certified test report showing that the payload complies with limits outlined in SSP 30237. Any transmitters, voltage multiplying circuits, or hazard control circuits should be identified on the ICA to ensure prompt evaluation of EMC testing requirements by Nanoracks and NASA.

4.4.3 Static Magnetic Fields

Payloads containing electromagnetic or permanent magnetic devices **shall not** generate static (DC) magnetic flux density exceeding 170 dB above 1 picotesla (3.16 Gauss) at a distance of 7 cm from the surface of the payload.

4.4.4 Grounding, Bonding, and Electrical Isolation

All powered modules **shall** be properly grounded and bonded. Verification of grounding, bonding, and isolation shall be by test and will be verified by Nanoracks prior to functional checkout and operation at our Webster, TX facility.

4.4.4.1 Power Isolation

Each electrical power source **shall** be DC isolated from the Nanolab chassis and signal returns by a minimum of 1 Megaohm resistance.

4.4.4.2 Single Point Ground

Each electrical power return **shall** be isolated from the Nanolab chassis by a minimum of 1 Megaohm resistance.

4.4.4.3 Electrical Bonding

Payloads with exposed conducting surfaces **shall** have less than 0.1 Ohm resistance from each exposed conducting surface to the shield pin(s) on the Nanode electrical connector.

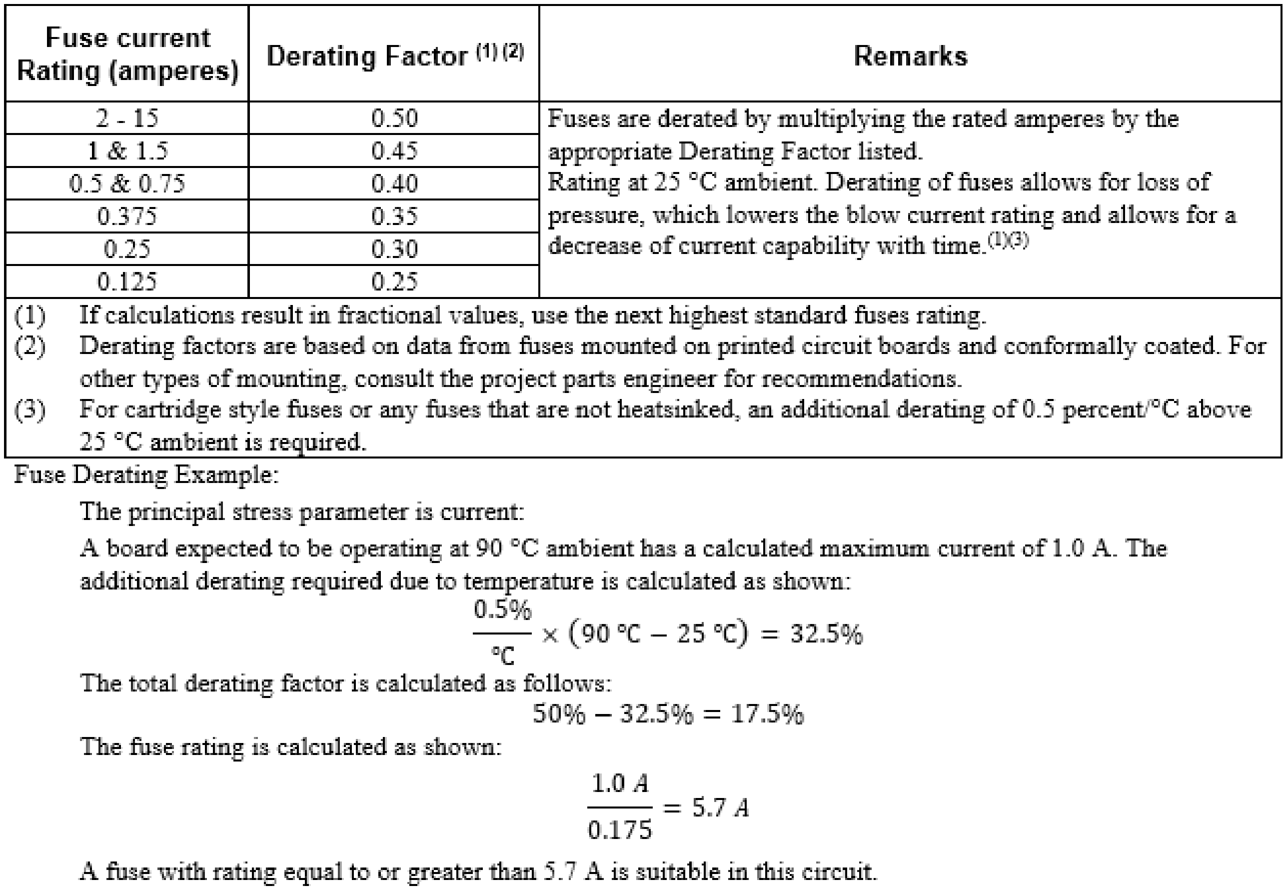
4.4.5 Wire Derating and Circuit Protection

4.4.5.1 Circuit Protection Devices

Overcurrent protection **shall** be provided at all points in the system where power is distributed to lower level and shall be derated according to tables 4.4.5.1-1 and 4.4.5.1-2.

Table 4.4.5.1-1: Fuse Derating

Ref SSP 57000, Rev S, Table 3.2.1.2.1-1



Fuse current Rating (amperes)	Derating Factor (1) (2)	Remarks
2 - 15	0.50	Fuses are derated by multiplying the rated amperes by the appropriate Derating Factor listed. Rating at 25 °C ambient. Derating of fuses allows for loss of pressure, which lowers the blow current rating and allows for a decrease of current capability with time.(1)(3)
1 & 1.5	0.45	
0.5 & 0.75	0.40	
0.375	0.35	
0.25	0.30	
0.125	0.25	

(1) If calculations result in fractional values, use the next highest standard fuses rating.

(2) Derating factors are based on data from fuses mounted on printed circuit boards and conformally coated. For other types of mounting, consult the project parts engineer for recommendations.

(3) For cartridge style fuses or any fuses that are not heatsinked, an additional derating of 0.5 percent/°C above 25 °C ambient is required.

Fuse Derating Example:

The principal stress parameter is current:

A board expected to be operating at 90 °C ambient has a calculated maximum current of 1.0 A. The additional derating required due to temperature is calculated as shown:

$$\frac{0.5\%}{°\mathrm{C}} \times (90\ °\mathrm{C} - 25\ °\mathrm{C}) = 32.5\%$$

The total derating factor is calculated as follows:

$$50\% - 32.5\% = 17.5\%$$

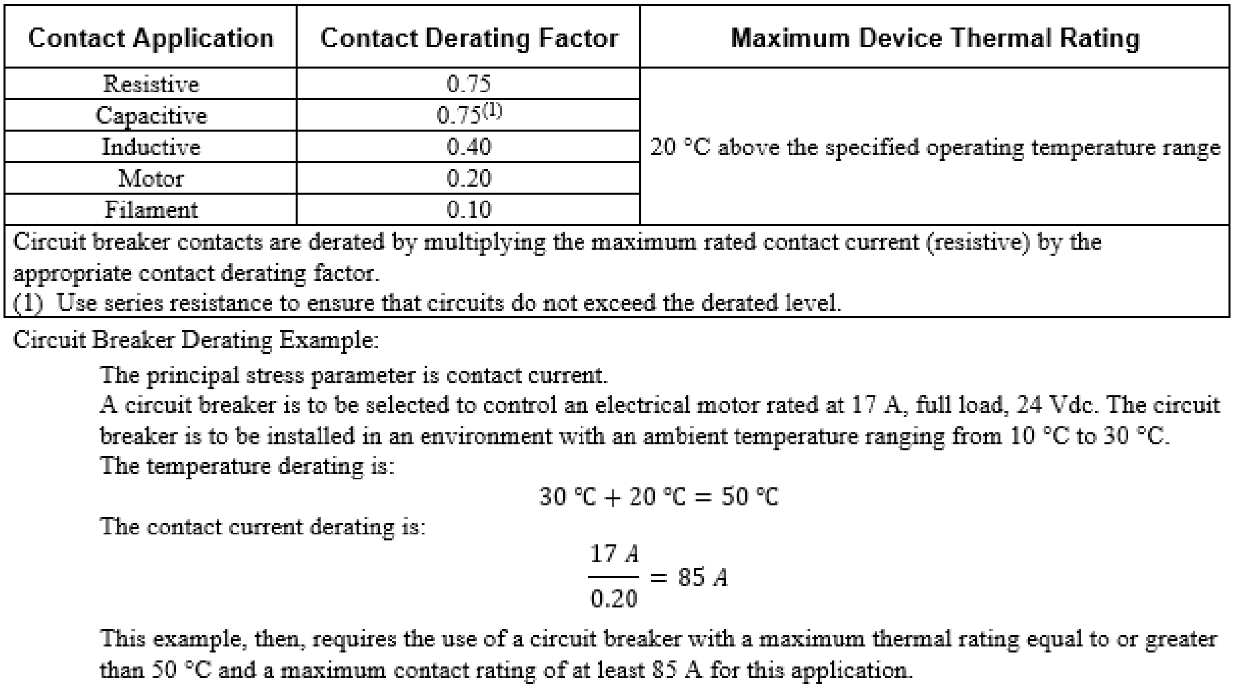
The fuse rating is calculated as shown:

$$\frac{1.0\ A}{0.175} = 5.7\ A$$

A fuse with rating equal to or greater than 5.7 A is suitable in this circuit.

Table 4.4.5.1-2: Circuit Breaker Derating

Ref SSP 57000, Rev S, Table 3.2.1.2.1-2



Contact Application	Contact Derating Factor	Maximum Device Thermal Rating
Resistive	0.75	20 °C above the specified operating temperature range
Capacitive	0.75(1)	
Inductive	0.40	
Motor	0.20	
Filament	0.10	

Circuit breaker contacts are derated by multiplying the maximum rated contact current (resistive) by the appropriate contact derating factor.

(1) Use series resistance to ensure that circuits do not exceed the derated level.

Circuit Breaker Derating Example:

The principal stress parameter is contact current.

A circuit breaker is to be selected to control an electrical motor rated at 17 A, full load, 24 Vdc. The circuit breaker is to be installed in an environment with an ambient temperature ranging from 10 °C to 30 °C.

The temperature derating is:

$$30\,^{\circ}\mathrm{C} + 20\,^{\circ}\mathrm{C} = 50\,^{\circ}\mathrm{C}$$

The contact current derating is:

$$\frac{17\,A}{0.20} = 85\,A$$

This example, then, requires the use of a circuit breaker with a maximum thermal rating equal to or greater than 50 °C and a maximum contact rating of at least 85 A for this application.

For more information or help in designing to these specifications, please contact Nanoracks.

4.4.5.2 Wire Derating

Internal payload wiring **shall** be derated per Tables 4.4.5.2-1 and 4.4.5.2-2. Wire gauges smaller than 24 AWG are not recommended and will require analysis and coordination with NASA to approve. Any payload wiring smaller than 24 AWG should be declared on the ICA. Every effort should be made to use TFE insulated wire in the payload. PVC insulated wire is flammable and generally not recommended. If the use of PVC wire is unavoidable, then the total PVC insulated wire length must not be longer than 6 inches. Often the use of PVC insulation found on or in off-the-shelf cables (USB, HDMI, SATA, etc.) is unavoidable. In these cases, the wire must be securely and completely wrapped in Teflon tape and documented on technical drawings and BOMs. Payload Providers should identify any PVC wiring on the ICA.

Table 4.4.5.2-1: Wire Derating Criteria

Ref SSP 57000, Rev S, Table 3.2.1.2.2-1

Wire Size (AWG)	Maximum Nominal Allowed Single Wire Current (I_{sw}), amperes[1, 2, 3]	Maximum Wire Temperature for the Maximum Single Wire Current [1, 2]	Maximum Allowed Smart Short Current, amperes [4]	Maximum Wire Temperature for the Maximum Smart Short Current	Estimated Maximum Nominal Wire Temperature with Air Flow [7]
26	3.8	118 °C (242 °F)	4.9	179 °C (352 °F)	33.0 °C (91.0 °F)
24	5.4	118 °C (242 °F)	7.0	179 °C (352 °F)	35.3 °C (95.0 °F)
22	7.4	118 °C (242 °F)	9.6	179 °C| (352 °F)	35.3 °C (95.0 °F)
20	10.0	118 °C (242 °F)	13.0	179 °C (352 °F)	40.3 °C (104 °F)
18	13.2	118 °C (242 °F)	17.2	179 °C (352 °F)	40.3 °C (104 °F)
16	15.0	118 °C (242 °F)	19.5	179 °C (352 °F)	38.1 °C (100 °F)
14	20.0	118 °C (242 °F)	26.0	179 °C (352 °F)	37.5 °C (99 °F)
12	29.0	118 °C (242 °F)	37.7	179 °C (352 °F)	43.1 °C (109 °F)
10	40.0	118 °C (242 °F)	52.0	179 °C (352 °F)	48.7 °C (119 °F)
8	63.0	118 °C (242 °F)	81.9	179 °C (352 °F)	42.0 °C (107 °F)
6	92.0	118 °C (242 °F)	119.6	179 °C (352 °F)	49.8 °C (121 °F)
4	120.0	118 °C (242 °F)	156.0	179 °C (352 °F)	51 °C (123 °F)
2	170.5	118 °C (242 °F)	221.6	179 °C (352 °F)	50.4 °C[5] (122 °F)
1/0	260.0	118 °C (242 °F)	338.0	179 °C (352 °F)	50.4 °C[6] (122 °F)

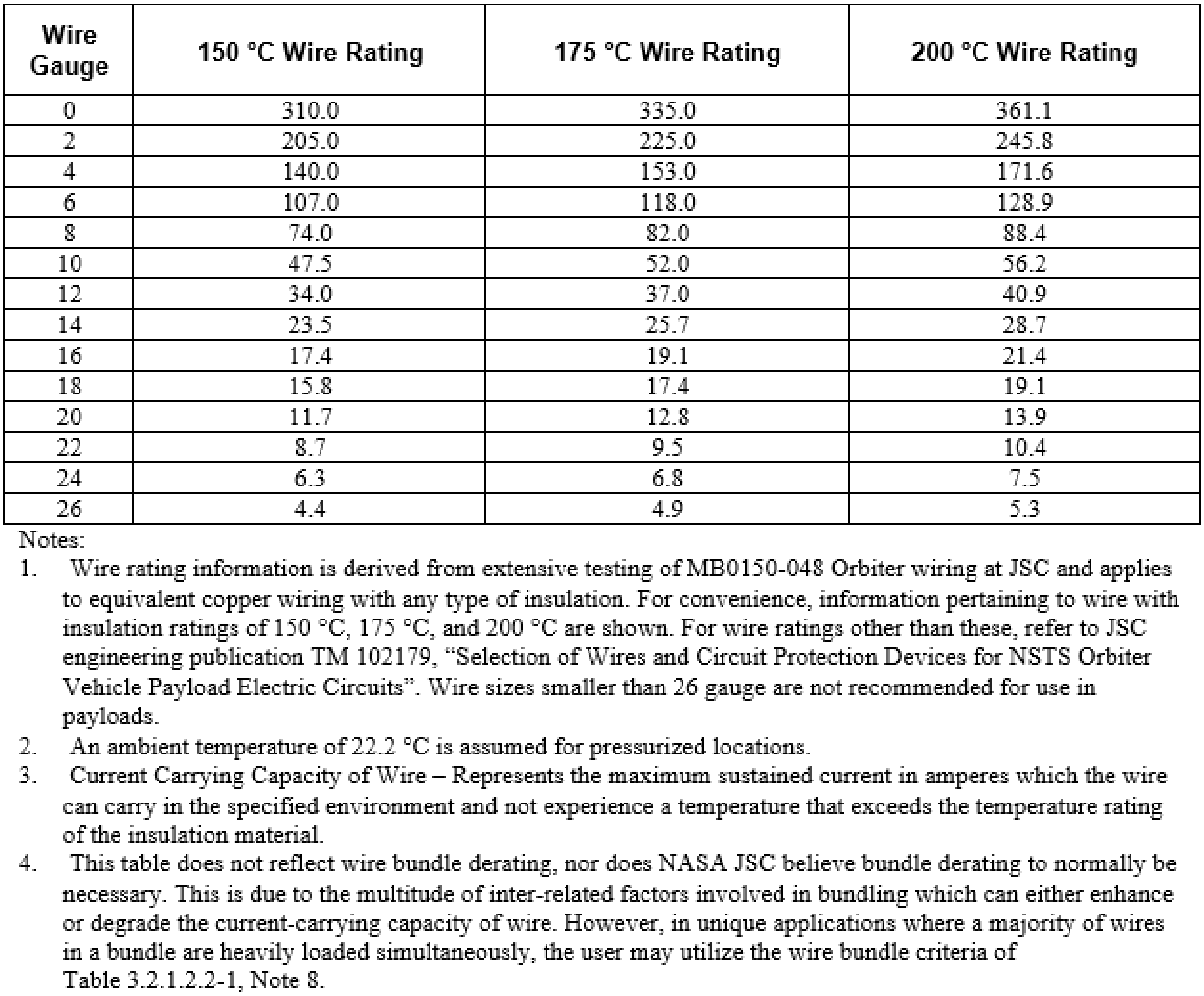
1. These currents are for wires on-orbit in cabin ambient at 22 °C (72 °F).
2. Deratings listed are for wire rated for 200 °C maximum temperature.
3. Wire with these currents and temperatures are not to be accessible to the crew.
4. This current is the 130% maximum fault current for circuit protection devices.
5. Maximum current to limit wire touch temperature to 122 °F for size 2 wire is 150 A.
6. Maximum current to limit wire touch temperature to 122 °F for 1/0 size wire is 210 A.
7. Data from Figure 3 of SAE AS 50881 at 60,000 feet altitude
8. When wire is bundled, the maximum design current for each individual wire is derated according to the following:

For N < 15
IBW = ISW × (29 - N)/28
Where: N = number of wires
IBW = current, bundle wire
ISW = current, single wire

For N > 15
IBW = (0.5) × ISW

Table 4.4.5.2-2: Wire Sizing Criteria

Ref SSP 57000, Rev S, Table 3.2.1.2.2-2



Wire Gauge	150 °C Wire Rating	175 °C Wire Rating	200 °C Wire Rating
0	310.0	335.0	361.1
2	205.0	225.0	245.8
4	140.0	153.0	171.6
6	107.0	118.0	128.9
8	74.0	82.0	88.4
10	47.5	52.0	56.2
12	34.0	37.0	40.9
14	23.5	25.7	28.7
16	17.4	19.1	21.4
18	15.8	17.4	19.1
20	11.7	12.8	13.9
22	8.7	9.5	10.4
24	6.3	6.8	7.5
26	4.4	4.9	5.3

Notes:

1. Wire rating information is derived from extensive testing of MB0150-048 Orbiter wiring at JSC and applies to equivalent copper wiring with any type of insulation. For convenience, information pertaining to wire with insulation ratings of 150 °C, 175 °C, and 200 °C are shown. For wire ratings other than these, refer to JSC engineering publication TM 102179, "Selection of Wires and Circuit Protection Devices for NSTS Orbiter Vehicle Payload Electric Circuits". Wire sizes smaller than 26 gauge are not recommended for use in payloads.
2. An ambient temperature of 22.2 °C is assumed for pressurized locations.
3. Current Carrying Capacity of Wire – Represents the maximum sustained current in amperes which the wire can carry in the specified environment and not experience a temperature that exceeds the temperature rating of the insulation material.
4. This table does not reflect wire bundle derating, nor does NASA JSC believe bundle derating to normally be necessary. This is due to the multitude of inter-related factors involved in bundling which can either enhance or degrade the current-carrying capacity of wire. However, in unique applications where a majority of wires in a bundle are heavily loaded simultaneously, the user may utilize the wire bundle criteria of Table 3.2.1.2.2-1, Note 8.

4.5 Command and Data Interface Requirements

Payloads that require data handling must adhere to interface requirements with Nanode regarding the timing and availability of the Nanolab module as a mass storage device. The ability for the payload to appear as a mass storage device allows for the operator to verify successful connection of the Nanolab to Nanode and ensure uninterrupted file transfers between the Nanolab and Nanode. If a payload requires data handling, it must meet the following requirements to ensure this communication:

- The Nanolab **shall** make its memory available to the Nanode Command & Data Handling system for at least 30 minutes after power up and shall not be actively using that memory during that time. This time will be used to verify good connection/access between Nanode and module and perform any actions that are needed prior to experiment execution.
- The Nanolab **shall** make its mass storage memory available for access periodically in order for experiment data to be downlinked to the ground. The time period for when the drive becomes accessible is dependent on the payload and the requirement on how often files must be downlinked. Payload can use clocks, timers, or other triggers to implement this periodic access. For each access window, the drive should remain open for at least 1 hour. The timing of the access windows will be assessed on a case-by-case basis as defined in the payload ICA.

Nanoracks is open to considering other command and data interfaces such as Ethernet over USB on a case-by-case basis provided that no additional software needs to be installed on Nanode. Alternative command and data interfaces need to be discussed, tested, and agreed upon early in the design process and documented in the payload ICA, and may trigger the need for JSL testing at NASA facilities.

4.6 Human Factors Requirements

Payloads **shall** pass an ISS Program Human Factors Interface Team (HFIT) Inspection. The HFIT inspection may take place at the Nanoracks facility with NASA oversight during ground processing activities.

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

Generic inspection requirements for the Payload Module are listed in Table 4.6-1. Payloads using the Standard Nanolab Module provided by Nanoracks are generally only inspected according to Table 4.6-1.

Non-standard modules that require crew access or that have custom enclosures may require additional inspection. Examples of some non-standard inspection requirements are listed in Table 4.6-2.

Table 4.6-1: Inspection Requirements to Meet HFIT

#	Inspection Description
1.	Verify smooth surfaces (no burrs), including that flush or oval head fasteners are used for fastening.
2.	Verify payload meets minimum edge and corner radii limits to protect crewmembers from sharp edges and corners (refer to Section 4.1.5).
3.	Verify holes that are round or slotted in the range of 0.4 to 1.0 in (10.0 to 25.0 mm) are covered.
4.	Verify payload meets Visibly Clean-Sensitive (VC-S) cleanliness level.

Table 4.6-2: Inspection Requirements for Non-Standard Nanolab Modules

#	ADDITIONAL INSPECTIONS FOR NON-STANDARD MODULES:	Why it Doesn't Apply to Standard Module
5.	Verify threaded ends of screws and bolts accessible by the crew and extending more than 0.12 in (3.0 mm) are covered or capped to protect against sharp threads, and that there are no materials that flake or create debris if the screw/bolt has to be removed.	Standard plug-n-play has no fasteners for crew access
6.	Verify levers, cranks, hooks, and controls are not located or oriented such that they can pinch, snag, or cut a crewmember.	Standard plug-n-play has no controls
7.	Verify safety wires or lockwire are not used on fasteners that are accessible to crewmembers.	Standard plug-n-play has no fasteners for crew access
8.	Verify payload has a means to restrain the loose ends of hoses and cables.	Standard plug-n-play has no exterior hoses/cables
9.	Verify cables (longer than 0.33 meters (one (1) foot)) are restrained as follows: Length(m) Restraint Pattern (% of length) +/- 10%) 0.33-1.00 50% 1.00-2.00 33%, 76% 2.00-3.00 20%, 40%, 60%, 80% >3.0 m at least each 0.5 meters	Standard plug-n-play has no exterior cabling
10.	Latches that pivot retract, or flex, so that a gap of less than 1.4 in (35 mm) exists (to prevent entrapment of a crewmember's fingers or hand).	Standard plug-n-play has no latches, nor opens for crew
11.	Closures or covers **are** provided for any area of the payload where debris, moisture, or other foreign materials could create a hazard.	Standard plug-n-play is closed system

Appendix A Requirements Matrix

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Appendix B Standard Nanolab Modules

B.1 Mechanical Definition

The following sections provide detailed information about the Nanoracks-provided Standard Nanolab Module. The Standard Nanolab Module consists of an extruded aluminum chassis with plastic end-caps on either end to encapsulate customer payloads. The standard module already meets the dimensional specification of interface requirement 4.2.1.1, ensuring that the payload interfaces correctly with the Nanode platform.

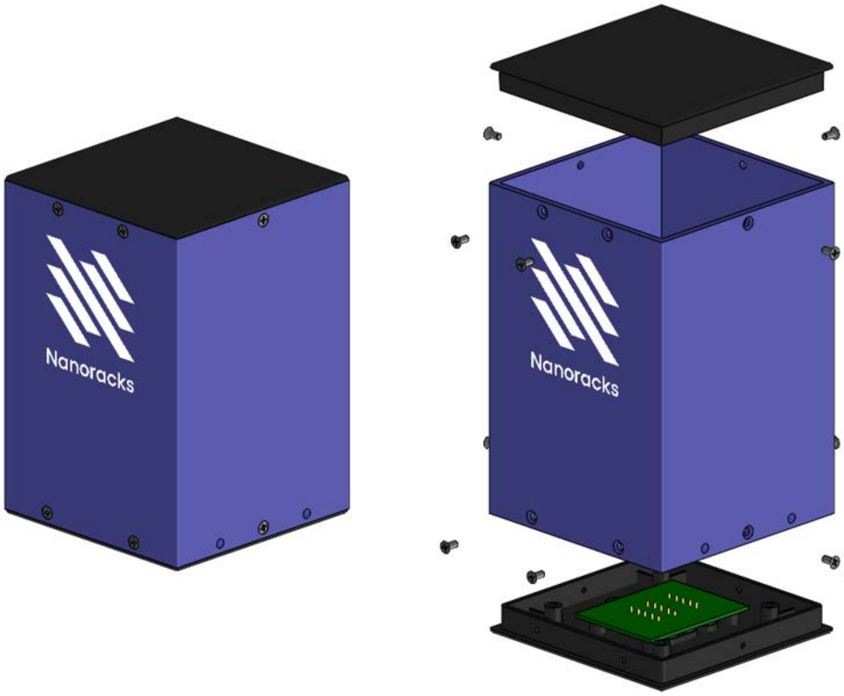

Figure B.1-1: The Standard Nanolab Module (1.5U)

B.1.1 Internal Dimensions

Payload hardware must fit within the nominal dimensions provided in Figure B.1.1-1 and Figure B.1.1-2. All dimensions are given in both inches and millimeters. Tolerances are included where applicable.

Note: The aluminum chassis is made from extruded Aluminum square tube toleranced per ANSI-H35.2; in extreme cases, variances in internal width may be as large as 0.050 in. Therefore, Payload Developers should take caution when designing tight-fitting hardware within the enclosure. It is recommended that upon receiving the Standard Nanolab, Payload Developers measure the internal dimensions of their particular chassis and design their hardware to match. Perform fit checks as often as possible to ensure a good fit. Reference ANSI H35.2 for specific guidance on tolerances. Chassis dimensions in Figures B.1.1-1 and B.1.1-2 governed by ANSI H35.2 are generally given as reference dimensions in parentheses ().

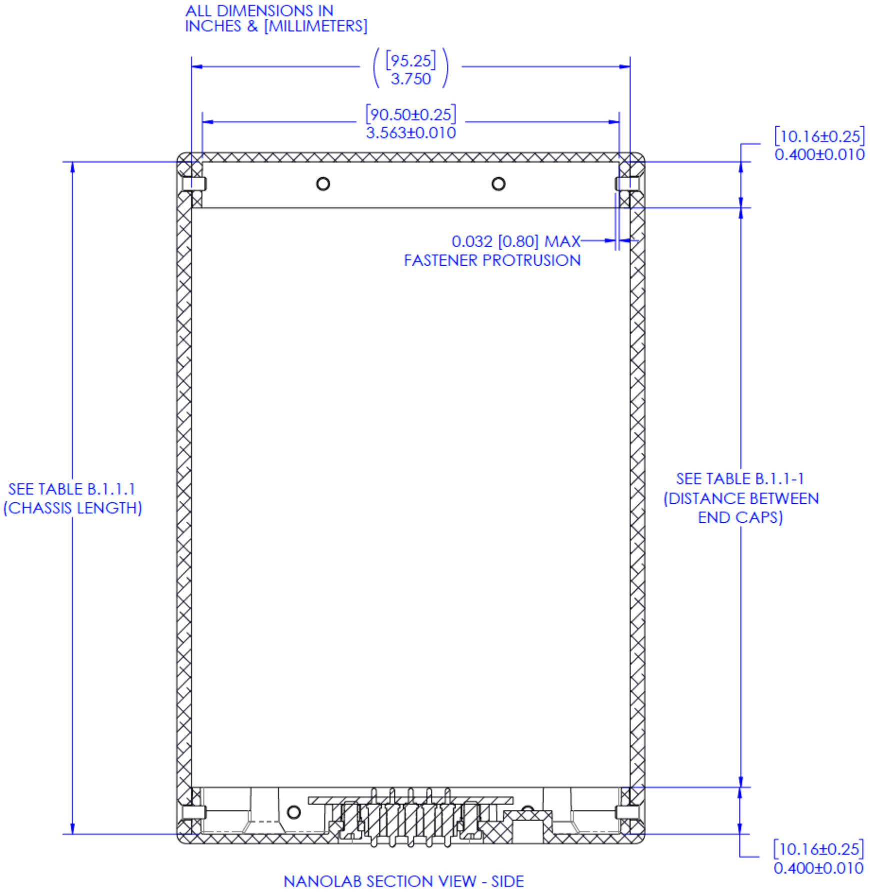

Figure B.1.1-1: Standard Nanolab Internal Dimensions

Table B.1.1-1: Table of Standard Nanolab Module Sizes

Form Factor	Chassis Length	Distance Between End Caps
1U	3.780±0.010 in (96±0.25 mm)	2.980±0.010 in (75.7±0.25 mm)
1.5U	5.748±0.010 in (146±0.25 mm)	4.948±0.010 in (125.7±0.25 mm)
2U	7.717±0.010 in (196±0.25 mm)	6.917±0.010 in (175.7±0.25 mm)

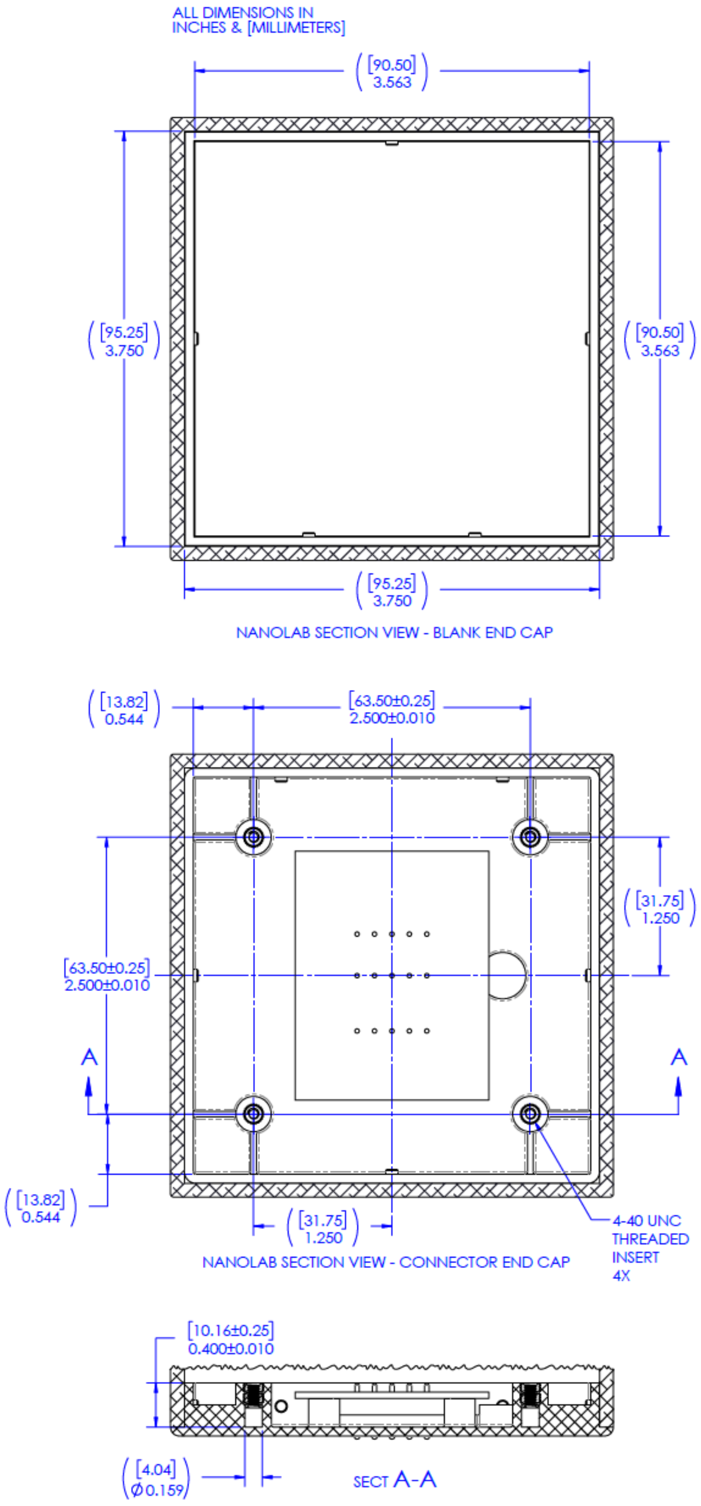

Figure B.1.1-2: Standard Nanolab Internal Dimensions

B.1.2 Mounting Points

The Standard Nanolab Module includes four (4) pre-installed 4-40 UNC threaded inserts to serve as mounting points on the Connector End Cap (dimensioned in Figure B.1.1-2).

B.1.3 Connector Breakout PCB Mounting Information

In the standard configuration, the connector breakout PCB is installed into the end-cap with six (6) NAS1101E04-4 offset-cruciform fillister head fasteners with Loctite or equivalent used as the secondary locking feature. The PCB fasteners are torqued to 45-56 in-oz.

B.2 Electrical Definition

The Standard Nanolab Module comes pre-installed with a connector-breakout PCB board containing all three (3) Mill-Max 858 Series spring loaded connectors for interfacing with Nanode.

B.2.1 PCB Pin Layout

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