Nanoracks Black Box
Interface Definition Document (IDD)

Nanoracks

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Revision:	A

List of Revisions

Revision	Revision Date	Revised By	Revision Description
-	10/10/2019	Joseph Kissling	Initial Release
A	7/22/2022	Steven Stenzel	General Updates

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1 Introduction

1.1 Purpose

This Interface Definition Document (IDD) provides the minimum requirements for compatibility of a payload to interface with the Nanoracks Black Box. This IDD also defines the requirements to the International Space Station (ISS) flight safety program when using the Nanoracks Black Box and defines the various environments applicable to the payload design process. 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 transport, ascent, and on-orbit phases of the pressurized payload operation. On-orbit requirements apply to all the payloads in the International Space Station (ISS).

1.3 Use

This document levies design interface and verification requirements on payload developers. These requirements are allocated to a payload through the unique payload 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
AAA	Avionics Air Assembly
BOM	Bill of Materials
CMC	Cargo Mission Contract
EMI	Electromagnetic Interference
EXPRESS	EXpedite the PRocessing of Experiments to Space Station
FOD	Foreign Object Debris
HTV	H-2 Transfer Vehicle
ICA	Interface Control Agreement
IDD	Interface Definition Document
ISS	International Space Station
JEM	Japanese Experiment Module
KuIP	Ku-band IP Services
NLT	No Later Than
NR	Nanoracks
PDR	Preliminary Design Review
PI	Principal Investigator
SDP	Safety Data Package
SDT	Safety Data Template
SpX	SpaceX
UL	Underwriters Laboratories
USB	Universal Serial Bus

Table 2-2: Applicable Documents

Doc No.	Rev	Title
SSP 57000	T	Pressurized Payloads Interface Requirements Document
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
SSP 51721	-	ISS Safety Requirements Document

3 Nanoracks Black Box Overview

The Nanoracks Black Box interfaces between customer payloads and the ISS, providing mechanical mounting points and electrical connections for power, data, and communication capabilities. The Nanoracks Black Box Assembly is shown in **Figure 3-1**, and in its Locker installed configuration in **Figure 3-2**. **Figure 3-3** contains directional references.

- Data, power and structural interface to the ISS
- Cooling air interface to the ExPRESS Rack AAA Plenum
- Twelve (12) switchable USB 3.0 Ports, 2A max current Ŧ
- Twelve (12) switchable 5VDC, 5A power ports Ŧ
- Twelve (12) switchable 12VDC, 3A power ports Ŧ
- Up to 20GB/Week, 6GB nominal, data download.
- 2100 in^3 (.034 m^3) payload volume
- Realtime ground interface through Nanoracks operations

Ŧ Total combined power draw from all ports (USB, 5VDC, 12VDC) is limited to 500W

Nanoracks also has a camera system available, provisions for its use and locations within the Black Box shall be laid out in the payload-specific ICA.

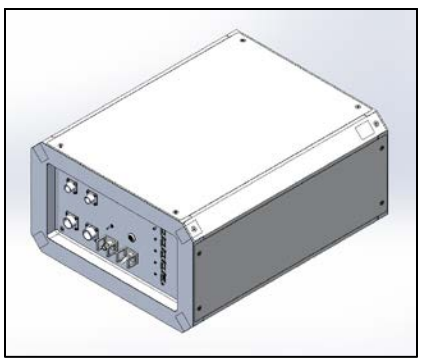

Figure 3-1: Nanoracks Black Box

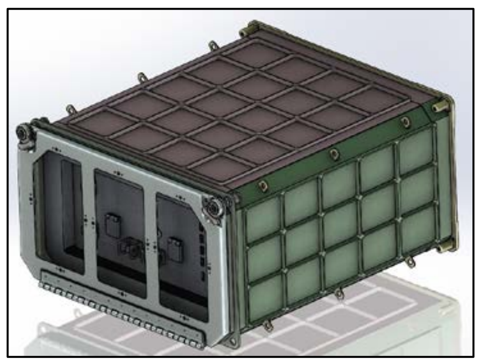

Figure 3-2: Nanoracks Black Box in locker

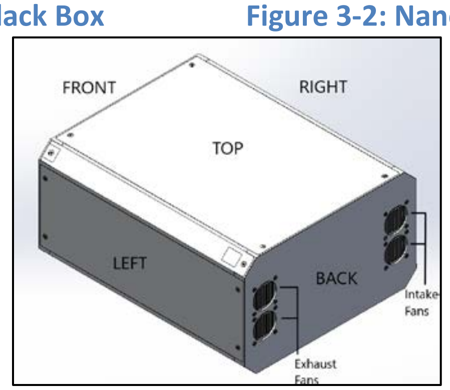

Figure 3-3 Directional References

3.1 Black Box Structural Interface Overview

3.1.1 Black Box Mounting

Black Box exists with two (2) mounting configurations: bare interior panels or a bolt hole grid; configuration selection is handled by the ICA. In the bare interior configuration, users will be able to affix payloads to the interior surfaces using either hook and loop fasteners or double-sided tape. The bolt hole grid configuration uses a grid of 2-inch centers of #8-32 fasteners on the base plate; this modified base plate protrudes ¼ inch into the interior volume of the Black Box. Securing the low mass and/or low heat generating portions of the payload can also be done with hook and loop or double-sided tape. In either configuration, the electronics plenum is used for securing cables only. Use of the provided grid pattern is encouraged as the positive retention provided increases the odds of mission success, especially against launch loads. **Figures 3.1.1-1** and **3.1.1-2** show the standard bolt hole pattern. See drawing NR-BBOX-D0001 or the CAD model for more detailed dimensional data.

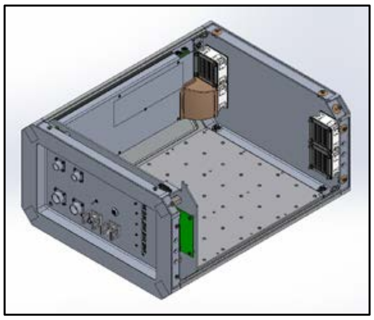

Figure 3.1.1-1: Bolt hole pattern within Black Box.

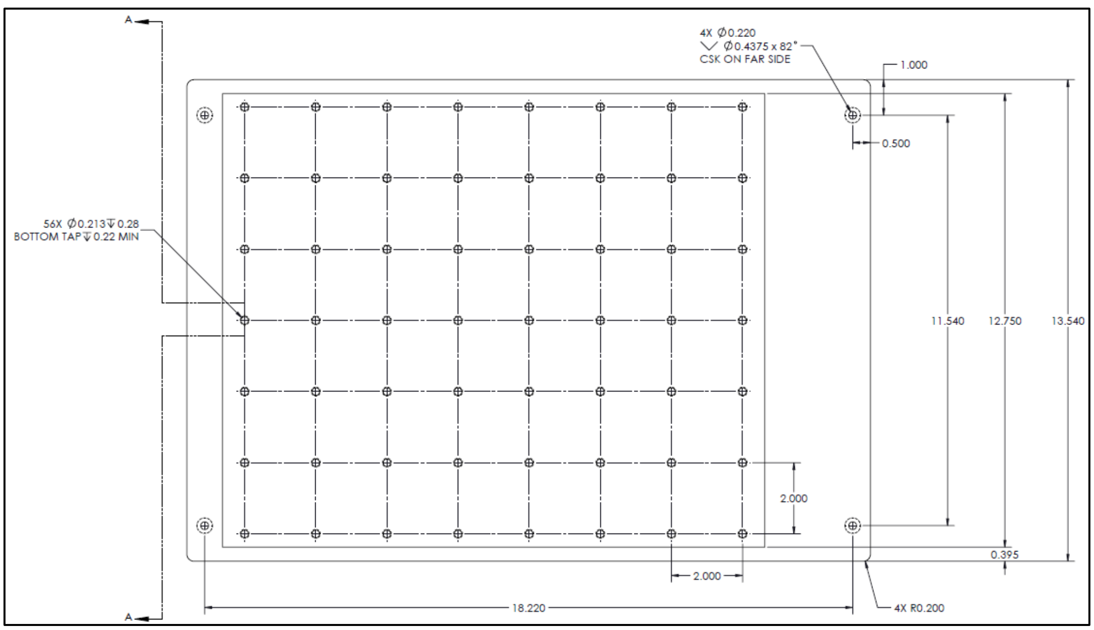

Figure 3.1.1-2: Bolt Hole pattern, dimensional drawing.

3.1.2 Work Envelope

Figure 3.1.2-1 shows the approximate working envelope of the Black Box with the bolt-grid configuration. Payload working envelope CAD with exact dimensions available at request.

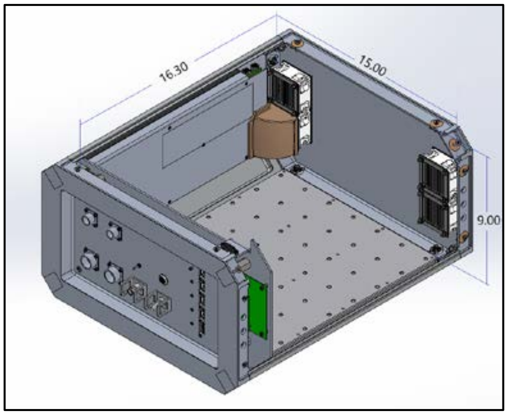

Figure 3.1.2-1 Bolt grid configuration work envelope.

3.1.3 Airflow

Black Box uses four (4) AFB0612H-AF00 DC fans in a pusher puller configuration. One (1) draws air in to cool the Black Box Avionics, and one (1) draws air in to cool the payload volume. Two (2) fans push air out. **Figure 3.1.3-1** showcases the air flow patterns within Back Box. Airflow within the work envelop changes with the specific physical configuration of the user-provided and mission-specific payload. Air is expected to be exchanged at a rate of 1.2 m^3 per minute with the Avionics Air Assembly (AAA) system of the ISS.

Air supplied by the AAA system will have a nominal temperature between 65°F and 85°F (18.3°C and 29.4°C). The actual air temperature is dependent upon the heat load recirculated into the AAA system by the EXPRESS Rack payload compliment. Payloads that require precise temperature data should incorporate a temperature monitoring system or work with Nanoracks to help develop one as a unique service.

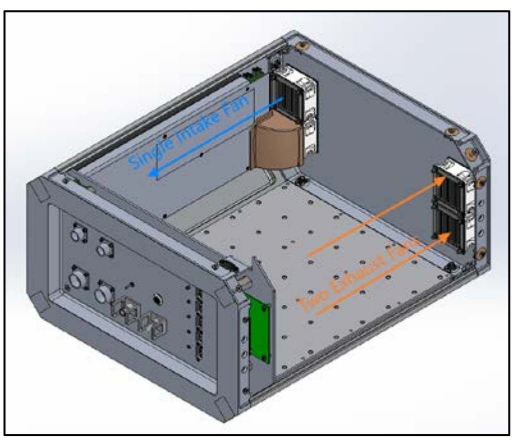

Figure 3.1.3-1 Airflow pattern within Black Box

3.2 Black Box Electrical Overview

Black Box electrical interfaces can support up to twelve (12) independently switchable payloads. Each payload electrical interface consists of:

- One USB 3.0 Type A connector providing 5 VDC @ 2A power. Reference **Figure 3.2-1**.
- One Auxiliary Power 6-pin connector which can provide 5 VDC @ 5 A and 12 VDC @ 3 A.
- **Figure 3.2-2** shows two paths the cables/harnessing can be fed through to the connectors.

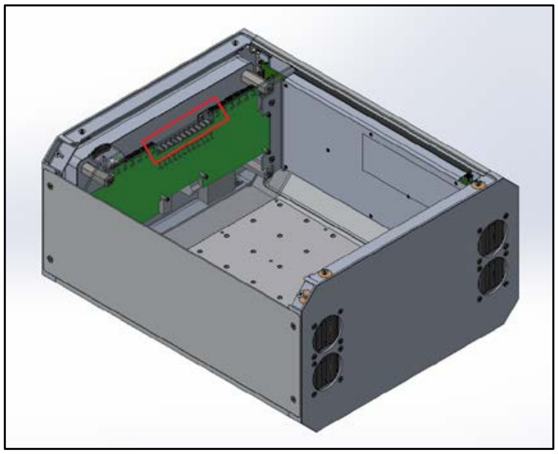

Figure 3.2-1: Black Box USB and Power Connectors Location

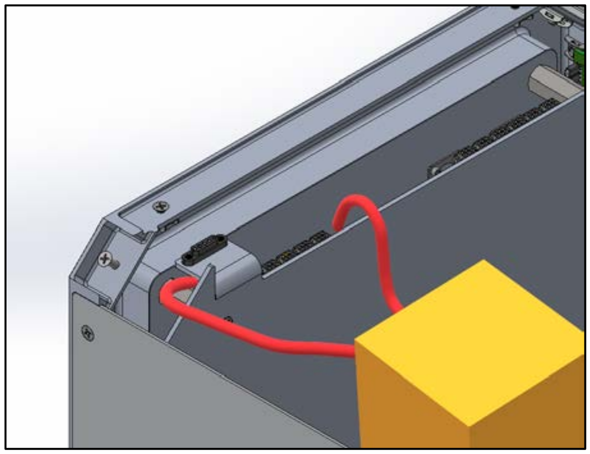

Figure 3.2-2: Black Box USB and Power Connectors Cable Paths

Payloads may use either a USB 3.0 Type A plug or a USB 2.0 Type A plug to interface to the Black Box USB ports. The 5V and 12V Aux power are provided through a Molex Micro-Fit 3.0 plug. See section 4.4.1 for details.

Each power source for each payload is independently switchable and protected from overcurrent. Payloads may use any combination of power sources from any position, but payloads **shall** not tie independent power sources together to increase the current output. Attempting to tie power sources together may cause the overcurrent protection to trip early for the channels.

Black Box payload voltage may range between 4.9VDC and 5.6VDC on the USB and 5V Aux Power channels and 11.9VDC to 12.6VDC on the 12V Aux Power channels depending on the overall load of the Black Box unit. Payloads requiring precise voltage regulation should include their own power conditioning circuits.

All payload channels are independently current limited. 5V USB ports have a current limit of 2A. The current limiter for the USB operates by reducing the output voltage to maintain 2A output current in the event of an exceedance. A persistent or very large exceedance will cause the USB port to turn off. The 5V and 12V Aux power channels have current limits set at 5A and 3A respectively. These current limiters are fast acting and will shut off the channel within 1ms in the event of an exceedance. All tripped power channels will remain off until reset by Nanoracks Operations.

3.3 Nanoracks Black Box Operations Overview

The launch, on-orbit installation, and duration of operation for Black Box service is defined in the individual ICA. The timeframe for payload activation will be documented in the ICA to ensure customer support for flight operations.

3.3.1 Ground Operations

3.3.1.1 Delivery to Nanoracks

The payload customer will deliver the integrated payload(s) to the Nanoracks Houston facility, or another facility as determined by the ICA, by the dates listed in the schedule. Any special requirements, such as 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 is required from the PD, and for sanitization of overall payload before or with turn-over to Nanoracks. Otherwise, Nanoracks cannot receive the item due to potential contamination hazard. Furthermore, the hardware is to be turned over to Nanoracks in sealed clear bagging (unless otherwise documented in the ICA) to allow verification that no containment break has occurred.

3.3.1.2 Nanoracks Inspection

Nanoracks will inspect the payload assembly to verify it meets the appropriate safety and ICA requirements. For final delivery, this includes, but is not limited to, the NASA Human Factors Implementation Team (HFIT) inspection, leak checks, and final mass properties and overall dimensions.

3.3.1.3 Nanoracks Data Gathering for Operations

Nanoracks will assess the combined payload to develop 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 an effective way for crew to assemble and install the payload, develop supporting procedures, and ensure successful operation of the Payload.

3.3.1.4 Nanoracks Testing

Nanoracks will perform any agreed-to testing of the payload based on the Interface Control Agreement. This will include, but is not limited to, grounding checks, bonding checks, verification of the concept of operations, magnetic field values (if applicable), and other testing as required. If the payload requires data handling, Nanoracks Operations will perform a functional test of the flight-ready payload. This functional test will check that the USB communication between the payload and Black Box is successful, ensure that the command and data handling requirements specified in this document are met, and conduct a subset of all required on-orbit operations including file transfers and recovery from power interruptions. Any special requirements will be documented in the payload specific ICA.

3.3.1.5 Customer Ground Servicing

The customer is allowed to perform last minute payload activities at the Nanoracks facilities (or alternate agreed upon delivery site) prior to final packaging, based on the agreements in the ICA. 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.

3.3.1.6 Nanoracks Packaging and Delivery

Nanoracks will deliver the completed payload assembly to the Cargo Mission Contract team for flight packing. Any special packing requirements (e.g., humidity, thermal, venting, or orientation) are to be listed in the payload specific ICA.

3.3.2 Launch

The Cargo Mission Contract team is responsible for delivering the final stowed configuration to the launch vehicle team for final integration into the ISS visiting vehicle.

3.3.2.1 Launch Scrub

The payload customer 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 customer needs to specify in the ICA if a swap-out replacement will be available, as well as how long a scrub timeframe can be tolerated by the payload before loss of science. This is to be documented in the ICA.

3.3.3 On-Orbit operations

3.3.3.1 Payload Destow

Once the launch vehicle is on orbit and berthed, the crew is responsible for transferring Black Box and placing it in the appropriate on-orbit location for installation.

3.3.3.2 Payload Installation

Once NASA schedules the payload installation window (subject to various constraints such as crew time, etc.) the on-orbit crew is responsible for unpacking the Black Box and installing into the ExPRESS Rack.

3.3.3.3 Experiment Operations

During the experiment performance the user can update their experiment via file uplink and/or gather experiment data from the payload via file downlink. 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 Black Box performance and ISS environment:

- Frequency and lead-time for updates and data downlink
- Data format and file sizes
- Whether the payload generated data, or some parts of the payload generated data need to be returned to the ground prior to payload return
- Thermal or humidity constraints/limits for the science while operating

3.3.3.4 Ground to Payload Communication

Communications to/from Nanoracks Black Box is accomplished through NASA managed Ku-band Internet Protocol (Ku-IP) which allows for a graphical interface into the platform. Ku-IP provides a Remote Desktop graphical interface to Black Box and any connected payloads. File transfer rates are dependent on many different factors. Payload required file sizes and frequency of file uplinks/downlinks will be documented in the ICA.

3.4 Schedule and Deliverables

3.4.1 Schedule

Table 3.4.1-1 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 3.4.1-1: 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.	L-13w	L-8w
Turnover to NASA[4]	L-10.5w	Ambient: L-30d, 5d, 36hrs Conditioned: L-4d, 3d
Launch		
Payload Operations (specified within ICA)		
Pack for return	Undock – 24Hr (note, payloads using a CS asset will be required to be conditioned between 72-24 hours before return)	
Return (as agreed upon within ICA)	SpX: ~45 days NG: Dependent on next available flight	
Splashdown	Undock + ~39hrs	
NOTE:	Nominal Return Payload	Early Return Payload
Return	SD + 2weeks	Helicopter to SSPF: SD+9-14hrs Boat to SSPF: SD+52 hrs Shipped to customer; NET SD+72hrs

3.4.2 Deliverables

Table 3.4.2-1 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 3.4.2-1: 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
11	Late Load Support Documentation	On-Site documentation to use labs at KSC or WFF	L-3M
12	Functional Test Report	Proof of payload working as expected	NLT H/W Turn-over

4 Payload Interface Requirements

Compliance to the requirements in this section ensure a payload can be successfully integrated and operated within the Nanoracks Black Box. This section is divided by the following disciplines: Structural, Electrical, Environmental, Safety and Human Factors

4.1 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

Hardware containing rotating equipment shall provide containment such that no rotating parts can be liberated from the payload AND any rotating components shall be less than 200 mm in diameter and rotate at less than 8000 RPM max. All rotating components within the payload must be identified and documented in the payload specific ICA.

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

Section 4.7.2 – Hazardous Materials, of SSP 51721, ISS Safety Requirements Document, Levels of Containment (LoC) for hazardous chemicals and biological materials are defined as:

> *…concentric independent layers (physical barriers) in the end item design where each individual layer is of a design integrity able to contain the hazardous material. The required number of independent levels of physical barriers is based on the hazard severity as identified above and is maintained throughout the flight.*
>
> *Each individual level of containment is required to be functionally separate, independent, and capable of containment (no leakage or erosion) under the worst-case conditions of use. Conditions of use, also referred to as environments, generally consist of all the environments that the end item will be exposed to, including handling, exposure durations, appropriate combinations of thermal, vibration, pressure (including module depressurization), mechanical, cycle life, and others as appropriate.*

Payloads containing materials (such as liquids, gases, gels, greases, powders, and/or particulates) 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 each independent seal/containment level 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** complete the Bill of Materials (BOM) template (provided by Nanoracks) and submit it to Nanoracks Mission Management/Safety for assessment of structural materials for off-gassing and flammability.

4.1.5 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.

Payloads containing real time clocks or requiring a battery to maintain volatile memory may use commercially available coin or button cell batteries provided they meet the Non-Critical Risk classification per JSC 20739. This lowest level of hazard control is reserved for low energy cells and battery designs for which standard emergency procedures are written and practiced. A battery is defined as one cell or an assembly of two or more cells. Payloads that require a battery in this context should use a battery that is UL listed and Payload Developers should provide details on all batteries and how the batteries are used in the ICA. The requirements for the Non-Critical Risk classification are listed below:

- Rated with a toxicological level of 1 or 2.
- Must not be contained in an intentionally sealed compartment.
- Meet one of the following chemistry criteria:
    - Alkaline or Silver Oxide non-rechargeable cells. Multiple cells may be used, but the cells must be arranged either all in parallel or all in series and the total battery must not exceed 12V and/or 60Wh capacity. There must be no potential charging source, and the cells must be located in a vented compartment.
    - Lithium non-rechargeable button cell batteries (only Li-MnO2, Li-CFX and LiFeS2) of up to 1000mAh capacity. Multiple cells may be used but must contain less than 4Wh total capacity.
    - Lithium-ion rechargeable button cell batteries of up to 1000mAh capacity. Multiple cells may be used but must contain less than 4Wh total capacity.

Batteries that do not meet the requirements listed above will be classified as Critical Risk or Catastrophic Risk. Approval of a battery system in these risk classifications 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.

4.2 Payload Structural Requirements

4.2.1 Dimensions

The dimensions of a Black Box payload **shall** not exceed those shown in **Figure 4.2.1-1**.

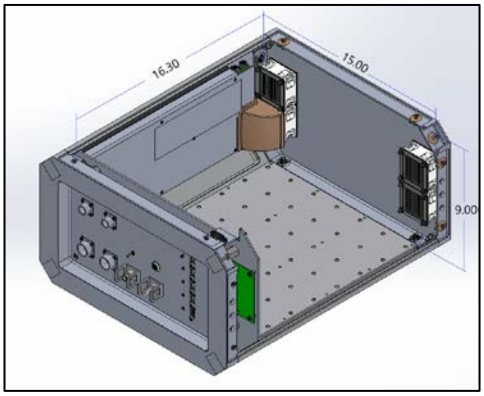

Figure 4.2.1-1 Bolt grid configuration work envelope.

4.2.2 Mass Properties

The mass of a payload within Black Box **shall** not exceed 18lbs. Larger payloads may be accommodated as negotiated and documented in a mission specific 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 1.5 (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 4.2.4.1-1** 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, (57000-IRD-PIRN-0118A,) Table D.3.1.1-1

	Nx (Axial) (g)	Ny (Lateral) (g)	Nz (Lateral)(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**	**Lateral RSS (Ny & Nz) +/- 9.3**		**N/A**	**N/A**	**N/A**

Note: For each load case, the maximum combined loads must be applied in all directions and all permutations of positive and negative loads in each direction must be covered

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 4.2.4.2-1**.

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, (57000-IRD-PIRN-0128A), Rev T, Table D.3.1.2-1

FREQUENCY (Hz)	PROTOFLIGHT TEST LEVEL (g^2/Hz)
20	0.35
100	0.35
100 - 160	-13.85 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).

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, items inside Black Box may exempt from this requirement due to no direct crew interface.

Table 4.2.5.1-1 Crew-Induced Loads
Ref SSP 57000, Rev T, 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.

4.2.5.3 Microgravity Disturbance Requirements

All Black Box payloads **shall** limit the force and vibrations they induce into Black Box such that they do not exceed the EXPRESS Rack vibratory limits shown in **Figure 4.2.5.3-1** and the transient force limit of 10 lb·s (44.5 N·s) over a ten-second period. Any moving parts within the payload (especially motors, pumps, valves, etc.) must be assessed. If sufficient manufacturer data for the motors, pumps, etc., is available to verify the payload is within limits, an analysis may be performed to show that the payload is within the required limits. Otherwise testing must be completed to verify compliance.

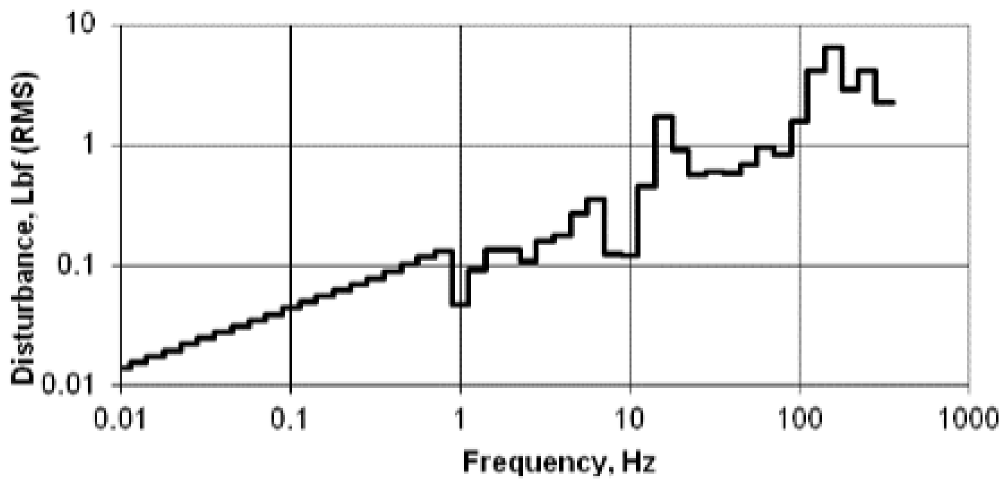

Figure 4.2.5.3-1: Express Rack Subrack Payload Vibratory Disturbances Allowable
Ref SSP 57000, Rev T, Figure F.3.1.3.2-1

4.3 Acoustic Requirements

Any payload 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 T, 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 **T**, 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 and Data Interfaces

Black Box can provide electrical power and USB 3.0 data connections for up to 12 individual payloads. Each USB 3.0 interface to the payload can provide 5 VDC at 2 Amps. Each of the auxiliary power ports can provides 5 volts at 5 Amps and 12 volts at 3 Amps. Payloads may use any combination of power sources within the restrictions outlined in the subsequent sections of this document.

Payloads can use the USB 3.0 data connection to allow for remote access to their payload via serial over USB or ethernet over USB protocols. Nanoracks Operations Engineers can use this connection to operate a payload, download data from a payload, or to update operating parameters or scripts for the payload. Black Box also offers up to 2TB of data storage for payloads that need to generate videos or other large data files but might not have sufficient internal storage to hold them. Files can be offloaded to the Black Box data storage drives and retrieved when the payloads return to earth.

4.4.1 Electrical Interface

4.4.1.1 USB Interface

The payload **shall** meet the USB 2.0, or USB 3.0 standard. The USB ports provide 5VDC at up to 2A of current. If there is an overcurrent event, the current limiter will hold the output current at 2A and reduce the output voltage commensurately. If the overcurrent event is sustained, a thermal shutdown will occur, and the USB port will be turned off. The USB port can be reactivated by Nanoracks Operations if no hazards exist. A pinout for a standard USB Type A plug is provided in **Figure 4.4.1.1-1**.

		USB 3.0 Type A Connector Pinout		
		Pin	Signal	Wire Color
USB 3.0	USB 2.0	1	VBUS	Red
		2	D-	White
		3	D+	Green
		4	GND	Black
		5	StdA_SSRX-	Blue
		6	StdA_SSRX+	Yellow
		7	GND_DRAIN	Bare
		8	StdA_SSTX-	Purple
		9	StdA_SSTX+	Orange
		Shell	Shield	Braid

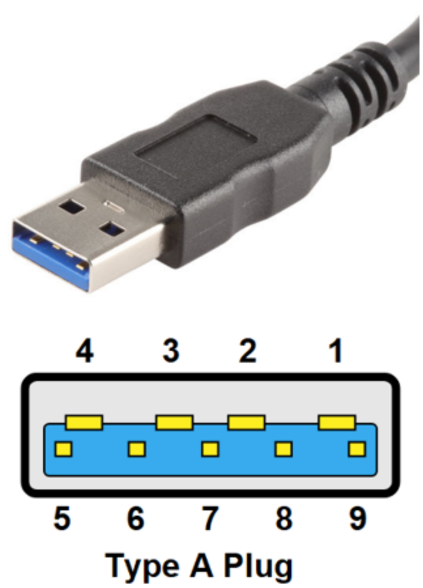

Figure 4.4.1.1-1 USB Type A Plug

4.4.1.2 Auxiliary Power Interface

The 5V and 12V Auxiliary power ports can be used if a payload requires more power than the USB ports can provide. The 5V Aux power can provide up to 5A of current to a payload, and the 12V Aux power can provide up to 3A of current to a payload. The Aux power sources may be used in conjunction with the USB power and each other but must remain electrically isolated from all other power sources. Current limiters for the Aux power ports are fast acting and shut off power to the port within 1ms of an exceedance. Payload developers should design their payloads to limit inrush current to prevent inadvertent tripping of the current limiters upon payload power on. A Pinout for the Aux power connector is shown in **Figure 4.4.1.2-1**, and the part numbers for the connector and contacts can be found in **Table 4.4.1.2-1.**

Aux Power Connector	
Pin	Function
1	12V Return
2	Shield
3	5V Return
4	+12V
5	Shield
6	+5V

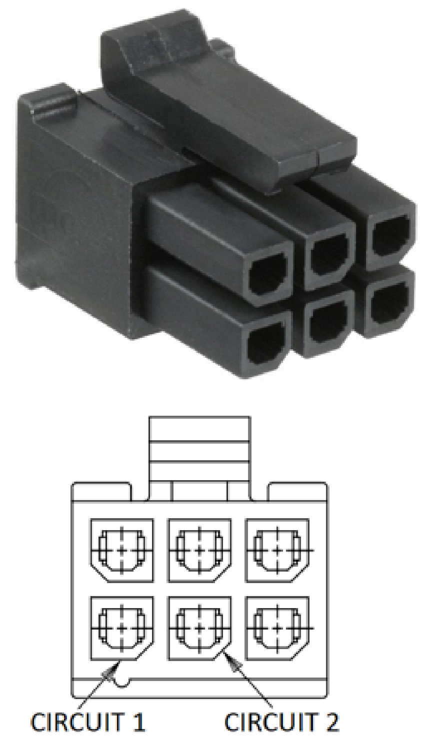

Figure 4.4.1.2-1 Black Box Aux Power Payload Side Connector

Table 4.4.1.2-1 Aux Power Connector Part Numbers

Part Number	Description
430250600	Micro-Fit 3.0 Receptacle Housing, Dual Row, 6 Circuit
430300002	Micro-Fit 3.0 Crimp Terminal, Female, with Select Gold (Au) Plated Phosphor Bronze Contact, 20-24 AWG
430300005	Micro-Fit 3.0 Crimp Terminal, Female, with Select Gold (Au) Plated Phosphor Bronze Contact, 26-30 AWG
430300039	Micro-Fit 3.0 Crimp Terminal, Female, with Select Gold (Au) Plated Phosphor Bronze Contact, 18 AWG

4.4.2 Electrical Compliance

4.4.2.1 Grounding, Bonding and Electrical Isolation.

All powered payloads **shall** comply with the Power Isolation, Single Point Ground, and Bonding requirements listed below. Verification of grounding, bonding, and isolation **shall** be by test and will be verified by Nanoracks prior to integration, functional checkout and operation at our Webster, TX facility. Payloads failing to meet these requirements will be rejected until they meet the requirements listed.

4.4.2.2 Power Isolation

Each electrical power source **shall** be DC isolated from all other power sources and the payload structure and shield connections by a minimum of 1 Megaohm resistance. Power sources cannot be electrically tied together, i.e., 5V USB power cannot be connected to 5V Aux power. These power channels are switched independently and have independent current limiting devices. Similarly, payloads that use multiple payload positions cannot tie power channels together across payload positions, i.e., a payload may use the 12V Aux power from position 1 to power a computer, and simultaneously use the 12V Aux power from position 2 to operate an actuator, but the two circuits must be electrically isolated from each other. These power sources may be used simultaneously to power independent and isolated circuits, but they cannot be used in parallel to increase the current supplied to a single circuit.

4.4.2.3 Single Point Ground

The ISS utilizes a single point ground scheme; power returns must remain isolated from structure all points except the power source. It is important to delineate the colloquial usage of “ground” from the defined uses in space flight hardware. The terms “power return”, or simply “return” describe the intended and discrete current source path designed for the payload. The terms “structure”, “case”, or “shield” describe the conductive elements of the payload structure and braided shielding on electrical cables. Electrical current is not permitted to flow through the ISS structure or cable shields except in fault conditions.

Power returns for the 5V USB, 5V Aux Power and 12V Aux Power **should** be isolated from each other. Failure to isolate the returns may cause a ground loop and interference in the payloads. Each electrical power source utilized by the payload **shall** utilize its associated power return. For example, if both the 5V Aux power and 12V Aux power sources are used by the payload, the power returns cannot be tied together to a single wire and connected to just a single pin on the Aux power connector. Both returns must be used to prevent overloading of a single connector pin.

All power returns **shall** be DC isolated from the payload structure and shield connections by a minimum of 1 Megaohm resistance. Many commercial electronics used in payloads connect mounting pads or cable shields to the power return. The payload developer must ensure that these connections are properly isolated from the payload structure by either severing the cable shields, modifying the PCB, or using non-conductive mounting hardware as required.

4.4.2.4 Electrical Bonding

A class H bond is required for all exposed conductive structures to prevent a shock hazard in the event a fault condition allows current to flow through the structure. The bonding path for Black Box payloads is provided through the shield pins on the connectors and through the bolted interface to the baseplate. The payload bond will be tested prior to integration into Black Box for functional testing.

Payloads utilizing metal enclosures, or with exposed conducting surfaces **shall** have less than 0.1 Ohm resistance from the enclosure or each exposed conducting surface to the shield pin(s) on the electrical connectors or to the Black Box baseplate when bolted in place. Two shield pins are provided in the Aux power connector. The USB cable shield may be used for bonding, but payload developers should be aware that most commercially available USB devices tie the shield on the cable to the power return plane on the device and thus violate the single point ground requirements in section 4.2.2.3.

Payloads with bolted interfaces between exposed conducting surfaces may use a bonding jumper or faying surfaces to create the bond path between the structures. Bonding jumpers must be sized to carry the worst-case fault current that could occur; generally, the worst-case fault current is considered to be 130% of the upstream circuit protection value. Payloads that utilize a faying surface between the two conductive parts or depend upon the bond between the structure and the base plate of Black Box must have a conducting contact area at least 4 times greater than the cross-sectional area of a wire sized to carry the worst-case fault current. An example calculation is demonstrated below.

Bonding Example:

For a circuit utilizing a 4-amp fuse:

Maximum fault current is 130% of fuse rating:

$$4A * 130\% = 5.2A$$

Minimum bonding wire size required:

24AWG - 175°C Rate TFE Insulated wire

Minimum faying surface contact area:

24AWG wire diameter: 0.0201”

Faying Surface Conductive contact area:

$$(0.0201in\ /\ 2)^\wedge 2 * \pi * 4 = 0.0013in^\wedge 2$$

4.4.2.5 Wire Derating

Internal payload wiring **shall** be derated per **Table 4.4.2.5-1**. Additionally, **Table 4.4.2.5-2** is provided to inform the payload developer of the maximum current carrying capability of each wire gauge. Exceeding the current limits specified in **Table 4.4.2.5-2** will cause pyrolyzation of the payload wiring.

To ensure adequate safety margins, wire gauges smaller than 24 AWG are not recommended. Payloads requiring wire gauges smaller than 24 AWG 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 or PTFE insulated wire with 200°C temperature rating in the payload.

Most commonly available wire uses PVC insulation. PVC wire insulation is flammable and generally not permitted. If the use of PVC wire is unavoidable, then the total length of PVC insulated wire in the payload 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. If payload providers cannot positively identify the wire insulation, they must assume the wire is PVC insulated, and they should identify it on the ICA.

Table 4.4.2.5-1 Single Wire IVA Derating Criteria

Ref SSP 51721, Rev -, Table 4.3.1.2-1

TABLE 4.3.1.2-1 WIRE SIZE DERATING AND CIRCUIT PROTECTION

	Column A		Column B		Column C
	Maximum Continuous Current Rating (100% of Circuit Protection Rating)		130% of Circuit Protection Rating (or worst-case upstream current >1 second)		Current Limits to meet touch temperature limited for crew accessible wire/cables
	IVA	EVA	IVA	EVA	IVA
Wire Size (AWG)	Upstream Current Protection Limit for a Single Wire (I_{sw}) (amps) [1, 2, 3.7]	Upstream Current Protection Limit for a Single Wire (I_{sw}) (amps) [1, 5,6,7]	Maximum Allowed Smart Short Current (amps) [1, 2, 4]	Maximum Allowed Smart Short Current (amps)[1, 4, 5]	Maximum Wire Current < 45C/113F[,7]
26	3.8	3.4	4.9	4.4	1.7
24	5.4	4.7	7.0	6.1	2.7
22	7.4	6.5	9.6	8.4	3.5
20	10.0	8.8	13.0	11.4	4.8
18	13.2	11.6	17.2	15.1	6.0
16	15.0	13.3	19.5	17.3	7.6
14	20.0	18.0	26.0	23.4	9.5
12	29.0	25.0	37.7	32.5	12.8
10	40.0	34.8	52.0	45.2	17.7
8	63.0	56.0	81.9	72.8	29.7
6	92.0	80.0	119.6	104.0	43.1
4	120.0	110.0	156.0	143.0	58.6
2	170.5	150.5	221.6	195.6	90.9
1/0	260.0	220.5	338.0	286.6	108

Note 1 – Wire size deratings listed are for wire insulation rated for 200°C.
Note 2 - These currents are for Intravehicular Activities (IVA) wires on-orbit in cabin ambient at 22°C (72°F).
Note 3 – IVA Wire with these currents will reach 118°C (242°F). The wires are not to be accessible to the crew. For IVA crew accessible wires, use Column C.
Note 4 - This current is the maximum sustained fault current allowable by the circuit protection device. Wire temperature could reach 185°C (365°F).
Note 5 - These currents are for IVA wires in a vacuum at 94°C (200°F) ambient.
Note 6 - Wire with these currents will reach 147°C (295°F) and are not to be accessible to the IVA crew.
Note 7 –It is necessary that wire bundle derating account for maximum continuous current rating and current limits.
Note 8 - Bundle derating may not be necessary if bundled power wiring is not significantly loaded. When wire is bundled, maximum design current for each individual wire is derated according to the following:
For N < 15 For N > 15
Bundled Wire (IBW) = Single Wire (ISW) × (29 - N)/28 IBW = (0.5) × ISW
Where: N = number of wires IBW = current, bundle wire
rent, single wire

Table 4.4.2.5-2 Wire Sizing Criteria
Ref SSP 57000, Rev T, 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.

4.4.2.6 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 **Table 4.4.2.6-1** and **Table 4.4.2.6-2**. Fuses and circuit breakers are thermal devices and the lack of natural convection and normal heat dissipation in the microgravity environment causes additional thermal stress on these devices. Fuses and circuit breakers must be derated, or oversized, to ensure they do not trip at a lower current limit than anticipated. Wiring and circuit traces must be sized appropriately for the circuit protection device. For example, a circuit nominally requires a 4A fuse and 24AWG wire, but fuse derating requires the fuse size to be increased to 8A, then the wire will have to be increased to 20AWG to account for the higher capacity circuit protection.

Table 4.4.2.6-1 Fuse Derating
Ref SSP 57000 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:

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

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 4.4.2.6-2 Circuit Breaker Derating
From SSP 57000 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:

$$30\ °C + 20\ °C = 50\ °C$$

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.

4.4.2.7 EMI

Payloads connecting to any power source or that are battery powered **shall** comply with the radiated emissions (RE) (RE02) limits defined in SSP 30237, paragraph 3.2.3.1.2.1, at 100 MHz and higher frequencies. Payloads must meet this requirement when integrated within the Black Box.

Payload safety-critical circuits that are connected to any power source or that are battery powered **shall** meet the radiated susceptibility (RS) 03 limits defined in SSP 30237, paragraph 3.2.4.2.2, at 100 MHz and higher frequencies. Non-safety-critical circuits *should* meet the radiated susceptibility (RS) 03 limits defined in SSP 30237, paragraph 3.2.4.2.2, at 100 MHz and higher frequencies.

4.5 Command and Data Interfaces

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

- The payloads shall make its memory available to the Black Box 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 Black Box and payload(s) and perform any actions needed prior to experiment execution.
- The Payload shall make its mass storage memory available for access periodically in order for experiment data to be downlinked to the ground. The time period when the drive becomes accessible is dependent on the payload and the requirement on how often files must be downlinked. Payload may use clocks, timers, or any other trigger to implement this periodic access as negotiated by the ICA. 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.

For downlink of experiment data to the ground, the nominal downlink capability is approximately 1 GB per day. If Payload requires additional downlink capacity, that must be negotiated as part of the ICA

4.6 Payload Environments

4.6.1 Thermal Environment

Expected thermal environments for all phases of payload integration are summarized in **Table 4.6.5-1** Expected Thermal Environments. Payloads with special thermal constraints should coordinate with Nanoracks.

Table 4.6.5-1: Expected Thermal Environments
Ref SSP 50835, Table E.2.10-1

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

Payloads shall be designed to not exceed a touch temperature of 45° C. A thermal analysis is required for payload heat release to the cabin.

4.6.2 Humidity

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

4.7 HFIT (Human Factors Implementation Team) Requirements

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

4.7.1 Recommended Compliance Methods and Best Practices

The following are recommended compliance methods and best practices to meet requirements. This information is representative of acceptable methods approved by NASA HFIT to date. Contact Nanoracks for specific guidance.

4.7.1.1 Protuberances, Deployable Elements and Appendages

Reserved

4.7.1.2 Surface Requirements Compliance

Burrs and sharp edges shall be removed by a process that leaves a radius, chamfer, or equivalent between 0.005in and 0.015in. Gauges not are not required. If radius or chamfer methods cannot be used then consider using covers

4.7.1.3 Securing Cables

Use of nylon locking "zip" ties or cable clamps as shown in **Figure 4.7.1.3-1** are examples of approved methods for securing cables in Black Box payloads.

Figure 4.7.1.3-1: Example Applications of Zip ties and Cable Clamps

4.8 Customer Deliverables

Table 4.8-1 describes the list of potential customer deliverables required to certify the payload for flight. More detailed information will be outlined in the payload ICA.

Table 4.8-1: Deliverables

Item	Deliverable	Description	Date
1	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-4M
2	Data for Tox/Bio Hazard Evaluation		NLT L-4M
3	MSDSs for each substance		NLT L-4M
4	Final mass and dimension report		NLT H/W Turn-over
5	Containment Level & Cleanliness Certification	Certificate of Compliance for Containment Levels and Sanitized Surface required for turn-over/handling acceptance or leak and vibration testing (if required)	NLT H/W Turn-over
6	Quality Assurance Certification	COC stating that the hardware was built, assembled, and meets the ICA; final mass/dimension report; Certifications and BOM provided.	Hardware Delivery

5 Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1	**Safety Requirements**			**NVR**	
4.1.1	**Safety Criticality Definitions**			**NVR**	
4.1.2	**Debris and Shatterable Materials**	Payloads **shall not** generate debris during launch or normal mission operations.	**A**	**I**	**CoC**
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.	**A**	**I**	**Drawings**
4.1.2.2	**Rotating Equipment**	Hardware containing rotating equipment shall provide containment such that no rotating parts can be liberated from the payload AND any rotating components shall be less than 200 mm in diameter and rotate at less than 8000 RPM max.	**A**	**I**	**Drawings**
4.1.3	**Pressure Systems**	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.	**A**	**A**	**Analysis**
4.1.4	**Hazardous Materials**			**NVR**	
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.	**A**	**I**	**HMST Report**
4.1.4.1.1	**Levels of Containment**	Payloads containing materials (such as liquids, gases, gels, greases, powders, and/or particulates) 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.	**A**	**I, A**	**Drawings and HMST Report**

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1.4.1.2	**Flammability and Off-Gassing**	Payloads **shall** complete the Bill of Materials (BOM) template (provided by Nanoracks) and submit it to Nanoracks Mission Management/Safety for assessment of structural materials for off-gassing and flammability.	**A**	**I**	**BOM**
4.1.5	**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.	**A**	**I**	**Battery Report**
4.2	**Structural Requirements**			**NVR**	
4.2.1	**Dimensions**	The dimensions of a Black Box payload **shall** not exceed those shown in **Figure 4.2.1-1**.		**I**	**Drawings**
4.2.2	**Mass Properties**	The mass of a payload within Black Box **shall** not exceed 18lbs. Larger payloads may be accommodated as negotiated and documented in a mission specific ICA.	**A**	**I**	**Mass Report**
4.2.3	**Structural Analysis FOS**	Structural analysis performed to verify the requirements in the following sections **shall** apply a FOS of 1.5 (yield) and 2.0 (ultimate) and result in a positive margin of safety (>0.00).	**A**	**A**	**Structural Report**
4.2.4	**Transportation Loads**			**NVR**	
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 4.2.4.1-1** 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.	**A**	**A**	**Structural Report**
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 4.2.4.2-1**.	**A**	**A**	**Structural Report**
4.2.4.3	**Shock Loads**			**NVR**	
4.2.5	**IVA Loads**			**NVR**	

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
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 items inside Black Box may exempt from this requirement due to no direct crew interface.	**A**	**A**	**Structural Report**
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.	**A**	**A**	**Structural Report**
4.2.5.3	**Microgravity Disturbance**	All Black Box payloads **shall** limit the force and vibrations they induce into Black Box such that they do not exceed the EXPRESS Rack vibratory limits shown in **Figure 4.2.5.3-1** and the transient force limit of 10 lb·s (44.5 N·s) over a ten-second period. Any moving parts within the payload (especially motors, pumps, valves, etc.) must be assessed. If sufficient manufacturer data for the motors, pumps, etc., is available to verify the payload is within limits, an analysis may be performed to show that the payload is within the required limits. Otherwise testing must be completed to verify compliance.	**A**	**T**	**Vibration Test**
4.3	**Acoustic Requirements**	Any payload 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.	**A**	**T**	**Acoustic Test**
4.4	**Electrical Requirements**			**NVR**	
4.4.1	**Electrical Interface**			**NVR**	
4.4.1.1	**USB Interface**	The payload **shall** meet the USB 2.0, or USB 3.0 standard. The USB ports provide 5VDC at up to 2A of current. If there is an overcurrent event, the current limiter will hold the output current at 2A and reduce the output voltage commensurately. If the overcurrent event is sustained, a thermal shutdown will occur, and the USB port will be turned off. The USB port can be reactivated by Nanoracks Operations if no hazards exist. A pinout for a standard USB Type A plug is provided in **Figure 4.4.1.1-1**.	**A**	**I**	**Drawings**

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.4.1.2	**Auxiliary Power Interface**	The 5V and 12V Auxiliary power ports can be used if a payload requires more power than the USB ports can provide. The 5V Aux power can provide up to 5A of current to a payload, and the 12V Aux power can provide up to 3A of current to a payload. The Aux power sources may be used in conjunction with the USB power and each other but must remain electrically isolated from all other power sources. Current limiters for the Aux power ports are fast acting and shut off power to the port within 1ms of an exceedance. Payload developers should design their payloads to limit inrush current to prevent inadvertent tripping of the current limiters upon payload power on. A Pinout for the Aux power connector is shown in **Figure 4.4.1.2-1**, and the part numbers for the connector and contacts can be found in **Table 4.4.1.2-1.**	**A**	**I**	**Drawings, Power Report**
4.4.2	**Electrical Compliance**			**NVR**	
4.2.2.1	**Grounding, Bonding and Electrical Isolation**	All powered payloads **shall** comply with the Power Isolation, Single Point Ground, and Bonding requirements listed below. Verification of grounding, bonding, and isolation **shall** be by test and will be verified by Nanoracks prior to integration, functional checkout and operation at our Webster, TX facility. Payloads failing to meet these requirements will be rejected until they meet the requirements listed.	**A**	**T**	**EMI/EMC Test**
4.4.2.2	**Power Isolation**	Each electrical power source **shall** be DC isolated from all other power sources and the payload structure and shield connections by a minimum of 1 Megaohm resistance. Power sources cannot be electrically tied together, i.e., 5V USB power cannot be connected to 5V Aux power. These power channels are switched independently and have independent current limiting devices. Similarly, payloads that use multiple payload positions cannot tie power channels together across payload positions, i.e., a payload may use the 12V Aux power from position 1 to power a computer, and simultaneously use the 12V Aux power from position 2 to operate an actuator, but the two circuits must be electrically isolated from each other. These power sources may be used simultaneously to power independent and isolated circuits, but they cannot be used in parallel to increase the current supplied to a single circuit.	**A**	**T**	**Magnetic Test**

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.4.2.3P	**Single Point Ground**	Power returns for the 5V USB, 5V Aux Power and 12V Aux Power **should** be isolated from each other. Failure to isolate the returns may cause a ground loop and interference in the payloads. Each electrical power source utilized by the payload **shall** utilize its associated power return. For example, if both the 5V Aux power and 12V Aux power sources are used by the payload, the power returns cannot be tied together to a single wire and connected to just a single pin on the Aux power connector. Both returns must be used to prevent overloading of a single connector pin. All power returns **shall** be DC isolated from the payload structure and shield connections by a minimum of 1 Megaohm resistance. Many commercial electronics used in payloads connect mounting pads or cable shields to the power return. The payload developer must ensure that these connections are properly isolated from the payload structure by either severing the cable shields, modifying the PCB, or using non-conductive mounting hardware as required.	**A**	**T**	**Grounding /Bonding Test**
4.4.2.4	**Electrical Bonding**	Payloads utilizing metal enclosures, or with exposed conducting surfaces **shall** have less than 0.1 Ohm resistance from the enclosure or each exposed conducting surface to the shield pin(s) on the electrical connectors or to the Black Box baseplate when bolted in place. Two shield pins are provided in the Aux power connector. The USB cable shield may be used for bonding, but payload developers should be aware that most commercially available USB devices tie the shield on the cable to the power return plane on the device and thus violate the single point ground requirements in section 4.2.2.3.	**A**	**T**	**Isolation test**
4.4.2.5	**Wire Derating**	Internal payload wiring **shall** be derated per **Table 4.4.2.5-1**. Additionally, **Table 4.4.2.5-2** is provided to inform the payload developer of the maximum current carrying capability of each wire gauge. Exceeding the current limits specified in **Table 4.4.2.5-2** will cause pyrolyzation of the payload wiring.	**A**	**A**	**Wiring Derating Analysis**

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.4.2.6	**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 **Table 4.4.2.6-1** and **Table 4.4.2.6-2**. Fuses and circuit breakers are thermal devices and the lack of natural convection and normal heat dissipation in the microgravity environment causes additional thermal stress on these devices. Fuses and circuit breakers must be derated, or oversized, to ensure they do not trip at a lower current limit than anticipated. Wiring and circuit traces must be sized appropriately for the circuit protection device. For example, a circuit nominally requires a 4A fuse and 24AWG wire, but fuse derating requires the fuse size to be increased to 8A, then the wire will have to be increased to 20AWG to account for the higher capacity circuit protection.	**A**	**A**	**Circuit Protection Report**
4.4.2.7	**EMI**	Payloads connecting to any power source or that are battery powered **shall** comply with the radiated emissions (RE) (RE02) limits defined in SSP 30237, paragraph 3.2.3.1.2.1, at 100 MHz and higher frequencies. Payloads must meet this requirement when integrated within the Black Box. Payload safety-critical circuits that are connected to any power source or that are battery powered **shall** meet the radiated susceptibility (RS) 03 limits defined in SSP 30237, paragraph 3.2.4.2.2, at 100 MHz and higher frequencies. Non-safety-critical circuits *should* meet the radiated susceptibility (RS) 03 limits defined in SSP 30237, paragraph 3.2.4.2.2, at 100 MHz and higher frequencies.	**A**	**T**	**EMI/EMC Test**
4.5	**Command and Data Interface Requirements**			**NVR**	
4.6	**Payload Environments**			**NVR**	
4.6.1	**Thermal Environment**			**NVR**	
4.6.2	**Humidity**			**NVR**	
4.7	**Human Factors**	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.	**A**	**I**	**HFIT Report**