NanoRacks Plate Reader-2
Interface Definition Document

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Nanoracks

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Revision: -

List of Revisions

Revision	Revision Date	Revised By	Revision Description
-	07/08/16	S. Stenzel	Initial Release

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1 Introduction

1.1 Purpose

This Interface Definition Document (IDD) provides the minimum requirements for compatibility of a payload to interface with the NanoRacks Plate Reader-2 platform. This IDD also defines the requirements to the International Space Station (ISS) flight safety program when using the Plate Reader-2. This IDD also defines the various environments applicable to the payload design process. NanoRacks verifies compliance on behalf of payload developers based on incremental data requests. An initial payload Interface Control Agreement (ICA) will be developed based on the available payload data. Subsequent iterations will follow that will fully define all payload applicable requirements, services, and interfaces.

1.2 Scope

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

1.3 Use

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

1.4 Exceptions

The unique Payload ICA documents the payload implementation of the IDD requirements. The Unique ICA is used to determine if the hardware design remains within the interface design parameters defined by this document. Limits of the ICA are established in a conservative manner to minimize individual payload and mixed cargo analyses.

Exception is the general term used to identify any payload-proposed departure from specified requirements or interfaces. Any exception to requirements, capabilities, or services defined in this IDD shall be documented in Section 5.0 of the derived ICA and evaluated to ensure that the stated condition is controlled. Section 5.0 will document the specific requirement excepted, the exception number, the exception title, and the approval status.

2 Acronyms, Definitions and Applicable Documents

Table 2-1: Acronyms

Acronym	Definition
BOM	Bill of Materials
CMC	Cargo Missions Contract
COC	Certificate of Compliance
GLACIER	General Laboratory Active Cryogenic ISS Experiment Refrigerator
HFIT	Human Factors Implementation Team
HMST	Hazardous Material Summary Table
ICA	Interface Control Agreement
IDD	Interface Definition Document
ISS	International Space Station
JEM	Japanese Experiment Module
MELFI	Minus Eighty-Degree Laboratory Freezer for ISS
MERLIN	Microgravity Experiment Research Locker Incubator
MSDS	Material Safety Data Sheet
NOC	NanoRacks Operation Center
PD	Payload Developer
PMT	Photomultiplier Tube
UV	Ultraviolet

Table 2-2: Applicable Documents

Doc No.	Rev	Title
SSP 57000	R	Pressurized Payloads Interface Requirements Document
SSP 51700	--	Payload Safety Policy and Requirements for the International Space Station
SSP 50835	D	ISS Pressurized Volume Hardware Common Interface Requirements Document
SSP 52005	F	Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures

3 NanoRacks Plate Reader-2 Overview

The NanoRacks Plate Reader-2 is an experiment platform that is installed in ExPRESS Rack 4 located in the Japanese Experimental Module (JEM) of the ISS. The Plate Reader-2 is a modified Molecular Devices SpectraMax® M5e Multi-Mode Microplate Reader. The SpectraMax® M5e Multi-Mode Microplate Reader provides ultrafast, full spectral range detection for 6-, 12-, 24-, 48-, 96-, 384-well microplates while utilizing SoftMax Pro data acquisition and analysis software.

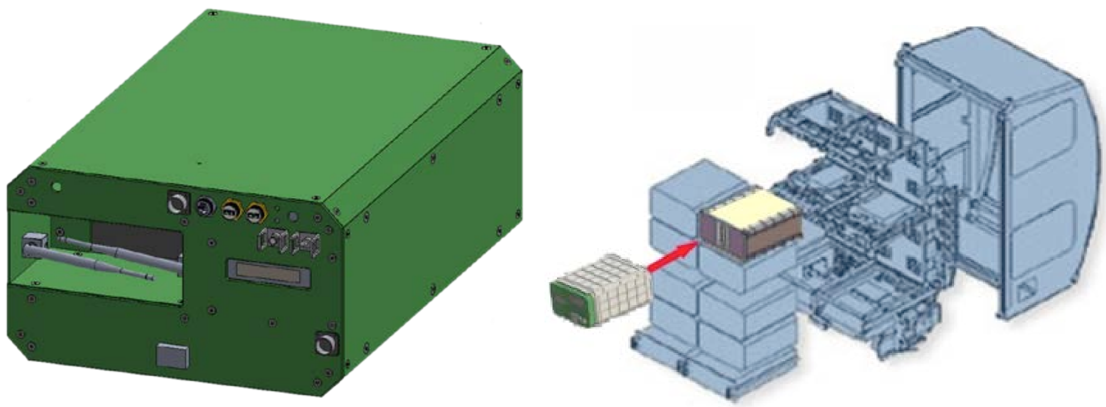

Figure 3-1: NanoRacks Plate Reader Installation to the ExPRESS Rack Locker on ISS

3.1 Experiment Capabilities

3.1.1 Modes of Operation

NanoRacks Plate Reader-2 can operate in four modes: UV-Visible Absorbance, Fluorescence Intensity, Time-Resolved Fluorescence, and Fluorescence Polarization, providing the benefit of multiple detection modes in one platform, as well as top and bottom plate reading capabilities. The NanoRacks Plate Reader-2 has an added thermal regulation capability making long-term incubation of samples possible, such as measuring microbial growth or monitoring reporter gene expression.

Using the patented PathCheck® Pathlength Measurement Technology, the SpectraMax M5e Microplate Reader transforms each well in a microplate to a fixed optical pathlength cuvette. This temperature-independent normalization corrects for varying well volumes and can eliminate standard curves by allowing the calculation of concentrations directly from the absorbance with a known extinction coefficient, as exemplified with nucleic acid and protein quantitation. The scanning range of the NanoRacks Plate Reader-2 is 200-1000 nm.

For fluorescence intensity, time resolved fluorescence, and fluorescence polarization assays, the optical design provides the highest level of flexibility. Users can select from top or bottom read modes for improved sensitivity for solution and cell-based assays. Assays can be better optimized by scanning across a range of wavelengths in increments as small as 1 nm. Up to 4 wavelength pairs can be read in one protocol for endpoint and kinetic measurements.

For luminescence, the NanoRacks Plate Reader-2 utilizes a dedicated luminescence photomultiplier tube (PMT), providing the user the maximum signal and lowest background possible for glow luminescence reporter gene assays.

3.1.2 Thermal Regulation

The Plate Reader-2 provides thermal control for more sensitive experiments. The platform can be used for long incubation for samples at 30 and 37°C. There is also no need to remove the plates between reads. The temperature requirement for an experiment is to be designated in the payload unique ICA.

3.2 Compatibility

3.2.1 Microplates

The SpectraMax Multi-Mode Microplate Reader can accommodate SBS standard 6-well to 384-well microplates. When reading optical density at wavelengths below 340 nm, special UV-transparent, disposable or quartz microplates allowing transmission of the deep UV spectra must be used.

Not all manufacturers' microplates are the same with regard to design, materials, or configuration. Temperature uniformity within the microplate may vary depending on the type of microplate used.

Microplates currently supported by the SoftMax Pro Software for use in this instrument are:

- 96-well Standard, 96 Costar, 96 Greiner Black, 96 Bottom Offset, 96 Falcon, 96 BD Optilux/Biocoat, 96 BD Fluoroblok MWInsert, 96 Corning Half Area, 96 MDC HE PS
- 384-well Standard, 384 Costar, 384 Greiner, 384 Falcon, 384 Corning, 384 MDC HE PS
- 48 Costar
- 24 Costar
- 12 Costar, 12 Falcon
- 6 Costar, 6 Falcon.

The SoftMax Pro Software plate list also includes half area and low-volume plates. SoftMax Pro can always be used to define a new plate type using the manufacturer's specifications for well size, spacing and distance from the plate edge. Note that because the plates are read in a microgravity environment, all wells should be filled to maximum capacity to avoid reading errors due to non-uniform liquid/air interface.

3.2.2 Cuvettes

The SpectraMax Multi-Mode Microplate Reader can accommodate standard-height (45 mm), 1 cm cuvettes by using a CuvettePlate Micro Plate Adapter (Figure 3.2.2-1), specifically StarnaCells Cuvette Micro Plate Adapter: (http://www.starnacells.com/d_ref/scp/scp.html).

Not all manufacturers' cuvettes are the same with regard to design, materials, or configuration (See Table 3.2.2-1). Temperature uniformity within the cuvette may vary depending on the type of cuvette used.

Cuvettes used for absorbance readings are frosted on two sides. Fluorescence cuvettes are clear on all four sides.

Figure 3.2.2-2: StarnaCells Curvette Micro Plate Adapter

Table 3.2.2-2: Standard Cuvette Dimensions

	Standard
Hellma Cat No.	100
Internal Dimensions	10 x 10
Fill Volume	4 mL

3.3 SoftMax Pro v. 6.5.1

SoftMax Pro 6 v. 6.5.1 MicroPlate Data Acquisition and Analysis Software is the latest Microplate reader analysis software available (at the time this was published). Please see the link below for more details. Please note, not all functions may be available. The required functions for an experiment are to be clarified in the payload unique ICA for review with NanoRacks.

http://www.moleculardevices.com/systems/microplate-readers/softmax-pro-data-acquisition-and-analysis-software

3.4 Plate Reader-2 Operations Overview

3.4.1 Schedule

Table 3.4.1-1: Milestone Schedule

Milestone/Activity	Launch-minus Dates
Contract signing, experiment name and general payload information	L – 8M to NLT L-6.5M
Detailed information (ICA completion) for Manifest, Safety, Interface Verification, and Ops	NLT L – 6M
Phase 0/I/II/III SDP	L – 5.5M
Complete hardware testing(containment levels)	L – 5.5 to L-4M
Phase III SVTL & Interface Verification submits/Fit Check and Functional Test	L – 3.5M
Turn over to NR for final reviews and prep (Label/Packing/HFIT Reviews) for Phase III Safety & Interface Verification Close Out. HMST V-2 is due at this time	NASA Turn-over – 2w to NASA Turn-over – 3d[1]
Turn over to NASA	Nominal Stow: L-9.5w for SpaceX / L-12w for Cygnus Late Load SpaceX[2]: L-24 d to NLT L-3d for SpaceX Late Load Cygnus[2]: L-30d to NLT L-7d

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

NOTES:

1. This option is case-by-case, must be requested in the ICA, and approval by NanoRacks depends upon rationale for need and schedule capability with other shipments for same flight.

2. Whether Nominal or Late Load, and which late load date, depends on designation of payload viability and/or cold-stow constraints provided as part of the detailed information submittal in the ICA.

3.4.2 Ground Operations

3.4.2.1 Delivery to NanoRacks

The payload customer will deliver the payload to the NanoRacks Houston facility by the dates listed in the schedule. Any special turnover requirements, such as delivery to lab near launch site, are to be listed in the payload specific ICA. 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. 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 to allow inspection that no containment break has occurred.

3.4.2.2 NanoRacks Inspection

NanoRacks will inspect the combined payload assembly to verify it meets the appropriate containment, cleanliness, and sharp edge requirements and arrange to complete further ISS Program reviews/inspections for labeling and Human Factors Implementation Team (HFIT) verification.

3.4.2.3 Customer Ground Servicing

The customer is allowed to perform last minute payload activities at the NanoRacks facilities or launch site preparation site prior to final packaging/HFIT reviews. The customer cannot increase or change chemical contents of the payload during this time. With the exception of launch scrub scenario activities, once the payload has been delivered to the Cargo Mission Contract (CMC), no further payload servicing will be allowed. Any special ground servicing requirements are to be listed in the payload specific ICA.

3.4.2.4 NanoRacks Packaging and Delivery

NanoRacks will package and flight label any payload samples and deliver the final configuration to the Cargo Mission Contract (CMC) or Cold-Stow Group (pending on transport configuration) for flight packing. Any special packing or orientation requirements are to be listed in the payload specific ICA.

3.4.2.5 Thermal Constraints

Payloads with special thermal constraints should coordinate with NanoRacks and document in the payload specific ICA. This way arrangements for thermal controls in transport and/or on-orbit can be arranged with Cold Stow group as needed, including incubation options if required.

The following thermal controls in transport and on-orbit to ISS are offered through Cold Stow group:

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

3.4.3 Launch

CMC, or the Cold-Stow Group, is responsible for delivering the final stowed configuration to the appropriate launch site facility and integration into the ISS visiting vehicle.

3.4.4 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.

3.4.5 On-Orbit Operations

3.4.5.1 Payload Destow

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

3.4.5.2 Experiment Operations

Operations for a Plate Reader-2 microplate sample are defined by the payload's timespan on-board the ISS. Plate Reader-2 microplate samples shall be standalone units. Crew interaction with a Plate Reader-2 microplate sample is limited to removal from any environmental control hardware, possible temporary stowage for equilibration to ambient temperatures, installation and removal from the NanoRacks Plate Reader-2 and re-stow in environmental control hardware. Additional crew time needs to be discussed and negotiated with NanoRacks personnel as early as possible and documented in the payload specific ICA. During and upon completion of the analysis, the internal computer utilizing the SoftMax Pro 6 data analytics software processes the acquired data.

3.4.5.3 Longevity/Time Constraints

Any operational time constraints for the payload are required to be communicated to NanoRacks through the ICA. To prevent loss of science, constraints on how soon the experiment(s) must be put in Plate Reader-2 facility need to be determined/estimated from the time hardware turn-over occurs to NanoRacks. There isn't exactly a guarantee from the ISS Program it can be met (due to berthing window/unpack timeframe/possible launch delays), but this allows them to prioritize to make best effort to prevent science loss. As mentioned in 3.4.4, the scrub time also needs documented for same reasons (to determine swap-outs to prevent science loss). To help determine if the time constraint can be met, keep in mind the following limitations in addition to the time your hardware is turned-over to NanoRacks:

- Launch to Berthing with ISS:
  - L+1d to L+5 for SpaceX
  - L+2d to L+4d for Cygnus (Orbital ATK)

- Hatch Open & Unpack:
  - Typically preferred to request NET Berth+ 3 days
  - Special requests for Late Load packed, might be able to achieve: Berth+13h to 25h

3.4.5.4 Data Handling

All data is collected by the on-board computer during real time use of the SoftMaxPro v. 6.4 and downlinked after each run and provided to the customer on the NanoRacks Online Portal.

4 Payload Interface Requirements

The requirements contained in this section will be complied with in order to certify a payload for integration into Plate Reader-2 as well as the ISS. This section is divided by the following disciplines: Environments, Human Factors and Safety.

4.1 Payload Environments

Per SSP 52005, if the payload has containment level requirements to prevent a hazard, it is considered a Safety Critical Structure.

4.1.1 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 4.1.1-1** at the CG of the item, with all six degrees of freedom acting simultaneously. The acceleration values are applicable to both soft stowed and hard mounted hardware. (Per SSP 57000, Section D.3.1.1)

Table 4.1.1-1: Launch/Landing Load Factors Envelope

	Nx (g)	Ny (g)	Nz (g)	Rx (rad/sec^2)	Ry (rad/sec^2)	Rz (rad/sec^2)
Launch	+/- 9.0	+/- 9.0	+/- 9.0	+/- 13.5	+/- 13.5	+/- 13.5
Landing	+/-10.0	+/-10.0	+/-10.0	N/A	N/A	N/A

All analysis and or testing shall be in accordance with the guidelines specified in SSP 52005 for payload hardware.

4.1.2 Random Vibration Loads Environment

Payload safety-critical structures packed in foam or bubble wrap and enclosed in hard containers such as lockers, boxes, or similar structures, and payload safety-critical structures packed in foam or bubble wrap and soft stowed in bags shall meet the specified performance requirements when exposed to the maximum flight random vibration environments defined in **Table 4.1.2-1.** Contact NanoRacks for the proper vibration test procedure. Random vibration testing may not even 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). The standard stowage configuration is the payload wrapped in bubble wrap. Otherwise, test to the stowage requirements as set in the payload ICA.

Table 4.1.2-1: Unattenuated and Attenuated Random Vibration Environments Ref. SSP 57000, Rev R, Table D.3.1.2-1

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

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

4.1.3 Launch Shock Environment

Integrated end items packed in the foam or bubble wrap materials do not experience significant mechanical shock. Shock verification is not required for launch events. 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.

4.1.4 IVA Loads Environment

Generally all payloads should be designed to provide positive margins of safety when exposed to the crew induced loads defined in **Table 4.1.4-1**, Crew-Induced Loads (reference SSP 57000, Table 3.1.1.1.2-1). HOWEVER, as a hand-held item to be placed in Plate Reader, this payload item is exempt from this requirement. The payload only needs to show positive margins of safety for on–orbit loads of 0.2 g acting in any direction for nominal on-orbit operations per SSP 57000, Rev R, Section 3.1.1.1.1.

Table 4.1.4-1: Crew-Induced Loads

CREW SYSTEM OR STRUCTURE	TYPE OF LOAD	LOAD	DIRECTION OF LOAD
Levers, Handles, Operating Wheels, Controls	Push or Pull concentrated on most extreme edge	222.6 N (50 lbf), limit	Any direction
Small Knobs	Twist (torsion)	14.9 N-m (11 ft-lbf), limit	Either direction
Exposed Utility Lines (Gas, Fluid, and Vacuum)	Push or Pull	222.6 N (50 lbf)	Any direction
Rack front panels and any other normally exposed equipment	Load distributed over a 4 inch by 4 inch area	556.4 N (125 lbf), limit	Any direction

Legend:
ft = feet, m = meter, N = Newton, lbf = pounds force

4.1.5 Thermal Environment

Expected thermal environments for all phases of payload integration are summarized in **Table 4.1.5-1** Expected Thermal Environments. Payloads with special thermal constraints should coordinate with NanoRacks.

Table 4.1.5-1: 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)
Dragon Pressurized Cargo	18.3°C to 29.4°C (65°F to 85°F)
Cygnus Pressurized Cargo	10°C to 46°C (50°F to 115°F)
On-orbit, Pre-deployment, U.S. and JEM Modules	16.7°C to 28.3°C (62°F to 83°F)
On-orbit, EVR deployment	To be analyzed by payload developer per ICA

4.1.6 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.

4.1.7 Cold Stowage Testing

4.1.7.1 Freezer Temperature Range

Verification of the payload Cold Stowage sample compatibility with the Cold Stowage System freezer temperature range shall be by test. The test shall be performed with the sample container and representative materials to a maximum expected fill level. This is to ensure that the container is not broken or otherwise destroyed after cycling a minimum of two times to the temperature range from ambient to -100 °C (-148 °F), at an environment heating/cooling rate of no less than 1 °C (1.8 °F)/minute. The sample container shall be held at the minimum temperature for at least 60 minutes for each cycle. Verification shall be successful upon inspection of container and sample during and after exposure to these temperatures with no evidence of damage or leakage being noted.

4.1.7.2 Refrigerated Temperature Range

Verification of the payload Cold Stowage sample compatibility with the Cold Stowage System refrigerated temperature range shall be by test. The test shall be performed with the sample container and representative materials to a maximum expected fill level. This is to ensure that the container is not broken or otherwise destroyed after cycling a minimum of two times to the temperature range from ambient to -10 °C (+14 °F), at an environment heating/cooling rate of no less than 1 °C (1.8 °F)/minute. (Going to -10 °C ensures a phase change occurs). The sample container shall be held at the minimum temperature for at least 60 minutes for each cycle. Verification shall be successful upon inspection of container and sample during and after exposure to these temperatures with no evidence of damage or leakage being noted.

4.1.7.3 Incubated Temperature Range

Verification of the payload Cold Stowage sample compatibility with the Cold Stowage System incubated temperature range *should* be by test. The test *should* be performed with the sample container and representative materials to a maximum expected fill level. This is to ensure that the container is not broken or otherwise destroyed after cycling a minimum of two times to the temperature range from +6 °C (+42.8 °F) to +49 °C (+120 °F) , at an environment heating/cooling rate of no less than 1 °C (1.8 °F)/minute. The sample container *should* be held at the minimum and maximum temperature for at least 60 minutes for each cycle. Verification *should* be successful upon inspection of container and sample during and after exposure to these temperatures with no evidence of damage or leakage being noted.

4.1.7.4 Cryogenic Freezer Temperature Range

Verification of the payload Cold Stowage sample compatibility with the Cold Stowage System cryogenic temperature range shall be by test. The test shall be performed with the sample container and representative materials to a maximum expected fill level. This is to ensure that the container is not broken or otherwise destroyed after cycling a minimum of two times to the temperature range from ambient to -150 °C (-238 °F), at an environment heating/cooling rate of no less than 1 °C (1.8 °F)/minute. The sample container shall be held at the minimum temperature for at least 60 minutes for each cycle. Verification shall be successful upon inspection of container and sample during and after exposure to these temperatures with no evidence of damage or leakage being noted

4.2 Payload Safety Requirements

4.2.1 Debris and Shatterable Materials

Payloads shall not have detachable parts or create any space debris during launch or normal mission operations. If the hardware has shatterable material, all shall be contained such that 50 micron or larger particles are not liberated. NanoRacks will pack each individual microplate in a sealed bag first (inner most layer of flight packing). 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 PD must accept risk to prevent a debris/frangible hazard. If the PD wants to reduce risk to their hardware breaking during transport to the ISS due to the loads environment shown in Section 4.1.1, the PD needs to specify further packing constraints in the ICA: such as specifically cut foam.

4.2.2 Hazardous Materials

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 PD will need to provide their final load values and sign-off. NanoRacks will forward the "V-1" (version from Safety Review) for mark-up as soon as it is available.

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 greater rated higher than a Toxicity hazard Level 2
- No explosive gases/reactive mixes

NOTE: PDs need to check that a chosen substances is compatible with the container material.

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

Note that depending on the Toxicity Hazard Level of the material, additional levels of containment will be required. Details are to be documented in the Interface Control Agreement. As already stated in Section 3.4.2.1, a Certificate of Compliance for all seals/containment levels is required from the PD, and for sanitization of overall payload before or with turn-over.

Otherwise, NanoRacks cannot receive the item due to potential contamination hazard. The hardware is to be turned-over to NanoRacks in sealed/clear bagging to allow inspection before handling as additional check that no containment break has occurred.

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

4.2.3 Sharp Edges

Hardware shall be inspected for sharp edges and corners. This is in order to be compliant with SSP 57000, which for this type of payload will generally only involve corner and edge radii as shown below in Table 4.2.3-1 and Table 4.2.3-2. NOTE: if the COTS item does NOT exactly meet the radii requirements below, this just needs to be documented and Nanoracks will work the issue/waiver with HFIT.

Table 4.2.3-1: Minimum Bend Radii for Exposed Edges

(Reference Table 3.12.8.2-1 of SSP 57000, Rev R)

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 4.2.3-2: Minimum Bend Radii for Exposed Corners

(Reference Table 3.12.8.2-2 of SSP 57000, Rev R)

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)

4.3 Customer Deliverables

Table 4.3-1 describes the list of potential customer deliverables required to certify the payload for flight. More detailed information will be provided in the payload ICA.

Table 4.3-1: Deliverables

Item	Deliverable	Description	Date
1	ICA	Payload Description & Constraints	L-6M
2	Bill of Materials	In lieu of off gas testing	L-4M
3	Data for Tox/Bio Hazard Evaluation		NLT L-4M
4	MSDSs for each substance		NLT L-4M
5	Final mass and dimension report		H/W Turn-over – 1 week
6	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
7	Cold Stowage Test Report		L-1M
7	Quality Assurance Certification	COC stating that the hardware was built, assembled, and meets the ICA; final mass/dimension report; Certifications and BOM provided inputs.	Hardware Delivery

5 Requirements Matrix

Table 5-1: Requirements Matrix

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1	**Payload Environment**				
4.1.1	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 4.1.1-1** at the CG of the item, with all six degrees of freedom acting simultaneously. The acceleration values are applicable to both soft stowed and hard mounted hardware. (Per SSP 57000, Section D.3.1.1)	A	I	Analysis or CoC (only COC if cold stowed)
4.1.2	Random Vibration Loads Environment	Payload safety-critical structures packed in foam or bubble wrap and enclosed in hard containers such as lockers, boxes, or similar structures, and payload safety-critical structures packed in foam or bubble wrap and soft stowed in bags shall meet the specified performance requirements when exposed to the maximum flight random vibration environments defined in **Table 4.1.2-1.** Contact NanoRacks for the proper vibration test procedure. Random vibration testing may not even 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). The standard stowage configuration is the payload wrapped in bubble wrap. Otherwise, test to the stowage requirements as set in the payload ICA.	A	A or I	Report or CoC (COC if leak test)

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1.3	Launch Shock Environments	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.	NVR		
4.1.4	IVA Loads Environment	Generally all payloads should be designed to provide positive margins of safety when exposed to the crew induced loads defined in **Table 4.1.4-1**, Crew-Induced Loads (reference SSP 57000, Table 3.1.1.1.2-1). HOWEVER, as a hand-held item to be placed in Plate Reader, this payload item is exempt from this requirement. The payload only needs to show positive margins of safety for on–orbit loads of 0.2 g acting in any direction for nominal on-orbit operations per SSP 57000, Rev R, Section 3.1.1.1.1.	A	I	CoC
4.1.5	Thermal Environment	Expected thermal environments for all phases of payload integration are summarized in **Table 4.1.5-1** Expected Thermal Environments. Payloads with special thermal constraints should coordinate with NanoRacks.	A	I	Table 4.3 #2
4.1.6	Humidity	The relative humidity will be 25% to 75% RH for ascent and on-orbit phases of flight Payloads with special humidity control requirements should coordinate with NanoRacks.	A	I	Table 4.3 #2
4.1.7	**Cold Stowage Testing**				

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1.7.1	Freezer Temperature Range	Verification of the payload Cold Stowage sample compatibility with the Cold Stowage System freezer temperature range shall be by test. The test shall be performed with the sample container and representative materials to a maximum expected fill level. This is to ensure that the container is not broken or otherwise destroyed after cycling a minimum of two times to the temperature range from ambient to -100 °C (-148 °F), at an environment heating/cooling rate of no less than 1 °C (1.8 °F)/minute. The sample container shall be held at the minimum temperature for at least 60 minutes for each cycle. Verification shall be successful upon inspection of container and sample during and after exposure to these temperatures with no evidence of damage or leakage being noted.	A	T	Table 4.3 #7
4.1.7.2	Refrigerated Temperature range	Verification of the payload Cold Stowage sample compatibility with the Cold Stowage System refrigerated temperature range shall be by test. The test shall be performed with the sample container and representative materials to a maximum expected fill level. This is to ensure that the container is not broken or otherwise destroyed after cycling a minimum of two times to the temperature range from ambient to -10 °C (+14 °F), at an environment heating/cooling rate of no less than 1 °C (1.8 °F)/minute. (Going to -10 °C ensures a phase change occurs). The sample container shall be held at the minimum temperature for at least 60 minutes for each cycle. Verification shall be successful upon inspection of container and sample during and after exposure to these temperatures with no evidence of damage or leakage being noted.	A	T	Table 4.3 #7

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.1.7.3	Incubated Temperature Range	Verification of the payload Cold Stowage sample compatibility with the Cold Stowage System incubated temperature range *should* be by test. The test *should* be performed with the sample container and representative materials to a maximum expected fill level. This is to ensure that the container is not broken or otherwise destroyed after cycling a minimum of two times to the temperature range from +6 °C (+42.8 °F) to +49 °C (+120 °F) , at an environment heating/cooling rate of no less than 1 °C (1.8 °F)/minute. The sample container *should* be held at the minimum and maximum temperature for at least 60 minutes for each cycle. Verification *should* be successful upon inspection of container and sample during and after exposure to these temperatures with no evidence of damage or leakage being noted.	A	T	Table 4.3 #7
4.1.7.4	Cryogenic Freezer Temperature Range	Verification of the payload Cold Stowage sample compatibility with the Cold Stowage System cryogenic temperature range shall be by test. The test shall be performed with the sample container and representative materials to a maximum expected fill level. This is to ensure that the container is not broken or otherwise destroyed after cycling a minimum of two times to the temperature range from ambient to -150 °C (-238 °F), at an environment heating/cooling rate of no less than 1 °C (1.8 °F)/minute. The sample container shall be held at the minimum temperature for at least 60 minutes for each cycle. Verification shall be successful upon inspection of container and sample during and after exposure to these temperatures with no evidence of damage or leakage being noted	A	T	Table 4.3 #7

Paragraph	IRD Title	Requirement Text	Payload Applicability	Verification Method	Submittal Data
4.2	**Payload Safety Requirements**				
4.2.1	Debris and Shatterable Materials	Payloads shall not have detachable parts or create any space debris during launch or normal mission operations. If the hardware has shatterable material, all shall be contained such that 50 micron or larger particles are not liberated.	A	I	Table 4.3 #2
4.2.2	Hazardous Materials	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.	A	I	Table 4.3 #2, 3, 4
4.2.3	Sharp Edges	Hardware shall be inspected for sharp edges and corners. This is in order to be compliant with SSP 57000, which for this type of payload will generally only involve corner and edge radii as shown below in Table 4.2.3-1 and Table 4.2.3-2.	A	I	CoC