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NanoRacks Feather Frame (NRFF) Payload User's Guide (PUG)

NANORACKS

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NanoRacks Feather Frame Payload User's Guide (NRFF PUG)

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List of Revisions

Revision	Revision Date	Revised By	Revision Description
-	11/7/2016	Mariel Rico	Initial Release
A	3/2/2018	Mariel Rico	Major Revision
B	10/5/2018	Zach Porter	Blue Origin *New Shepard* PUG Rev E

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1 Introduction

1.1 Purpose

The NanoRacks Feather Frame (NRFF) is a system designed to fit within a single payload locker of Blue Origin's *New Shepard* vehicle. The NRFF is located within one of the six payload stacks within the *New Shepard* crew capsule (CC) cabin. The NRFF provides a platform for micro-payloads called NanoLabs. Each NRFF allows as many as 12 individual NanoLabs to fly on a *New Shepard* suborbital flight.

This Payload User's Guide (PUG) describes the mechanical, electrical, and data interfaces between a NanoLab and the NRFF. In doing so, this document provides the minimum requirements for a NanoLab to be compatible with the NRFF. This PUG also defines the requirements for flying on Blue Origin's *New Shepard* via the NRFF, and defines the various environments applicable to the NanoLab design process. NanoRacks works with payload developers to integrate payloads into the NRFF platform within the *New Shepard* vehicle.

1.2 Scope

This document includes the physical, functional, and environmental design requirements associated with payload safety and interface compatibility. The requirements defined in this document apply to all phases of NanoLab operations, from the integration and review process leading up to the flight, loading into the Feather Frame through flight and up to removal. The interface requirements defined herein primarily address the NanoLab's direct interfaces to the NRFF.

1.3 Use

This document levies design interface and verification requirements on NanoLab developers. This document also acts as a guideline to establish commonality with respect to analytical approaches, models, test methods and tools, technical data, and definitions for integrated analysis.

2 Acronyms, Definitions and Applicable Documents

Table 2-1: Acronyms

Acronym	Definition
ASD	Acceleration Spectral Density
CC	Crew Capsule
ICD	Interface Control Document
NLT	No Later Than
NR	NanoRacks
NRFF	NanoRacks Feather Frame
PUG	Payload User's Guide
SDS	Safety Data Sheet
USB	Universal Serial Bus
WTLS	West Texas Launch Site

Table 2-2: Applicable Documents

Doc No.	Rev	Title
NSPM-MA0002-E	E	*New Shepard* Payload User's Guide

3 NanoRacks Feather Frame Overview

This section is an overview of the NRFF. It describes the various system interfaces and the operational elements of the NanoLab lifecycle.

3.1 NRFF Description

The NRFF (see Figure 3.1-1) is a payload platform for NanoLabs, CubeSat form factor experiments. Each NRFF platform supports up to 12 powered NanoLabs. Detailed information on mechanical interfaces can be found in Section 4.

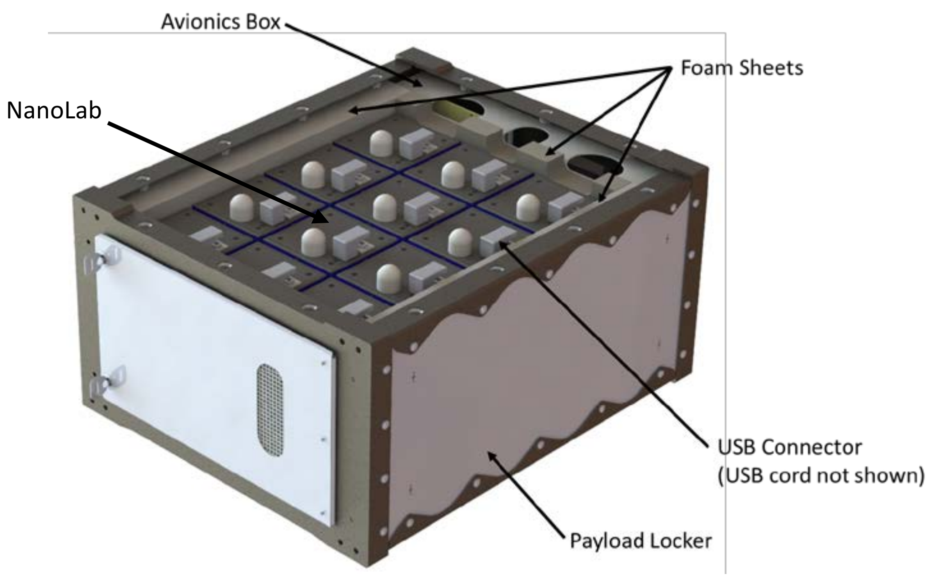

Figure 3.1-1: NanoRacks Feather Frame (left side locker configuration shown)

3.1.1 NanoRacks Feather Frame Description

The NRFF is a self-contained system that receives power from the CC, and provides a power and data interface between the NanoLab and Blue Origin's *New Shepard* vehicle. The NRFF consists of a *New Shepard* Single Payload Locker with a foam structure and an electronics system, known as the avionics box. The foam structure damps loads that NanoLabs are exposed to during their operational lifespan in the NRFF, including shipping, handling, and flight. The avionics box provides a total of 12 USB cables to provide power and data to each of the NanoLabs.

3.1.2 NanoLab Definition

A NanoLab is a customer-developed payload package. The nominal dimensions for an individual NanoLab are 4.0 by 4.0 by 8.0 in (101.6 by 101.6 by 203.2mm). Each NanoLab may be equipped with either a standard USB 3.0 or USB 2.0 Type B port, allowing for a plug-and-play interface. Other NanoLab packaging, such as larger sizes or masses, can be accommodated provided it is documented and approved by NanoRacks and Blue Origin; options are listed in Table 4.1.1-1. These options add additional cost and are limited in availability.

3.1.3 Standard Services

The following are considered standard for NanoLab customers:

- A single experiment with no more than one chief science objective and no significant hazards (biological, chemical, etc.)
- Dimensions not to exceed 4.0 by 4.0 by 8.0 in (101.6 by 101.6 by 200mm)
- Mass not to exceed 1.1 lbm
- Power draw not to exceed 4.5W (5V at 0.9A)
- Real-time flight data provided to the NanoLab via USB
- Fit Check and Run Check at NanoRacks Houston two weeks prior to launch (L-2 w)
- Loading into the *New Shepard* vehicle by Blue Origin four days prior to launch (L-4 d)
- Recovery from the *New Shepard* vehicle by Blue Origin a few hours post-flight
- Return of NanoLab to customer post-flight by NanoRacks (return shipping covered)
- Remote support only (no customers at the launch site)

Any changes to these services are considered non-standard but may be handled on a case-by-case basis.

3.1.4 Pad Loading Services

For NanoLabs that require late integration into the NRFF for science purposes, customers may request pad load services at additional costs. Pad load services can include on-site support two days before launch until one day after launch and loading of the NanoLab into *New Shepard* on the morning of flight. Refer to Section 3.2.2.1 below for details regarding delivery logistics for pad load NanoLabs.

3.2 NRFF Operations Overview

This section is an overview of the operations of the NRFF.

3.2.1 Schedule

The NRFF integration process involves the milestones and schedule shown in Table 3.2.1-1 below. Additional time may be required depending on the complexity of the NanoLab.

Table 3.2.1-1: Standard NanoLab Integration Milestones

Milestone (Deliverables shown in **bold)**	**Due: No Earlier Than (NET) to No Later Than (NLT)**
Kick off Meeting (teleconference)	L-18 to L-6 months
1st Payload Data Package Submittal	L-12 to L-5 months
Payload Data Package Review (teleconference)	L-11.5 to 4.5 months
2nd Draft Payload Data Package Submittal	NLT L-3.5 months
Final Payload Data Package Review (teleconference)	NLT L-3 months
Payload Data Package is Finalized and Released	NLT L-2.5 months
NanoLab Processing and Shipping Checklist Submittal	NLT L-6 weeks
NanoLab Processing and Shipping Package Review (teleconference)	NLT L-5 weeks
Delivery of NanoLab to NanoRacks (for functional testing)	NLT L-2 weeks

Note: Deliverable milestones are shown in **bold**.

3.2.2 Ground Operations

3.2.2.1 Delivery to NanoRacks

The NanoLab developer typically delivers a flight-ready NanoLab to the NanoRacks Houston facility, or another facility as agreed, no later than two weeks prior to the anticipated launch date. The mission manager for the payload should be made aware of any special requirements, such as ground support hardware, special handling instructions, etc. as soon as possible. These must be approved by NanoRacks and Blue Origin before the Payload Data Package is finalized and released (L-2.5 months) and documented in the Processing and Shipping Checklist.

NanoLabs that require a delivery time closer to flight must be documented and approved by NanoRacks and Blue Origin.

NanoLab developers utilizing pad load services also are required to deliver their NanoLab two weeks prior to launch for power-up and connectivity testing. The NanoLab should be in flight configuration (i.e., finalized hardware and software), with the exception of the science samples. NanoRacks is responsible for transporting the NanoLab to West Texas Launch Site (WTLS), where it will be returned to the customer for sample loading. The NanoLab developer will then turn over the NanoLab to NanoRacks for integration into the NRFF. NanoRacks hands over the fully integrated NRFF to Blue Origin for loading into the *New Shepard* vehicle approximately six to eight hours before the targeted liftoff time.

3.2.2.2 NanoLab Inspection

NanoRacks inspects the NanoLab assembly to verify it meets the appropriate safety and PUG requirements and complies with the finalized PDP. This includes, but is not limited to, leak checks, mass properties, and overall dimensions.

3.2.2.3 NanoLab Testing

NanoRacks performs a mass check and a power-up test before integrating the NanoLab into the Platform. The mass check ensures that the NanoLab mass is within limits defined in the NanoLab Payload Data Package. The power-up test ensures that the NanoLab arrived at NanoRacks in flight-ready configuration and operates as expected. If the NanoLab fails the power-up test, it may be removed from the manifest and reassigned to fly at a later date for an additional cost. NanoLabs that fail after this test may be required to remain onboard for flight to maintain vehicle mass and CG limits, but will not be powered. Special requirements that do not allow the NanoLab to be powered prior to launch for this test shall be documented in the NanoLab Processing and Shipping Checklist.

3.2.2.4 Customer Ground Servicing

The customer is expected to deliver the NanoLab in flight configuration. Once the NanoLab is delivered to NanoRacks, no further servicing can be supported. Any special requirements must be documented and approved by NanoRacks and Blue Origin. NanoLabs that require direct delivery to Blue Origin's WTLS must be documented and approved by NanoRacks and Blue Origin and may result in increased costs.

3.2.2.5 NanoRacks Packaging, Shipment, and Delivery

After NanoRacks performs the mass and power-up test, NanoLabs are outfitted with NanoRacks-provided Velcro and polycarbonate stand-offs and bumpers as needed in preparation for integration to the NRFF. (See Figure 3.2.2.5-1.) Cable tie mounts and/or RTV silicone also are applied to secure the USB cable connection. Kapton tape may be added to protrusions (see Section 4.1.4 Protrusions) to prevent snagging on the foam structure. Special requirements that do not allow the payload to be externally modified in this way must be documented in the PDP and approved by Blue Origin and NanoRacks.

NanoRacks delivers the completely outfitted NanoLabs to Blue Origin at WTLS for flight. NanoRacks is responsible for shipping the NanoLabs between the NanoRacks Houston Facility and WTLS. NanoLabs are shipped installed within the NRFF.

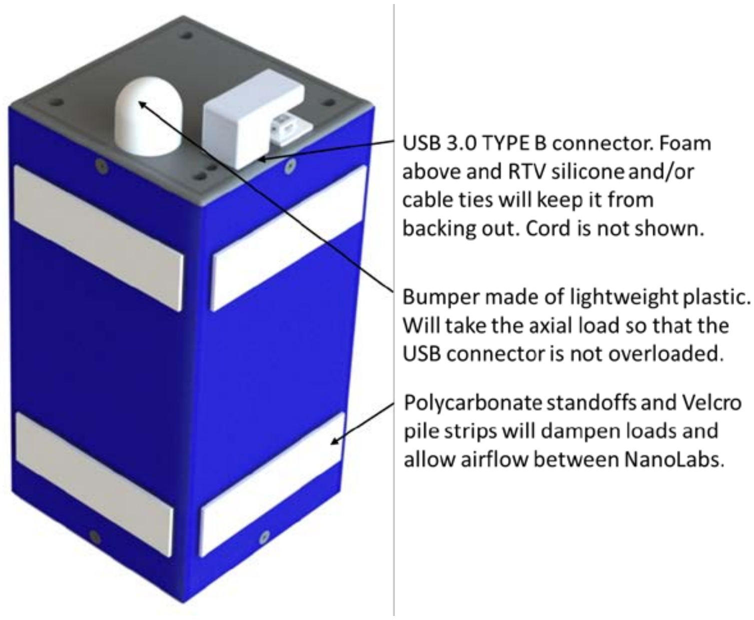

Figure 3.2.2.5-1: NanoLab Bumpers and Velcro

3.2.2.6 Returning NanoLab to Customer

The NRFF is returned to NanoRacks within no more than eight hours after the mission. NanoLab customers on-site receive their NanoLab immediately after the NRFF is returned to NanoRacks.

For customers utilizing standard services, the NRFF and NanoLabs are shipped to the NanoRacks Houston facility before returning the NanoLabs to customers. NanoLabs being shipped within the U.S. typically are sent though a standard ground service. NanoRacks covers standard ground shipping fees. Additional costs for expedited and international shipping, additional packaging (bubble wrap, etc.), or temperature control (dry ice, blue ice, etc.) are the responsibility of the customer and must be approved and coordinated with NanoRacks in the NanoLab Processing and Shipping Checklist.

3.2.3 Integration into *New Shepard*

Blue Origin is responsible for the integration of the fully integrated NRFF into *New Shepard* for launch.

3.2.4 Flight Profile and Events

Table 3.2.4-1 shows the approximate parameters at specific trajectory events for a representative nominal flight of the *New Shepard* capsule. The sensed acceleration shown is primarily along the vehicle's vertical axis. The actual flight profile may differ from the representative trajectory shown in the table, and trajectory parameters may deviate substantially from the table if there are off-nominal or unplanned events during the flight.

Table 3.2.4-1: Nominal *New Shepard* CC Flight Profile

Event	Time (seconds)	Altitude (ft ASL)	Vertical Velocity (ft/second)	Sensed Acceleration (g)
Main Engine Ignition Command	0	3,650	0	1.00
Liftoff	7	3,650	0	1.06
Max G on Ascent	128	140,900	3,080	2.87
Main Engine Cut Off	146	196,700	3,110	0.001
Separate CC	162	242,200	2,600	2.4
Sensed Acceleration < 0.001 g	177	277,800	2,140	-0.001
Apogee	246	351,100	0	0.00
Sensed Acceleration > 0.01 g	332	235,600	-2,680	0.01
Sensed Acceleration > 0.1 g	348	187,600	-3,180	0.10
Sensed Acceleration > 1.0 g	364	132,900	-3,490	1.00
Max G on Re-entry	381	80,900	-2,340	5.12
Mortar Deploy Drogues	501	10,100	-300	1.05
Peak Parachute Load	517	6,700	-175	3.03
Initiate Terminal Decelerator	622	3,660	-23	3.78

4 NanoLab Interface Requirements

The requirements contained in this section must be complied with in order to qualify a NanoLab for integration into the NRFF. This section is divided by the following disciplines: Structural, Electrical, Environmental, and Safety.

4.1 NanoLab Structural Requirements

4.1.1 NanoLab Dimensions

All NanoLabs shall conform to one of the external dimensions options stated in Table 4.1.1-1 within a tolerance of +/- 0.06 in (1.6mm).

Table 4.1.1-1: NanoLab Dimensions

NanoLab Form Factor	Length	Width	Height
1U	4.00 in (101.6mm)	4.00 in (101.6mm)	3.94 in (100mm)
1.5U	4.00 in (101.6mm)	4.00 in (101.6mm)	5.91 in (150mm)
2U	4.00 in (101.6mm)	4.00 in (101.6mm)	8.00 in (203.2mm)

4.1.2 Orientation

NanoLabs are loaded with the long axis oriented vertically in the NRFF. The NRFF may be reoriented multiple times between loading and flight; NanoLabs should be designed to withstand being tipped on their sides for extended periods of time. Pad load NanoLabs will have a maintained orientation through liftoff. NanoLabs that require a different orientation or have orientation constraints must be documented and approved by NanoRacks and Blue Origin.

4.1.3 Mass Properties

The total mass of a NanoLab (including structure) cannot exceed 1.1 lbm. To ensure that mass does not exceed this value, customers are required to provide mass estimates and measurements throughout the NanoLab preparation process. Mass must be finalized prior to finalization and release of PDP. NanoLabs that do not meet this requirement may be removed from the flight.

Polycarbonate standoffs, bumpers, and cable tie mounts provided by NanoRacks to outfit the NanoLab in preparation for flight do not count toward the NanoLab's mass allocation. Heavier NanoLabs can be accommodated as a special service at additional cost.

4.1.4 Protrusions

NanoLabs shall be designed with no fasteners or components protruding more than 0.625 in from the top the external housing and 0.1 in from the sides of the external housing (see Figure 4.1.4-1). There shall be no protrusions on the bottom of the NanoLab. Protrusions shall not interfere with the placement of the bumper, USB cable, cable tie mount, or polycarbonate standoffs. Placement and dimensions of the polycarbonate standoffs are specified in Figure 4.1.4-2. The USB port shall be mounted so that it does not protrude from the NanoLab or recess from the top surface further than 0.125 in.

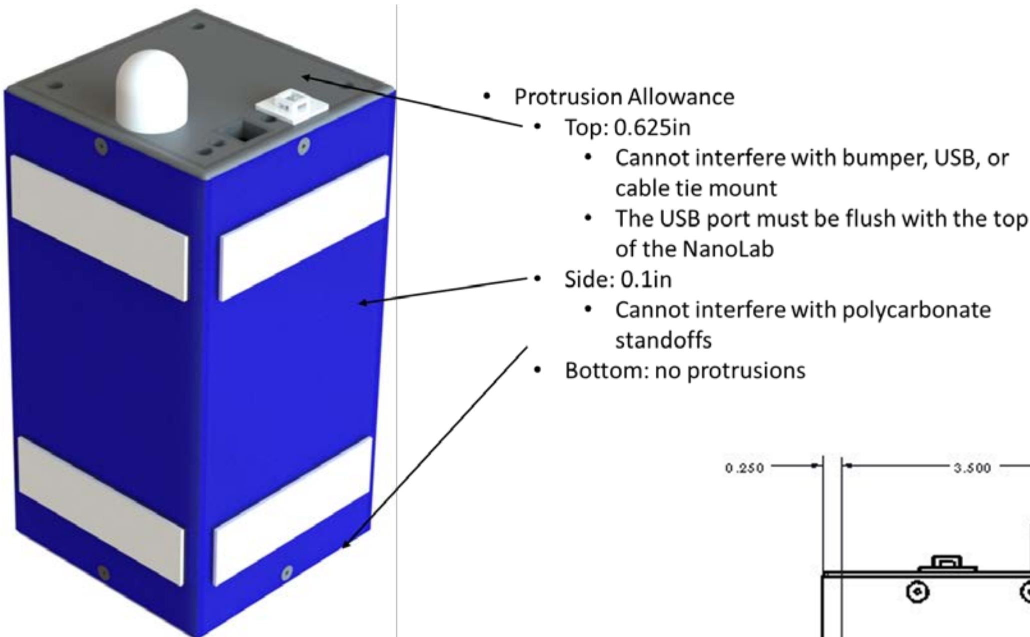

Figure 4.1.4-1: NanoLab Protrusions Allowances

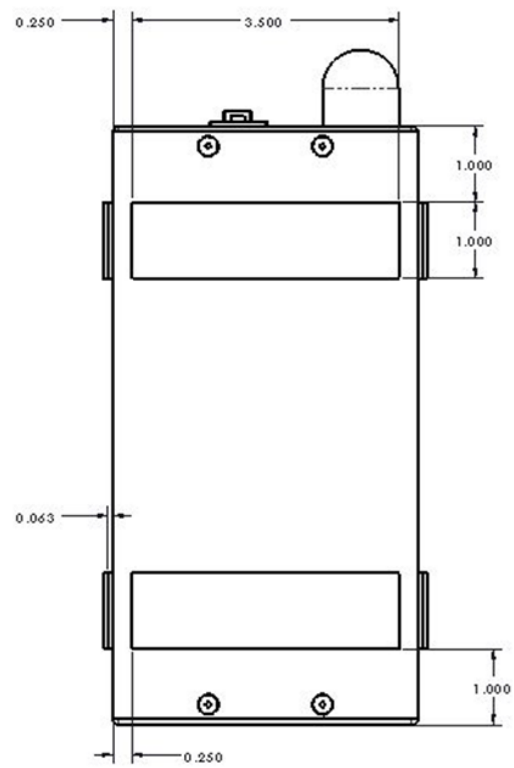

Figure 4.1.4-2: Polycarbonate Standoff Dimensions and Placement (in inches)

4.1.5 USB Port Placement

NanoLabs that require power and data will interface with the NRFF through at least one Type B female USB 2.0 or 3.0 port. This USB port needs to be located on the top face end cap. Proper positioning of the USB port is identified in Figure 4.1.5-1. Customers should place the USB port as close to the center as possible.

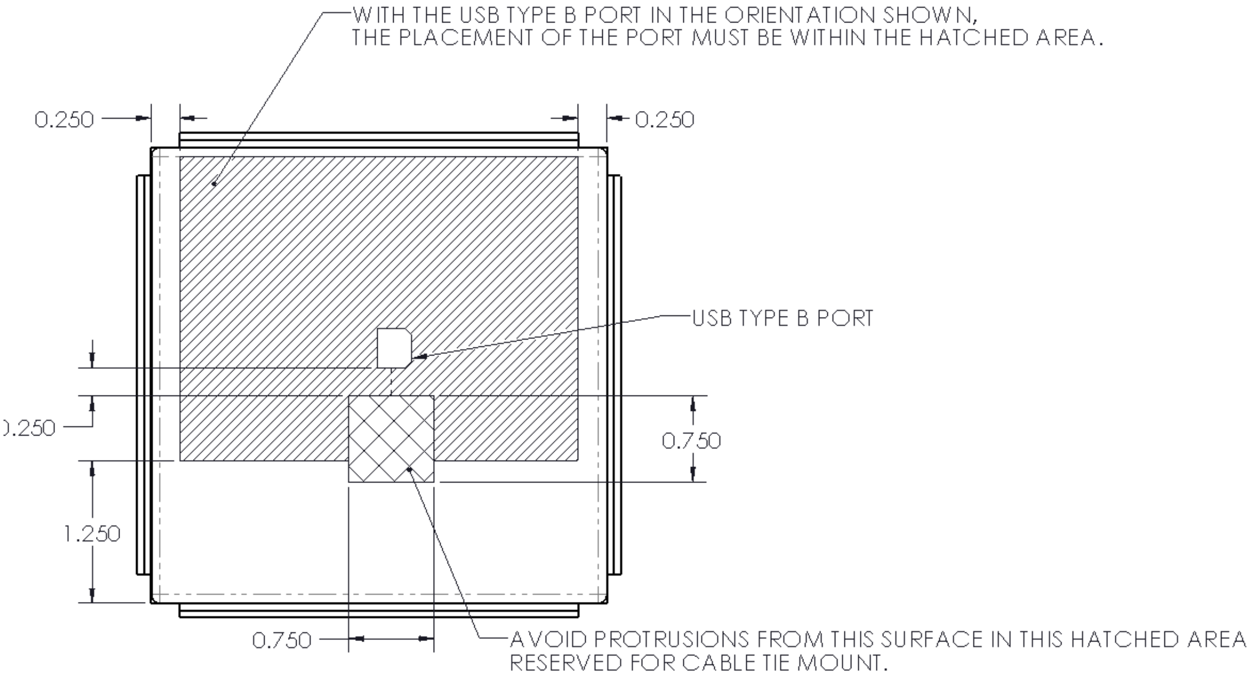

Figure 4.1.5-1: NanoLab USB Connector Location (in inches, top view)

4.2 Payload Electrical and Data Interfaces

4.2.1 5 VDC USB Power

The NRFF-provided USB cable is capable of delivering up to 5 VDC per NanoLab in accordance with the USB 3.0 High Power Standard. The NanoLab shall not exceed the power requirements as specified according to the USB 3.0 High Power standard, allowing a maximum current draw of 900 mA. Nominally, power is available from approximately seven minutes before launch until approximately five minutes after landing. NanoLab may experience power cycling due to flight conditions. NanoLabs should be robust to having power applied, removed, and then reapplied before flight.

Additional USB cables (for payloads requiring additional power) and/or power up as early as T-10 minutes can be provided as a special service at additional cost.

4.2.2 Grounding and Bonding

To ensure safe electrical functioning, proper grounding and bonding are required for all powered NanoLabs. A single-point ground shall be implemented by connecting the ground of all NanoLab electronics to the USB connector shell. NanoLabs using conductive material for their external housing shall also ground all components to the housing including the USB connector shell. The resistance of the grounding/bounding shall measure less than 0.1 Ohms. For more information, please contact NanoRacks personnel.

4.2.3 Data Storage

Any data storage is the responsibility of the NanoLab.

4.2.4 Data Interface Coordinate System

The CC coordinate system referenced in Section 4.2.5 is shown in Figure 4.2.4-1. Axial loads are aligned with the X vector, which points forward out of the top of the CC and is co-aligned with the long axis of the NanoLab. Lateral Y and Z vector data are provided in the frame of the CC as shown below. The Y and Z vectors of an individual NanoLab are dependent on the position of the NRFF within the CC. This information can be provided at approximately L-2 months.

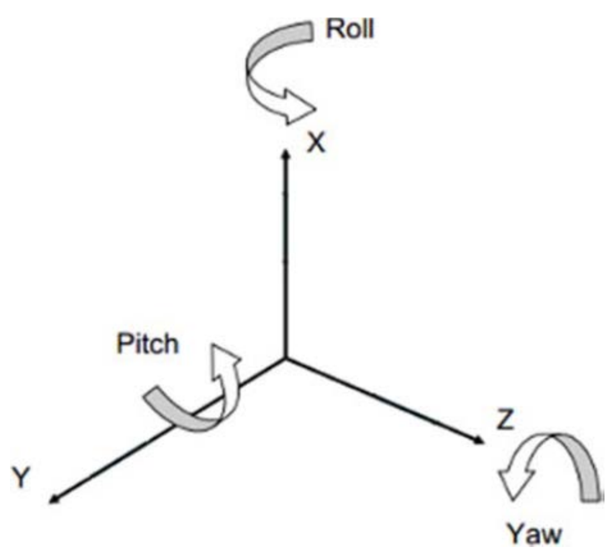

Figure 4.2.4-1: Crew Capsule Coordinate System

4.2.5 Data Interface

NanoLabs that require real-time flight information during the mission (e.g., for triggering events or correlating with other data post-flight) may access a data stream over the USB interface.

The transmission of the data packets begins when the NRFF starts receiving flight status information from the *New Shepard* vehicle, approximately one minute after the NanoLabs are powered up. Data is sent to the payloads every 0.1 seconds throughout the flight, and stops approximately 5 min after landing.

To receive this data, a NanoLab must be recognizable as a serial device when connected to the NRFF and must open a serial connection over the USB interface. The device should be configured to receive data packets serially at a baud rate of 115,200 and with a data configuration of 8 data bits, no parity, and 1 stop bit per data frame. (8N1 is the default for most devices.)

The format of the data packets is an ASCII character string consisting of 21 comma-separated data fields. The size of the data packets shall not exceed 250 bytes, and no individual data field shall exceed 20 bytes in size.

The order of the data fields, along with a description of each, are as follows:

1. Flight Events – The most recent flight event reached as a single ASCII character; possible flight events are:
    a. None Reached: '@' = No flight event has been reached yet (typically the time prior to liftoff).
    b. Escape Enabled: 'A' = This event is triggered when the emergency escape solid rocket motor is enabled on the CC. This is a nominal event that occurs before liftoff. If an anomaly on the vehicle is detected any time after this, the CC may ignite the solid rocket motor and escape rapidly from the propulsion module.
    c. Escape Commanded: 'B' = This event is triggered when the emergency escape system has been commanded to perform the escape maneuver. This event is not reached during a nominal flight, but may be used by NanoLabs as a way of aborting already started experiments or preventing them from starting.
    d. Liftoff: 'C' = This event is triggered once the vertical velocity exceeds a set threshold.
    e. Main Engine Cut Off (MECO): 'D' = This event is triggered after the propulsion module's rocket engine is shut down. MECO occurs during ascent, right before the CC and primary module separate. Although the sensed acceleration immediately following MECO may be within the micro-gravity limits (< 0.1g), experiments dependent on prolonged, quiescent micro-gravity ***should not*** use MECO as the triggering flight event unless they can tolerate a short high impulse event after the trigger and before the prolonged microgravity period.

f. Separation Commanded: 'E' = This event occurs after the rocket and capsule are commanded to separate, shortly before the microgravity portion of the flight begins. The accelerations felt immediately following separation, caused by CC attitude control thrusters firing to null CC body angular rates, may exceed the micro-gravity limits (< 0.1g). Experiments dependent on prolonged, quiescent micro-gravity ***should not*** use separation as the triggering flight event, since thruster firing occurs for a period of time following separation.

g. Coast Start: 'F' = This event indicates the beginning of the cleanest microgravity operations onboard the capsule. Most experiments should begin logging data at this time.

h. Apogee: 'G' = This event occurs when the vehicle has reached its maximum altitude and begins to descend.

i. Coast End: 'H' = This event indicates the end of microgravity operations onboard the capsule, as it begins to experience atmospheric acceleration. Most experiments cease logging data at this time.

j. Drogue Chutes: 'I' = This event indicates that the drogue parachutes have been commanded to deploy.

k. Main Chutes: 'J' = This event indicates that the main parachutes have been commanded to deploy.

l. Touchdown: 'K' = This event indicates that the CC has detected touchdown (landing).

m. Safing: 'L' = After touchdown, this event indicates that the CC has started performing its post-flight safing procedure, following touchdown. NanoLabs may choose to use the safing flight event to stop data logging after touchdown.

n. Mission End: 'M' = This event is triggered once the CC has finished performing its post-flight safing procedure. This is the last flight event that NanoLabs can use to close out their experiments prior to being powered down. It is recommended to close out your experiment prior to reaching this flight event, as there may be less than a second before power is lost.

2. Experiment time – Elapsed time in seconds since the IPC has been initialized on the launch pad prior to launch.
3. Altitude – The current vehicle altitude above ground level in feet as a decimal number with 6 digits following the decimal point. The reference point for this measurement is the WRT landing pad.
4. GPS Altitude – The current vehicle altitude with respect to the WGS84 geodetic reference as a decimal number with 6 digits following the decimal point.

5. Velocity Up– The current vehicle velocity in feet per second along the Up axis with respect to the landing pad as a decimal number with 6 digits following the decimal point.
6. Velocity East – same as (5) but for the East axis.
7. Velocity North – same as (5) but for the North axis.
8. Acceleration Magnitude – The magnitude of the current vehicle sensed acceleration in feet per second squared as a decimal number with 6 digits following the decimal point.
9. Acceleration x-axis – The current sensed acceleration along the x-axis in feet per second squared as a decimal number with 6 digits following the decimal point.
10. Acceleration y-axis – same as (9) but for the y-axis.
11. Acceleration z-axis – same as (9) but for the z-axis.
12. Attitude phi – The phi component of the current vehicle attitude described as a 1-2-3 Euler rotation with respect to the geodetic frame in radians as a decimal number with 6 digits following the decimal point.
13. Attitude theta – same as (12) but for the theta component.
14. Attitude psi – same as (12) but for the psi component.
15. Angular velocity x-axis – The current vehicle angular velocity in radians per second about the x-axis as a decimal number with 6 digits following the decimal point.
16. Angular velocity y-axis – same as (15) but for the y-axis.
17. Angular velocity z-axis – same as (15) but for the z-axis.
18. Liftoff Imminent warning – warning triggered when the vehicle has entered the final countdown before launch; the value is a single digit with a 1 when the warning is true and 0 when it is false.
19. Drogue Chute Deployment Imminent warning – warning triggered when vehicle has descended below the highest altitude where the drogue chutes may be deployed; same format as (18).
20. Landing Imminent warning – warning triggered when vehicle is about to touchdown; same format as (18).
21. Chute Fault warning – warning triggered in anticipation of an abnormally hard landing; same format as (18).

An example data packet would be:

"F,240.76,294889.549000,4694.760000,442.619000,-13.020000,33.935000,32.230000,32.221000,0.002000,0.003000,0.197900,-0.248500,0.000600,-0.000100,0.002000,-0.009000,0,0,0,0"

Looking at the fields we can discern that:

<table>
<tr><td colspan="2">Flight event = Coast Start (F)
Experiment time = 240.76 sec
Altitude = 294889.549000 ft
GPS Altitude = 4694.760000 ft</td><td colspan="2">Attitude: phi-component = 0.197900 radians
theta-component = -0.248500 radians
psi-component = 0.000600 radians</td></tr>
<tr><td>Velocity:</td><td>Up -axis = 442.619000 ft/sec
East-axis = -13.020000 ft/sec
North-axis = 33.935000 ft/sec</td><td>Angular velocity:</td><td>x-axis = -0.000100 radians/sec
y-axis = 0.002000 radians/sec
z-axis = -0.009000 radians/sec</td></tr>
<tr><td colspan="2">Acceleration (Mag) = 32.230000 ft/sec^2
Acceleration: x-axis = 32.221000 ft/sec^2
y-axis = 0.002000 ft/sec^2
z-axis = 0.003000 ft/sec^2</td><td>Liftoff Imminent warning = false
Drogue Chute Deployment Imminent warning = false</td><td>Landing Imminent warning = false
Chute Fault warning = false</td></tr>
</table>

4.2.6 NRFF Toolbox

NanoRacks delivers the NRFF toolbox after the kickoff meeting to assist with configuration setup and testing of NanoLabs. The toolbox contains sample code and the NRFF simulator. The NRFF simulator is a Windows executable program that simulates the flight behavior onboard the NRFF. A separate user's manual is provided to assist with setup and testing.

4.3 NRFF Environments

This section describes the predicted environments experienced by NanoLabs within the NRFF during *New Shepard* flights. Predicted environments may vary from those experienced during flight.

4.3.1 Microgravity Duration

NanoLabs within the NRFF experience approximately three minutes of microgravity during a nominal *New Shepard* flight. For the acceleration profile of the flight, refer to Section 3.2.4.

4.3.2 Acceleration

NanoLabs within the NRFF may be exposed to the acceleration environments listed in Table 4.3.2-1 for durations up to 50 msec. It should be noted that axial and lateral loads may be applicable simultaneously. Off-nominal flight conditions are listed in case NanoLab developers wish to design their experiments to sustain this environment without damage. Safety critical payloads may be required to demonstrate they can withstand off-nominal environments. Off-nominal loads are expected to be a rare event.

Table 4.3.2-1: Maximum Experiment Acceleration Environments

Condition	Direction	Peak Acceleration	Max. Duration
Nominal Mission	Axial	+ 15 / -4.5 g	50 msec
Nominal Mission	Lateral	+/-7.5 g	50 msec
1-Chute Failure Landing	Axial	+26 / -7 g	50 msec
1-Chute Failure Landing	Lateral	+/- 12 g	50 msec
Escape Event	Axial	+ 32 / -6 g	50 msec
Escape Event	Lateral	+/- 10 g	50 msec

4.3.3 Vibration

To promote mission success for a NanoLab, developers may wish to test the performance and functionality of their NanoLab in the expected vibration environment for a nominal mission. Performance and functionality of flight hardware typically are verified by testing a fully integrated payload at levels shown in Table 4.3.3-1 for one minute in each of three axes. Payload developers also may wish to perform qualification testing on non-flight units as good engineering practice to establish some level of performance margin. Safety-critical payloads may be required to demonstrate they can withstand vibration environments.

Table 4.3.3-1 : Suggested Random Vibration Spectrum for Acceptance Testing (MIL-STD-1540E)

Freq [Hz]	ASD (Acceleration Spectral Density) [g^2/Hz] (+0 dB)	Proto-Qualification Testing ASD [g^2/Hz] (+1.5 dB)	Qualification Testing ASD [g^2/Hz] (+3.0 dB)
20	0.0053	0.0053	0.0053
150	0.04	0.04	0.04
800	0.04	0.04	0.04
2000	0.0064	0.0064	0.0064
Expected GRMS	6.94	8.25	9.80

4.3.4 Shock

To promote mission success for the NanoLab, the developer may wish to test the performance and functionality of their NanoLab in the expected shock environment for a nominal mission. Performance and functionality of flight hardware in a shock environment typically are verified by testing at the levels shown in Table 4.3.4-1. Safety-critical payloads may be required to demonstrate they can withstand shock environments.

Table 4.3.4-1 : Suggested Half-Sine Pulse Shock Levels (MIL-STD-1540E)

	Half-Sine Pulse, Vehicle Vertical Axis	Half-Sine Pulse, Vehicle Lateral Axis
Duration (ms)	6	15
Amplitude (G)	30	13

4.3.5 Thermal

The ambient temperature inside the CC on *New Shepard* flights is expected to remain in the range of 50-90°F (approximately 10-32.2°C) during pre-flight and flight operations. Note that these temperatures refer to the ambient temperatures in the cabin. Temperature profile within the NRFF has not yet been determined and may rise above these values.

In the event of an off-nominal capsule recovery, flight temperatures inside the CC may rise above 90°F (32.2°C) or fall below 50°F (10°C) after landing. The extreme high predicted temperature on payload flights with no astronauts on board is 130°F (54.4°C) and the extreme low is 32°F (0°C) for a period of up to three hours. NanoLabs that are sensitive to temperature excursions should document this in their Payload Data Package.

Depending on the experiment, it is recommended that researchers consider including pressure and temperature sensors within their NanoLab.

4.3.6 Air

The pressure inside the CC cabin will nominally be maintained within 10.1 – 14.2 psi (approximately 0.696 – 0.979 bar) throughout the mission. The ambient pressure in West Texas is approximately 12.8 psi (0.883 bar).

Any airtight structures, such as primary or secondary liquid containment vessels, must be robust to all pressures within the nominal operating range. Cabin air is temperature-controlled, but humidity is not regulated from West Texas ambient and may be quite dry. Payloads with concerns about electrostatic discharge at low humidity should consider coating bare and/or exposed electronic components with a conformal barrier. Such a barrier also will provide protection from contaminants and moisture.

4.4 NanoLab Payload Safety Requirements

This section provides general safety guidelines and requirements to NanoLab developers. Safe operation of a NanoLab under the full range of environments described above is required for flight. A safety review is conducted on each NanoLab using the data from the NanoLab Payload Data Package. This ensures the safety of ground and flight operations and confirms that each NanoLab does not negatively affect the Feather Frame or other NanoLabs.

4.4.1 Structural Integrity

NanoLabs shall be designed and built to withstand a minimum of 15 lb in the axial direction for 2 minutes and 10 lb in both lateral directions (i.e., faces which are perpendicular to each other) for 2 minutes, as demonstrated by separate static load tests (e.g., by placing a weight on the NanoLab). This ensures that the NanoLab can withstand nominal acceleration loads as specified in Table 4.3.2-1. Customers must confirm this with photographs in the Payload Data Package. Additional structural analysis may be involved depending on the NanoLab experiment.

4.4.2 Liquid and Hazardous Materials Containment

All NanoLabs containing liquids shall protect against leakage. All liquids must be reviewed by NanoRacks and Blue Origin to determine the appropriate level of containment. Generally, non-hazardous liquids require two levels of verified containment, and hazardous liquids require three levels of verified containment. Researchers may consider adding absorbent material to the bottom of their NanoLab as an additional safety measure, with guidance and approval from NanoRacks and Blue Origin. The customer also must disclose the type and quantity of all liquids or hazardous materials, and provide Safety Data Sheets (SDS), for further evaluation of potential hazard. Hazardous materials may not be shipped to NanoRacks prior to completion of the safety evaluation, and approval of clean-up, loading, spill, or any other safety procedures. All hazardous shipments must be coordinated with NanoRacks and Blue Origin.

4.4.3 Flammability

All materials used for NanoLabs, when exposed to a standard ignition source, should self-extinguish and not transfer burning debris that can ignite adjacent materials. Existing flammability test data for many materials are compiled in the NASA Marshall Space Flight Center Materials and Processes Technical Information System (https://maptis.nasa.gov/). Materials that do not exhibit self-extinguishing behavior require a thorough analysis to characterize the potential hazard and may not be approved for flight.

4.4.4 Bare and/or Exposed Conductors

Bare and/or exposed conductors shall be coated with a conformal barrier to mitigate electrostatic discharge concerns. For more clarification, please contact NanoRacks personnel.

4.4.5 Batteries and Other Energy Storage Devices

All batteries and other energy storage devices present in the payload, regardless of voltage, must be identified by manufacturer and model number in the Payload Data Package, and must be consistent with the Blue Origin Battery Policy in Appendix C: *New Shepard* Payload Battery Policy.

4.4.6 Offgassing and Outgassing

NanoLabs shall not generate or release flammable, non-breathable, and/or toxic gases into the NRFF and CC. NanoLabs that release inert gases into the NRFF are reviewed on a case-by-case basis. The volume and temperature of any released gases must be measured or calculated and submitted in the Payload Data Package and approved by NanoRacks and Blue Origin. The released gases shall not impact the NRFF or other NanoLabs.

4.4.7 Explosive Safety

At the discretion of Blue Origin and NanoRacks, quantities up to 250mg cumulative explosive weight *may* be flown in the NRFF (individual NanoLab explosive weight must be approved by Blue Origin and NanoRacks). At a minimum, the material shall be classified by the U.S. Department of Transportation/United Nations organization as Class 1.3 or 1.4, be fully contained, and pass a Blue Origin safety review.

NanoLabs that contain explosives require additional structural analysis to verify explosion containment, acoustic analysis, and explosion analysis. The added expense of such analysis is the responsibility of the customer.

4.4.8 Thermal

NanoLabs shall not thermally impact (by generating heat or cooling) the NRFF or other NanoLabs. The thermal output (negative or positive) of a NanoLab must be measured or calculated and submitted in the Payload Data Package and approved by NanoRacks and Blue Origin. This is reviewed on a case-by-case basis.

4.4.9 Vibration

NanoLabs shall not impart vibration loads onto the NRFF or to adjacent NanoLabs. This will be verified by NanoRacks during checkout. Customers should contact NanoRacks a mission manager for assistance in determining if a payload may violate this policy.