New Shepard Payload User’s Guide
FOR RESEARCH AND EDUCATION MISSIONS
## REVISION HISTORY

<table>
<thead>
<tr>
<th>Rev</th>
<th>Date</th>
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<tr>
<td>NC</td>
<td>03 June 2015</td>
<td>Completed for public release</td>
</tr>
<tr>
<td>A</td>
<td>31 August 2015</td>
<td>Updated humidity, acceleration output, and Payload Locker door access</td>
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<tr>
<td></td>
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<td>Updated Payload Integration timelines</td>
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<tr>
<td>B</td>
<td>10 May 2016</td>
<td>Updated vibe levels and recommended practice to MIL-STD-1540E (Section 4.2)</td>
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<td></td>
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<td>Updated overall document based on M1-M4 mission data (RCS firing Section 2.7, power timelines for nominal ops under Section 3.3.6, operations timeline under Section 5.4 and 5.5)</td>
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<td>Clarified description on fasteners to the interior of Payload Locker (Section 3.2.1)</td>
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<td>Removed J1/J2 pinout list</td>
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<td>Updated Payload Data Package, Payload Safety Package, and Launch Site Integration Package in the Appendices.</td>
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<th>Definition</th>
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<th>Definition</th>
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<tbody>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
<td>TRL</td>
<td>Technology Readiness Level</td>
</tr>
<tr>
<td>BOM</td>
<td>Bill of Materials</td>
<td>UEI</td>
<td>United Electronic Industries</td>
</tr>
<tr>
<td>BPC</td>
<td>Benchtop Payload Controller</td>
<td>VPF</td>
<td>Vehicle Processing Facility</td>
</tr>
<tr>
<td>CC</td>
<td>Crew Capsule</td>
<td>WTLS</td>
<td>West Texas Launch Site</td>
</tr>
<tr>
<td>CG</td>
<td>Center of Gravity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIO</td>
<td>Digital Input/Output</td>
<td></td>
<td></td>
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<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
<td></td>
<td></td>
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<tr>
<td>FPC</td>
<td>Flight Payload Controller</td>
<td></td>
<td></td>
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<tr>
<td>GSE</td>
<td>Ground Support Equipment</td>
<td></td>
<td></td>
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<tr>
<td>HAZOP</td>
<td>Hazard and Operability Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICD</td>
<td>Interface Control Document</td>
<td></td>
<td></td>
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<tr>
<td>I/O</td>
<td>Input/Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LH</td>
<td>Left-Handed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MECO</td>
<td>Main Engine Cut Off</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>Principal Investigator</td>
<td></td>
<td></td>
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<tr>
<td>PM</td>
<td>Propulsion Module</td>
<td></td>
<td></td>
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<tr>
<td>PWM</td>
<td>Pulse Width Modulation</td>
<td></td>
<td></td>
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<tr>
<td>PUG</td>
<td>Payload User's Guide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCS</td>
<td>Reaction Control Subsystem</td>
<td></td>
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<tr>
<td>REM</td>
<td>Research and Education Missions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RH</td>
<td>Right-Handed</td>
<td></td>
<td></td>
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<td>RTD</td>
<td>Resistance Temperature Detector</td>
<td></td>
<td></td>
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<tr>
<td>SDS</td>
<td>Safety Data Sheet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPL</td>
<td>Sound Pressure Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Determined</td>
<td></td>
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1. INTRODUCTION

Welcome, Payload Flyers!

This guide is intended to provide a technical entry point for preparing your payload for flight on Blue Origin’s New Shepard system. Whether you are looking to break new scientific ground, demonstrate space technologies, engage students, or simply be part of the opening of the space frontier, our simple interface and dedicated technical team can help you get ready for launch.

This Payload User’s Guide (or “PUG”, as it’s affectionately known) is organized into five main sections:

- **Section 2: New Shepard Description** – This introductory section describes the spacecraft your payload will be flying on, as well as our West Texas Launch Site where you’ll conduct any immediate pre- and post-flight operations. A brief overview of the flight profile will help you design your payload to take advantage of the unique spaceflight environment.

- **Section 3: Payload Standard Services and Interfaces** – This section provides the bulk of your technical interface information. We’ve detailed the mechanical, electrical, and software connections available to your payload and the design constraints you’ll be working within. We also introduce our Benchtop Payload Controller, a streamlined solution for designing, testing, and operating sensors, effectors, and data collection for your payload.

- **Section 4: Experiment Environments** – Here, we walk you through the detailed environments of a flight on the New Shepard system from launch loads through the shirtsleeve cabin atmosphere and on through payload recovery.

- **Section 5: Payload Integration** – Next, we describe the team and processes that you will be working with as you prepare your payload for flight. We outline the standard pre-flight reviews, flight week activities, and post-flight operations needed to support a successful payload campaign.

- **Section 6: Safety** – Last, but most definitely not least, we step through the safety considerations that you and we will keep in mind throughout this journey.

The PUG appendices contain today’s drafts of the various forms we are using to prepare payload customers for flight. Please do check with us to ensure you have the latest copies!

At the end of the day, the PUG is intended as a guide for the conceptual design of your future payloads to fly on untended flights of Blue Origin’s New Shepard system. We are continuing to developing this capability over time, and information in this document is subject to change without notice. So, before you undertake detailed design, experiment fabrication, or other major efforts, please contact payloads@blueorigin.com to discuss your specific needs and flight availability.
2. **NEW SHEPARD DESCRIPTION**

2.1 **New Shepard Overview**

2.1.1 **New Shepard System**

Blue Origin was created to develop spacecraft and launch systems with the goal of contributing to an enduring human presence in space. Blue Origin is developing the *New Shepard* system, a suborbital vehicle that will ultimately carry up to six astronauts and/or payloads to an altitude of at least 328,000 feet (100 km). It consists of a Propulsion Module (PM) and separable Crew Capsule (CC) carrying the astronaut crew and payloads. The *New Shepard* mission profile begins with completion of propellant loading and all preflight system checks. After liftoff, the vehicle ascends vertically for approximately 150 seconds before main engine cutoff in the upper atmosphere. Several seconds after engine cutoff, the CC separates from the PM and is pushed away by mechanical springs. From this point, the CC and PM coast and reenter separately. The vehicles experience microgravity for a period of about 3 minutes before returning to earth. The PM maneuvers back to a landing pad, restarts its engine, and deploys landing gear to perform a rocket-powered vertical landing. The CC reenters and lands under a three-parachute canopy with assistance of a retro-thrust system to reduce landing loads. The entire flight occurs autonomously.

In the case of an anomaly detected during boost, the CC is equipped with a solid rocket motor that can propel it away from the PM before the nominal separation point. After this escape maneuver, the CC will execute an independent parachute landing.

Figure 1 shows the *New Shepard* vehicle with the CC mated to the PM. The stacked vehicle is approximately 60 feet (18 meters) in height and 10 to 12 feet (3 to 3.6 meters) in diameter, not including its fins. It is powered by a single 110,000-lbf (489,304 Newton) thrust BE-3 liquid rocket engine.

![Figure 1: Integrated New Shepard Vehicle (CC and PM)](image-url)
2.2 Crew Capsule

Early New Shepard experiments will fly on a prototype version of the CC that will carry no crew. The flight profile for this vehicle is expected to be substantially similar to later human-capable iterations, however, the apogee altitude and the duration of the zero-G portion of flight may be reduced.

The initial New Shepard CC, shown in Figure 2, is designed to accommodate up to six research and/or ballast racks in a ringed configuration. Future upgrades will include windows, seats, and environmental controls.

![New Shepard Crew Capsule Initial Configuration](image)

Figure 2: New Shepard Crew Capsule Initial Configuration

2.3 Research and Education Mission Applications

New Shepard Research and Education Mission (REM) payloads may include, but are not limited to microgravity sciences, space life sciences, Earth and space sciences, land use, education and public outreach, technology development and demonstration/space systems development and Technical Readiness Level (TRL) raising demonstrations.

The primary Payload capabilities of the New Shepard vehicle will include:

- The ability to launch payloads, and ultimately payload operators, to suborbital altitudes on a frequent basis.
- A high volume cabin able to accommodate multiple experiments and, ultimately, researchers.
- Standard interfaces to mount experiments and provide power, cooling, command and control, and video and data recording.
- Rapid post-landing access by ground personnel to time-sensitive payloads.
2.4 Launch Site Description & Accommodations

2.4.1 Launch Site Location

Blue Origin’s West Texas Launch Site, where all New Shepard launch operations will initially be performed, is located in Culberson County in the state of Texas. The site is approximately 25 miles (40 kilometers) north of the town of Van Horn, Texas along state Highway 54 (see Figure 3). Travelers normally fly into El Paso, Texas, and stay overnight in Van Horn. The drive from El Paso International Airport to Van Horn is approximately 2 hours (120 miles/193 km). The drive from Van Horn to the launch site is approximately 30 minutes. Blue Origin can provide more specific travel directions and suggestion for accommodations in Van Horn at the time of scheduling a customer visit. All customer visits must be pre-coordinated with the customer’s Payload Integration Manager.

![Figure 3: Launch Site Location](image)

2.4.2 Launch Site Description

Blue Origin’s launch site covers approximately 18,600 acres (7,527 hectares) of remote desert encircled by a perimeter fence. Figure 4 shows a diagram of the site, which is accessed via a security gate that is positioned along Highway 54.
The Vehicle Processing Facility (VPF) contains a high bay where New Shepard vehicles are maintained between flights. In the immediate vicinity of the VPF is the Administrative Support Center housing the Operations Control Center, from which the New Shepard launch operation is controlled. On the day of launch, the New Shepard vehicle is rolled out horizontally from the VPF and travels 1.8 miles (2.9 km) to the Launch Pad. The vehicle is erected vertically on the launch stand and fueled for flight.

The New Shepard PM will land on the North Landing Pad, located 2 miles (3.2 km) north of the Launch Pad. The CC will land separately in the CC Primary Landing Area. Both vehicles will be returned to the VPF after the mission. If earlier access is required for sample retrieval, special arrangements can be made for access shortly after CC landing in the recovery zone.

Blue will provide a Payload Facility for storage, staging, flight preparations, and post-mission processing of REM experiments. The facility will be shared by all researchers unless special arrangements are made in advance. The facility is climate controlled and provides electrical power (standard U.S. 110 volt AC), phone access (including long-distance service), and Internet access. Tables and standard office furniture will also be provided. There are no special clean room provisions at this time. Any additional accommodations specific to the REM experiments will be identified as part of the Launch Site Integration Package with individual researchers (see Section 5.2).
2.4.3 Shipping
FedEx and UPS both ship directly to the Blue Origin launch site. All shipments should be coordinated with the Payload Integration Manager assigned by Blue Origin. Hazardous materials will require SDS (Safety Data Sheets) and additional advance coordination.

2.5 Launch Windows
Blue Origin plans to conduct initial New Shepard launch operations during daylight hours, nominally in the early morning. In the future, Blue Origin may offer New Shepard launches during the night for research purposes.

2.6 Flight Profile and Events
Table 1 below shows approximate trajectory parameters at specific trajectory events for a representative nominal flight profile of the New Shepard CC. The sensed acceleration shown is in the peak predicted direction due to aerodynamic drag only, which is primarily along the vehicle’s vertical axis. As described in greater detail in Section 2.7, the table does not include small accelerations that may be induced by Reaction Control System (RCS) thruster firings or slow vehicle rotation in any axis that might happen during the microgravity phase of flight. The table extends through the point just before activation of the retro-thrust system prior to touchdown. Additional details may be provided upon request.

The actual flight plan and flight profile may differ from the representative trajectory shown in the table. In particular, if there are off-nominal, unplanned events during the flight, trajectory parameters may deviate substantially from the values in the table below.
Table 1: Representative New Shepard CC Flight Profile

<table>
<thead>
<tr>
<th>EVENT</th>
<th>Time (seconds)</th>
<th>Altitude (ft ASL)</th>
<th>Vertical Velocity (ft/second)</th>
<th>Sensed Acceleration (g)</th>
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<td>Main Engine Ignition Command</td>
<td>0</td>
<td>3,650</td>
<td>0</td>
<td>1.00</td>
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<tr>
<td>Liftoff</td>
<td>7</td>
<td>3,650</td>
<td>0</td>
<td>1.00</td>
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<td>Max G on Ascent</td>
<td>135</td>
<td>142,706</td>
<td>2,981</td>
<td>2.8</td>
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<tr>
<td>MECO (main engine cut off)</td>
<td>153</td>
<td>195,343</td>
<td>2,890</td>
<td>-0.01</td>
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<tr>
<td>Separate CC</td>
<td>160</td>
<td>215,346</td>
<td>2,661</td>
<td>2.2</td>
</tr>
<tr>
<td>Sensed Acceleration &lt; 0.001 g</td>
<td>179</td>
<td>260,739</td>
<td>2,059</td>
<td>-0.001</td>
</tr>
<tr>
<td>Apogee</td>
<td>245</td>
<td>328,475</td>
<td>0</td>
<td>0.00</td>
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<tr>
<td>Sensed Acceleration &gt; 0.001 g</td>
<td>307</td>
<td>269,939</td>
<td>-1,913</td>
<td>0.001</td>
</tr>
<tr>
<td>Sensed Acceleration &gt; 0.01 g</td>
<td>324</td>
<td>231,517</td>
<td>-2,463</td>
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<tr>
<td>Sensed Acceleration &gt; 0.1 g</td>
<td>342</td>
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<tr>
<td>Sensed Acceleration &gt; 1.0 g</td>
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<td>Max G on Reentry</td>
<td>375</td>
<td>80,399</td>
<td>-2,242</td>
<td>4.7</td>
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<td>Mortar Deploy Drogues</td>
<td>451</td>
<td>23,822</td>
<td>-382</td>
<td>1.0</td>
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<td>Peak Parachute Load</td>
<td>527</td>
<td>6,400</td>
<td>-151</td>
<td>3.05</td>
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<tr>
<td>Initiate Terminal Decelerator</td>
<td>632</td>
<td>3,651</td>
<td>-23</td>
<td>1.00</td>
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</tbody>
</table>
Figure 5 shows the sensed acceleration profile vs. time for this reference trajectory. These sensed accelerations result from aerodynamic drag, engine thrust, and parachute loads. The profile extends to just before activation of the retro-thrust system and touchdown. The profile includes all events for this reference trajectory during boost under the PM, separation of the CC, the microgravity coast phase, re-entry, and parachute deployment events.

Figure 6 shows altitude above sea level vs. time for this reference trajectory.
2.7 Microgravity Quality and Attitude Control

The previous section discussed the expected duration and quality of the microgravity environment on a New Shepard mission. There are several factors which may shorten or degrade the quality of the microgravity environment from nominal predicted values.

The CC has a system of cold-gas thrusters to perform attitude control during the exo-atmospheric coast phase of flight, called the Reaction Control System (RCS). On a nominal mission, nearly all RCS thruster firings will happen during the 10-15 seconds immediately following separation from the PM. During this period, the CC RCS will attempt to null rates in pitch, yaw, and roll axes induced by any asymmetries in the mechanical separation spring force or residual aerodynamic disturbances. After this period, the frequency of RCS thruster firings is expected to drop significantly. Approximately 35 seconds after separation, the vehicle will provide a "coast_start" signal, indicating that during most missions, the RCS thrusters are not expected to fire again during the microgravity coast phase until reentry, when the sensed acceleration due to aerodynamic drag will be far greater than any RCS-induced acceleration. However, if the CC adopts a pitch or yaw angle during the microgravity coast phase that is more than 45° offset from
base-first trim or it builds up an angular rate of greater than 5°/second in any axis during the microgravity coast phase, the RCS thrusters will again fire to return the CC below these limits.

During the microgravity coast phase, small thrusters may be fired to maintain attitude and attitude rates. When these thrusters are firing, they will individually induce approximately 0.001 - 0.0025g of brief sensed acceleration to the CC. These accelerations will be in the lateral Y-Z plane of the CC.

As previously mentioned, the CC may have residual rates up to 5°/second about any axis during the microgravity coast phase. During most missions, the rates are expected to be significantly less, and even on missions where the rates do reach 5°/second, they are only expected to do so during small portions of the mission before the RCS thrusters activate to null rates. A residual rate of 5°/second may induce a centripetal acceleration on the experiment of up to 0.001 g in addition to the sensed accelerations described in Section 2.6 resulting from aerodynamic drag (although these sensed accelerations may not be in the same direction). Information on jet thruster timing and CC dynamics may be reported post-flight to researchers, if required.

At this time, it is not possible to provide a precise timeline or expected frequency of disturbances due to residual CC angular rates or RCS thruster firings. Among the variables that will influence these disturbances are uncertainties in CC lateral center of gravity location (which will vary from flight to flight); high altitude wind direction and magnitude on the day of flight; day-to-day variations in atmospheric density at high altitudes; tip-off rate from the PM induced the separation system (a function of expected asymmetries in separation spring force and variation in timing of separation bolt releases); and asymmetry in the CC shape which will induce small aerodynamic torques on the body. Blue Origin will accumulate greater knowledge of the microgravity environment during its flight test program and be able to update the predictions with higher fidelity estimates in the future.

The microgravity environment during a typical CC flight can be summarized as follows:

- A sensed acceleration will be induced by aerodynamic drag as described in Table 1. This acceleration is predominantly in the vehicle’s vertical axis.
- A sensed acceleration may be induced by occasional RCS thruster firings. Blue Origin expects nearly all of these thruster firings during the microgravity coast phase to occur during the 10-15 seconds immediately after separation. Approximately 35 seconds after separation, the vehicle will provide a “coast_start” signal, indicating that firings will be infrequent and very likely there will be none at all until the vehicle reenters the atmosphere and aerodynamic drag is significantly greater than RCS thruster force. Each thruster firing will induce 0.001g – 0.0025g to the CC in the lateral plane (perpendicular to the predominant direction of drag).
- A sensed acceleration may be induced by residual angular rates on the CC. The worst-case angular rate during the microgravity coast phase in any axis are expected to be up to 5°/second. Above this threshold, the RCS thrusters will activate to null rates in that axis. The magnitude of sensed acceleration will depend on the location of the experiment relative to the CC center-of-gravity. See Section 3.1.1 for a description of the standard experiment location relative to the vehicle center-of-gravity.

For missions requiring the CC to hold a specific attitude (e.g., to point an instrument at a specific location on Earth or in the sky), the CC RCS will hold the CC to within +/- 5° of commanded attitude in any axis. Holding a specific attitude will degrade the microgravity environment as it will require periodic RCS thruster firings to correct for attitude excursions. Flights carrying a mixture
of experiments, some which desire a high-quality microgravity environment, and some which desire to orient to a specific attitude, may need to be divided into two or more phases of RCS control (e.g., an attitude-hold phase followed by a rate-null phase), with the requirements of a particular experiment addressed in a specific phase.

Finally, the presence of flight crew or other astronauts on future flights may affect the quality of the microgravity environment. Crew movement, such as pushing off the walls of the CC, may induce accelerations and attitude rates that will degrade the quality of the microgravity environment.

2.8 Flight Rules

Similar to any other launch or aviation activity, the New Shepard system will operate with a number of flight rules that will be constraints to launch. These flight rules will be refined during the New Shepard flight test program, but they fall into the following broad categories:

- **Weather**: Ground-level winds, upper-air winds, level of precipitation, proximity of natural lightning, and other weather conditions will be potential launch commit criteria. Blue Origin plans to change weather-related commit criteria over time as it accumulates knowledge of the vehicle’s performance in various weather conditions.

- **Vehicle Readiness**: Blue Origin will perform pre-flight testing of New Shepard systems before committing to flight. These tests are expected to begin several days before launch and continue right up until liftoff. Failure of systems to pass pre-flight testing may delay or cancel a launch attempt.

- **FAA**: Blue Origin will obtain clearance from the Federal Aviation Administration (FAA) Air Traffic Control (ATC) to allow the New Shepard vehicle to transit the national air space. This clearance will cover a specific pre-arranged launch window during which local air traffic will be routed around the perimeter of the launch site. If, for some reason such as weather or lack of vehicle readiness, Blue Origin is not able to fly the New Shepard vehicle during this window of time, a new window must be arranged with FAA ATC before a flight can occur.

Researchers are responsible for delivering their experiment to the launch site on schedule and ensuring experiment readiness in advance of final integration and checkout on CC as described in Section 5.4. If for some reason the experiment is not delivered on time or is not otherwise functional at the required time of installation, it can be considered for flight on a future launch.
3. REM PAYLOAD STANDARD SERVICES AND INTERFACES

3.1 Payload System Overview

The standard interface for experiments to the New Shepard vehicle is via Blue Origin Payload Stack.

3.1.1 Payload Stack

The Payload Stack is a modular system consisting of up to four stackable layers as shown in Figure 7. The bottom layer, referred to as the Payload Support Enclosure, is reserved for Blue Origin to store four Flight Payload Controllers (FPCs) which provide power, data recording, command, and control services to experiments. The top three layers are for experiment use. Each experiment layer consists of two Payload Lockers, for a total of up to six Lockers per Payload Stack. Each Payload Locker provides a usable interior experiment volume of 1.73 cubic feet (approximately 49 liters) of usable volume. Electrical connectors on the sides of the Payload Lockers interface with cables that run externally to the Flight Payload Controllers. In addition to a door on the front side, as shown in Figure 7, the Payload Locker has a removable top plate for ease of experiment insertion and servicing. Detailed drawings are provided in Section 3.2.1.

Researchers may use one to six Payload Lockers for their experiment or more if the experiment can be accommodated in multiple Payload Stacks. If fewer than six Lockers are being used, Blue Origin reserves the right to accommodate multiple experiments from different organizations in the same Stack.

The Payload Stack will have three right-sided single Lockers on the right half and three left-sided single Lockers on the left half. Blue Origin can also provide a left-sided double-height Locker with an interior experiment volume of 3.60 cubic feet (approximately 102 liters) for experiment use. Only one double Locker can be accommodated in the same Payload Stack along with four single Lockers. Single and double configurations are illustrated in Figure 8.
Figure 8: View of Single and Double Left-Sided Payload Lockers

Figure 9 shows the initial layout of the six possible Payload Stack locations within the CC.

Figure 9: Top-Down View of Initial Configuration for Payload Stacks

Table 2 describes the locations of the center of each level of Lockers within a given Stack with respect to the CC center of mass, in terms of both vertical ($\Delta X$) and radial ($R$) offset. Figure 10 illustrates the allowable center of mass for a given payload within these boxes.
### Table 2: Location of Payload Locker CG Relative to CC Center of Mass ($\Delta X = 0$, $R = 0$)

<table>
<thead>
<tr>
<th>Location in Payload Stack</th>
<th>$\Delta X$</th>
<th>$R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top two Payload Lockers</td>
<td>15.1 in (38.4 cm)</td>
<td>46.2 in (117.3 cm)</td>
</tr>
<tr>
<td>Middle two Payload Lockers</td>
<td>4.8 in (12.2 cm)</td>
<td></td>
</tr>
<tr>
<td>Bottom two Payload Lockers</td>
<td>5.6 in (-14.2 cm)</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 10: Allowed Payload Center of Mass Offset](image)

### 3.1.2 Supporting Avionics Hardware and Software

The function of the Payload Stack is to contain the experiment during all phases of flight and provide services to experiments such as power, data recording, and command and control, with minimal required interfaces to the CC vehicle Avionics. A functional block diagram of the Payload Support Enclosure is shown in Figure 11, including major interfaces to the CC vehicle avionics and interfaces available to experiments. Experiments can utilize all or some or none of the interfaces.
to the Flight Payload Controllers. Figure 12 shows a diagram of the hardware that resides in the Payload Support Enclosure at the bottom of each Payload Stack. Four separate Flight Payload Controllers inside the Payload Support Enclosure can interface to up to four distinct experiments per rack. Each experiment has its own experiment battery, with additional logic power provided to support the Flight Payload Controllers. The mechanical and electrical interfaces are described in greater detail in Sections 3.2 and 3.3.

Figure 11: Functional Block Diagram of the Payload Support Enclosure
To ease integration, Blue Origin will deliver the actual Payload Locker that will be used on the flight to the researcher prior to flight. In addition, Blue Origin can deliver Benchtop Payload Controllers (BPCs) that are functionally identical to the flight units to assist in configuration setup and testing. These ground units will come pre-installed with a web-browser based configuration toolkit that allows researchers to define their experiment’s behavior based on a given set of trigger events, and specify logging requirements for data received from their experiment. In addition, this toolkit includes a simulation tool to test their experiment configuration in the lab before flight. This software is described in greater detail in Section 3.4. A separate user’s manual will be provided to assist with the setup and testing of the Benchtop Payload Controllers and their software.

The configuration software provides a common interface for setting up measurements, control signals, communications, and scripting of actions based on vehicle mission data. With delivery of these items to the researcher, the experiment can be nearly fully integrated and extensively tested at the researcher’s lab before delivery to the launch site, speeding integration with the Payload Stack. For these ground units, Blue Origin will not deliver flight-like batteries or power conditioning units. Standard laboratory power supplies can be used in their place to emulate the vehicle’s electrical power system. Researchers will require a 28VDC power source capable of providing 6A (or greater).

Checkout of experiments with flight electronics will occur off the vehicle in the Payload Facility, as described in Section 2.4.2. Before the actual flight, payloads will be brought to the vehicle and will be installed by Blue Origin personnel, with bolts secured between Lockers as they are stacked. After installation, cables between the modules and Flight Payload Controllers will be connected and pre-flight checkout of experiments performed before the CC cabin is sealed for flight.
3.2 Mechanical Interfaces

3.2.1 Mechanical Interface Drawings

The single Payload Locker is essentially a box as described in Table 3 with a minor volume occupied by door hinges – see Figure 14. A single Payload Locker therefore has a usable interior volume of 1.73 cubic feet (approximately 49 liters) for experiments.

The interior volume has a standard pattern of threaded holes for mechanical fastening experiment hardware. The bottom interior of each Locker has a pattern of .2500-28-UNJF-3B threaded holes (self-locking) at 2-inch intervals and 0.315-inch depth for fastening in experiments. Fasteners should be torqued to 23 in-lbs. The sides and back of each Locker have four .2500-28-UNJF-3B threaded holes to provide additional anchor points.

The Double Payload Locker has the same type and number of attachment holes, but with an interior volume of 20.31 inches x 16.45 inches x 18.67 inches (approximately 51.59 cm x 41.78 cm x 47.42 cm) (Length x Width x Height) minus hinge volume, in total a usable volume of 3.61 cubic feet (approximately 102 liters). The captions in the figures provide a reference to the corresponding Blue Origin mechanical interface drawings for greater detail.

<table>
<thead>
<tr>
<th>Property</th>
<th>English Units</th>
<th>Metric Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Payload Locker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>20.31 in</td>
<td>51.59 cm</td>
</tr>
<tr>
<td>Width</td>
<td>16.45 in</td>
<td>41.78 cm</td>
</tr>
<tr>
<td>Height</td>
<td>9.02 in</td>
<td>22.91 cm</td>
</tr>
<tr>
<td>Hinge Volume</td>
<td>0.039 ft³</td>
<td>1.10 liters</td>
</tr>
<tr>
<td>Usable Volume</td>
<td>1.73 ft³</td>
<td>49 liters</td>
</tr>
<tr>
<td>Double Payload Locker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>20.31 in</td>
<td>51.59 cm</td>
</tr>
<tr>
<td>Width</td>
<td>16.45 in</td>
<td>41.78 cm</td>
</tr>
<tr>
<td>Height</td>
<td>18.67 in</td>
<td>47.42 cm</td>
</tr>
<tr>
<td>Hinge Volume</td>
<td>0.085 ft³</td>
<td>2.4 liters</td>
</tr>
<tr>
<td>Usable Volume</td>
<td>3.61 ft³</td>
<td>102 liters</td>
</tr>
</tbody>
</table>

All Locker sides are constructed from sandwich panels of fiberglass cloth reinforced epoxy laminate and Aramid honeycomb core. The front door has a neoprene gasket. The top plate is removable for accessing the interior and the two side-mounted electrical connectors (see Figure 13). Unless the Locker is mounted on top of the Payload Stack, the top cover would not be accessible once the Lockers are integrated into the Stack.

The door is closed with an over-center shear pin latch that visibly identifies its locked state. No mounting points are located on the door.

It should be noted that the Payload Lockers are still in development. Parts that may change in the future include the door ports, hinges, latch, and layout of mounting holes on the bottom and sides of the box.
In advance of the flight, Blue Origin will deliver the actual flight Locker(s) to the researcher for physical integration of the experiment. Refer to the detailed Blue Origin drawings for additional detail, which will be available to all contracted researchers.

Some researchers will need both a left-sided and right-sided Locker in order to fit the experiment on one Payload Stack. The right-sided Payload Locker is merely a mirrored version of the left-sided Payload Locker (drawing CD326007), with the door opening the other direction and the Avionics cables connecting on the opposite side. Drawings for the right-sided Locker can be supplied as needed. Only left-sided Double Payload Lockers are available at this time.

Figure 13: Isometric View of Single Left-Sided Payload Locker
(see drawing CD326006-NC)
Figure 14: Top-Down View of Single or Double Payload Locker Showing Hinge Keep-Out Zone (Drawing CD326006-NC)

Figure 15: Interior Left Panel View for Single Left-Sided Payload Locker (Drawing CD326006-NC)
Figure 16: Interior Right Panel View for Single Left-Sided Payload Locker
(Drawing CD326006-NC)

Figure 17: Interior Door View for Single Left-Sided Payload Locker,
Showing Hinges and Latch (Drawing CD326006-NC)
Figure 18: Isometric View of Double Payload Locker, (Drawing CD326008-NC)

Figure 19: Interior Right Panel View for Double Left-Sided Payload Locker, (Drawing CD326008-NC)
Figure 20: Interior Left Panel View for Double Left-Sided Payload Locker, (Drawing CD326008-NC)

Figure 21: Interior Door View for Double Payload Locker, Showing Hinges and Latch, (Drawing CD326008-NC)
3.2.2 Dynamic Envelope Clearance

If an experiment is enclosed within its own container inside the Payload Locker, a minimum spacing of 1/2-inch (1.27 cm) is recommended for any sides of an experiment box or hardware that are not fastened to the sides of the Locker. This allows for dynamic movement of the experiment box relative to the Locker during flight. Two backshell connectors, adjustable from 180° to -180°, will be attached to the Locker prior to delivery to accommodate harness entry into the Locker, with the required clearance shown in Figure 22. These backshell connectors protect the side plate connectors by providing strain relief, and may be removed for extra payload volume provided that the payload team uses caution while handling the wires. They do not provide shielding from electromagnetic interference (EMI).

![Figure 22: Keep-out Dimensions (in Inches) for Harness Entry](image)

3.2.3 Loading Dimensions

If the experiment is intended to be lowered down through the top opening of the Locker, then its size should fit within the opening of 14.59 inches (37.06 cm) by 18.53 inches (47.06 cm). Note that these dimensions exclude the area in which the hinge protrudes, which is shown separately in Figure 14. The front door of a Single Payload Locker has an access opening of at least 9.75 inches (24.765 cm) by 8.0 inches (20.32 cm). A Double Payload Locker has a front door access opening of at least 9.75 inches (24.765 cm) by 17.75 inches (45.085 cm). Also, the backshell connectors can be temporarily unscrewed to allow for baseplate insertion.


3.2.4 Mass Limit

The contents manifested per Payload Locker must not exceed 25.0 pounds (approximately 11.34 kilograms), or in the case of a Double Payload Locker, 50.0 pounds (approximately 22.68 kilograms). This does not include the mass of the Locker structure itself or wire harnesses provided by Blue Origin.

3.2.5 Cameras

At researcher request, Blue Origin can provide up to two standard video cameras with each Payload Locker. The cameras and associated lenses will be delivered with the Locker, along with standard mounting hardware to allow them to be placed in the location and viewing angle of the researcher’s choosing. Note that these cameras would use part of the overall interior volume described in Section 3.2.1 and part of the mass limit allocation described in Section 3.2.3. More information on the standard video camera is described in Section 3.3.3.

3.2.6 Cooling

Blue Origin may add additional features for dissipating heat out of the Payload Locker. These provisions may include fans on the front and rear panels. This determination will be made between Blue Origin and the researcher after receipt of the Payload Data Package and captured in the experiment-specific ICD (see Section 5.2).

3.2.7 Hazardous and Liquid Material Containment

For experiments that will fly with liquid, stored gas, or hazardous materials, it will be the responsibility of the researcher to provide a Blue Origin-approved containment system. The exact provisions will depend on the type and quantity of liquid or gas in the experiment. At a minimum, Blue Origin requires secondary containment of liquids, e.g., a fully enclosed test vessel surrounded by a secondary enclosure in addition to the Payload Locker. Placement of absorbent material within the secondary containment to further control spilled liquid may be required by Blue Origin for some experiments.
3.3 Electrical Interfaces

3.3.1 Signal List

Table 4 lists the data ports provided by a Flight Payload Controller for data collection and experiment communication. Up to four such units can be accommodated per Payload Stack. Analog and digital I/O data acquisition functions are handled by a United Electronic Industries UEIPAC 600-1G, pre-populated with modules for measurement, signal conditioning, control, and communication. The default configuration will support all of the data signals described in Table 4. For streaming interfaces, such as RS-232 and Ethernet connections, discrete messages may be written to the attached devices from either a text or binary dictionary file, and responses may be logged in either format, with optional timestamps inserted into the stream.

Signal rates depend on the total number and types of channels used, although logging is limited up to 300 kb/s throughput. A telemetry time stamp is available for correlation with flight logs.

<table>
<thead>
<tr>
<th>Port Identity</th>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Inputs</td>
<td>4</td>
<td>Differential, 16-bit resolution, High impedance Configurable range (±10 V, ±5 V, ±1 V, ±0.2 V) 250 kS/s aggregate sample rate</td>
</tr>
<tr>
<td>Digital I/O</td>
<td>3 channels</td>
<td>TTL (Input 2.2V Hi min, 0.8V Lo max) Source 4.4V at 2 mA Sink 0.26V at 2 mA</td>
</tr>
<tr>
<td>PWM Output</td>
<td>2</td>
<td>Up to 10 KHz &gt;2V max, &lt;0.8V min at ±12mA Dedicated servo modes available</td>
</tr>
<tr>
<td>RS-232</td>
<td>1</td>
<td>Configurable baud rate</td>
</tr>
<tr>
<td>Ethernet</td>
<td>2</td>
<td>GigE capable devices must request a static IP assignment from Blue</td>
</tr>
<tr>
<td>RTD</td>
<td>6</td>
<td>Thermal measurements. 100 Ohm RTD</td>
</tr>
</tbody>
</table>

3.3.2 Data Storage

Data collected from experiments are written to an SD card in each Payload Controller. Up to 32 GB of data storage is available per Payload Locker, with 64 GB of additional storage per Blue Origin-provided video camera.

3.3.3 Cameras

At researcher request, Blue Origin will provide up to two video cameras that can be mounted inside each Payload Locker. The standard cameras available are the GoPro HERO3 Silver Edition, modified with a Back-Bone Ribcage for support of standard M12, CS or C-mount lenses. With mounting brackets and lens, the camera is expected to weigh less than a half pound. The camera body is approximately 1 1/8” x 2 1/4” x 1 7/8” without lenses.
A selection of lenses, selected based on their capability to image components within the dimensions of the Locker interior, is available to borrow from Blue Origin. These lenses have focal lengths in the range of 8-23mm and less than 6% image distortion. Blue Origin can provide a selection guide upon request to aid researchers in determining an appropriate lens for imaging their payload setup. Researchers are also welcome to use their own compatible lenses.

![GoPro HERO3 Camera with Back-Bone Ribcage Modification](image)

**Figure 24: GoPro HERO3 Camera with Back-Bone Ribcage Modification**

If requested, the researcher can also use their own camera and video recording equipment. However, Blue Origin provided cameras have the advantage of being vibration tested and familiar to the technical support team.

The camera records to its onboard microSD card with externally supplied power, and is currently capable of four hours of continuous operations at 1080p and 60 fps. It is recommended that researchers incorporate a time-synchronizing event, such as turning on an LED, to aid in post-processing video data with other experimental data.

Camera mounting hardware falls under the responsibility of the researcher. As shown in Figure 25, the Ribcage-modified camera provides a row of three 1/4"-20 UNC threaded mounting holes spaced at 9/16” intervals along its base. These holes are compatible with a standard photographic tripod mount. However, researchers are encouraged to build a more rugged mount using two or more of these mounting holes.
3.3.4 Payload Connector Interface

Each Payload Locker has two side-mounted bulkhead connectors for interfacing with the Payload Support Enclosure. The placement of these connectors is shown in the mechanical interface drawings, Figure 15 and Figure 20. Cables will run on the exterior of the Payload Stack from the experiment Locker down to bulkhead connectors in the Payload Support Enclosure. The Lockers will be delivered to the researcher with the bulkhead connector in place. On the side of the connector inside the Locker, Blue Origin will pre-crimp pig-tail leads with adequate wire length to run to components anywhere in the Locker. For convenient use with Blue Origin-provided GoPros, camera leads are terminated with female USB-A sockets. The researcher should coil and stow excess wire length after the experiment components are placed. If desired, the researcher may also construct their own experiment wiring harness with standard D38999 sized connectors.
3.3.5 Grounding

Blue Origin requires the researcher to follow standard grounding practices by returning all circuit grounds in the experiment to a single point ground. The single point ground should be returned to the chassis ground pins (CHAS) allocated in the J1 connector. The recommended method for grounding is to have all four chassis pins (J1:103-106) be connected by ring lug or conductive screw to an aluminum payload baseplate. All components connected to the baseplate will then also be electrically connected to the baseplate. Continuity to the base plate should be verified on all case grounds for components.

Analog and digital channels, along with the cameras, are grounded using the signal grounds and shields provided in the cable.

3.3.6 Power

The following table describes provisions for electrical power from the system. Each payload has access to four 26 +/- 4V services, with each service limited to 2A max draw by an active overcurrent protection device. A payload can therefore access 200 W peak power. Since there are 4 active payload interfaces per Payload Stack, the Stack itself can support 800 W peak power to all experiments in it. Because camera power is provided by separate batteries, their power draw is excluded from the limits described in this section.

Payload power will typically be made available during terminal count, approximately 5 minutes before launch. After a nominal mission of around 11 minutes, power service is typically maintained until vehicle safing, approximately 5 minutes later. The CC recovery team will reach the CC landing site approximately 30-60 minutes after landing. Total energy available is summarized in Table 8. Power requests above the “Standard” levels will be available as a special service and will be allocated on a mission-by-mission basis to balance manifest power and thermal considerations. Payloads requiring power sooner in the pad timeline or later in the recovery cycle should discuss options with Blue Origin.

Experiments may be powered prior to liftoff at researcher request with specific durations and power levels to be agreed upon. However, it is recommended that power be turned off during the ascent portion of the flight in order to reduce the chances of powered components being affected by vibration or shock.

There is currently no plan to regulate the power supply, although a DC/DC converter could be easily implemented on the experiment side. Voltage is expected to vary within the range described in Table 5, dependent on the state of charge.

It is highly recommended that researchers use Blue Origin-provided power services rather than including their own batteries, regardless of size. Best design practice suggests that payloads incorporate fuses in order to protect sensitive equipment in the unlikely event of a power surge.
3.3.7 Telemetry

Real-time vehicle telemetry from experiments, whether pre-flight, flight, or post-flight, is not a standard Payload service. Data recorded from the experiment in-flight will normally be available after the vehicle is recovered and returned to the VPF.

3.4 Software Interfaces

Blue Origin has developed the REMConfig software configuration tool for programming the Payload Controllers to interface with all experiment inputs and outputs. The REMConfig software is a tool for editing an XML configuration file. The user is able to configure device options and names for each I/O channel, set up logging files to record the captured data, and specify basic scripted actions to take based on vehicle mission data.

The REMConfig software can trigger actions based on reference signals (DIO pins, analog thresholds), warnings, and flight events, listed in Table 6. A mock data feed will be provided for benchtop testing, and actual flight data will be made available to researchers post-flight.

<table>
<thead>
<tr>
<th>Flight Events</th>
<th>Reference Signals</th>
<th>Warning Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liftoff</td>
<td>Time</td>
<td>Liftoff warning</td>
</tr>
<tr>
<td>Main engine cutoff (MECO)</td>
<td>Analog input channels</td>
<td>Capsule escape imminent</td>
</tr>
<tr>
<td>CC separation</td>
<td>Digital input channels</td>
<td>Attitude thruster firing</td>
</tr>
<tr>
<td>Coast start</td>
<td>Serial command</td>
<td>Parachute deployment</td>
</tr>
<tr>
<td>Apogee</td>
<td>Acceleration</td>
<td>Landing imminent</td>
</tr>
<tr>
<td>Coast end</td>
<td>Velocity</td>
<td>Landing fault warning</td>
</tr>
<tr>
<td>Parachutes deploy</td>
<td>Position</td>
<td></td>
</tr>
<tr>
<td>Landing</td>
<td>Altitude</td>
<td></td>
</tr>
<tr>
<td>Vehicle safing</td>
<td>Latitude / Longitude</td>
<td></td>
</tr>
<tr>
<td>Mission end</td>
<td>Attitude</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Angular Velocity</td>
<td></td>
</tr>
</tbody>
</table>

The REMConfig software provides the configurable settings listed in Table 10 for each of the available ports listed in Section 3.3.1 and the power services listed in Section 3.3.6:
Table 7: REMConfig Software Configurable Port Settings

<table>
<thead>
<tr>
<th>Port Identity</th>
<th>Configurable Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Inputs/RTDs</td>
<td>Input signal range, Sample rate, Sample count, Start and stop conditions, Logging gain and offset</td>
</tr>
<tr>
<td>Digital I/O</td>
<td>Sampling rate (input), Port direction per pin, Start and stop conditions</td>
</tr>
<tr>
<td>PWM</td>
<td>Frequency, Duty cycle, Start and stop conditions</td>
</tr>
<tr>
<td>RS-232</td>
<td>Baud rate, Messaging and logging formats, Start and stop conditions</td>
</tr>
<tr>
<td>Ethernet</td>
<td>IP Addresses, Listen ports, Messaging and logging formats, Start and stop conditions</td>
</tr>
<tr>
<td>Discrete Power</td>
<td>Current limits, Start and stop conditions</td>
</tr>
</tbody>
</table>

The REMConfig software is web-browser based, and will be delivered to the researcher pre-installed on their Benchtop Payload Controller. Use of this software is optional – Researchers may run their own control programs on their own computer installed in their Payload Locker. However, Blue Origin cannot provide software support to researchers who use their own control programs.
4. PAYLOAD ENVIRONMENTS

This section describes preliminary predicted environments experienced by Payloads in single Payload Lockers during New Shepard flights. Predicted environments may vary from those experienced during flight.

4.1 Accelerations

Blue Origin expects experiments in the Payload Stacks to handle accelerations bounded by the environments listed in Table 8 for durations up to 50 msec. It should be noted that axial and lateral loads may be applicable simultaneously. It is recommended that experiments be designed to these environments, with a minimum ultimate factor of safety of 2.0 relative to nominal loads.

Also included are peak acceleration environments that may be encountered if the CC fails to deploy one of its three main parachutes, landing on only two fully open main parachutes, or if the CC experiences an unplanned escape from a flight anomaly. This type of failure is expected to be a rare event, but researchers may wish to design their experiments to sustain this environment without damage. The Payload Lockers are designed to contain debris for nominal and off-nominal load cases. All loads are for payloads only; astronaut loads will be reduced due to seat design.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Direction</th>
<th>Peak Acceleration</th>
<th>Max. Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Mission</td>
<td>Axial</td>
<td>+15 / -4.5 g</td>
<td>50 msec</td>
</tr>
<tr>
<td>Nominal Mission</td>
<td>Lateral</td>
<td>+/- 7.5 g</td>
<td>50 msec</td>
</tr>
<tr>
<td>1-chute Failure Landing</td>
<td>Axial</td>
<td>+36 / -10 g</td>
<td>50 msec</td>
</tr>
<tr>
<td>1-chute Failure Landing</td>
<td>Lateral</td>
<td>+/- 18 g</td>
<td>50 msec</td>
</tr>
<tr>
<td>Escape Event</td>
<td>Axial</td>
<td>+30 / -18 g</td>
<td>50 msec</td>
</tr>
<tr>
<td>Escape Event</td>
<td>Lateral</td>
<td>+/- 15 g</td>
<td>50 msec</td>
</tr>
</tbody>
</table>

4.2 Vibration

To promote mission success for the experiment, the experiment should meet its performance and functionality requirements in the expected vibration environment for a nominal mission. Performance and functionality of flight hardware in an induced vibration environment is typically verified by acceptance test at the levels shown in Table 9 for 1 minute in each of 3 axes.

If researchers wish to follow industry standards for vibration testing their payload, Blue Origin suggests performing qualification testing for at least one minute (and, if more than two flights are planned, for 30 seconds per planned flight) at 3 dB above the levels in Table 9. Qualification testing should be undertaken on a separate, identical piece of hardware, with lower-level acceptance testing on the flight hardware. While qualification vibe testing is not a mission requirement for the payloads, it is good engineering practice to establish some level of performance margin like this.
Table 9: Suggested Random Vibration Spectrum for Acceptance Testing (MIL-STD-1540E)

<table>
<thead>
<tr>
<th>Freq [Hz]</th>
<th>ASD [g²/Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.0053</td>
</tr>
<tr>
<td>150</td>
<td>0.04</td>
</tr>
<tr>
<td>800</td>
<td>0.04</td>
</tr>
<tr>
<td>2000</td>
<td>0.0064</td>
</tr>
<tr>
<td><strong>Grms (0 dB)</strong></td>
<td><strong>6.94</strong></td>
</tr>
</tbody>
</table>

During quiet flight between RCS firings, accelerations in the coast phase typically average at or below 5 milli-g’s (0.005 G). Most of the power in that vibration environment has been observed above 100 Hz. Payloads with sensitivity to high frequency vibration should consider passive 50 Hz isolators, appropriately tuned to the mass of the hardware, or an active isolation platform.

### 4.3 Air

The pressure inside the CC cabin will nominally be maintained within 10.1 – 14.2 psi (approximately 0.696 – 0.979 bar). The air is ambient West Texas composition. Relative humidity in the cabin during flight as well as during experiment processing in the Payload Facility and VPF is expected to vary from 20-70%. Blue Origin will attempt to maintain cleanliness in the cabin during all operations but cannot guarantee a specific cleanliness level.

The ambient pressure in West Texas is approximately 12.8 psi (0.883 bar). During pre-flight leak checks prior to vehicle rollout, the crew cabin may be pressurized approximately 2 psia (0.138 bar) over the ambient pressure and held at that pressure long enough to verify good containment. Researchers should be aware that this process will add additional pressure differential to any air-tight structures. The actual flight pressure, however, should be closer to ambient pressure, and only in the case of a leak will the flight cabin temperature and pressure reach the quoted lower bounds.

### 4.4 Thermal

The ambient temperature of the CC cabin on REM flights is expected to remain in the range of 50-90°F (approximately 10 – 32.2°C) during pre-flight and flight operations. The ambient temperature inside the Payload Facility and VPF will nominally be maintained at 60-85°F (approximately 15.6–29.4°C).

Note that these temperatures refer to the ambient temperature in the cabin. Temperatures inside Payload Lockers may rise above these values if the experiment dissipates heat.

Note that on REM flights temperatures inside an experiment may rise above 90°F (32.2°C) or fall below 50°F (10°C) after landing in the event of an off-nominal extended time (more than 30 minutes) to recover the CC after landing. The extreme high predicted temperature on REM 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 3 hours.

Depending on the experiment, it is recommended that researchers consider including pressure and temperature sensors within their Payload Locker.
4.5 EMI/EMC

The electromagnetic environment inside the cabin has not yet been determined.

4.6 Noise

Table 10 shows the predicted acoustic levels by one-third octave band and overall level inside the early model prototype CC cabin during nominal New Shepard liftoff. Acoustic levels for experiments in Payload Lockers are assumed to be equivalent to those of the cabin in general. During the remainder of a nominal flight, acoustic levels are expected to be considerably lower.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>CC Cabin dB</th>
<th>CC Cabin dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>124</td>
<td>105</td>
</tr>
<tr>
<td>125</td>
<td>124</td>
<td>108</td>
</tr>
<tr>
<td>160</td>
<td>123</td>
<td>110</td>
</tr>
<tr>
<td>200</td>
<td>123</td>
<td>112</td>
</tr>
<tr>
<td>250</td>
<td>123</td>
<td>115</td>
</tr>
<tr>
<td>315</td>
<td>124</td>
<td>117</td>
</tr>
<tr>
<td>400</td>
<td>125</td>
<td>120</td>
</tr>
<tr>
<td>500</td>
<td>125</td>
<td>122</td>
</tr>
<tr>
<td>630</td>
<td>125</td>
<td>123</td>
</tr>
<tr>
<td>800</td>
<td>123</td>
<td>122</td>
</tr>
<tr>
<td>1000</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>1250</td>
<td>118</td>
<td>118</td>
</tr>
<tr>
<td>1600</td>
<td>115</td>
<td>116</td>
</tr>
<tr>
<td>2000</td>
<td>112</td>
<td>113</td>
</tr>
<tr>
<td>2500</td>
<td>110</td>
<td>111</td>
</tr>
<tr>
<td>3150</td>
<td>108</td>
<td>109</td>
</tr>
<tr>
<td>4000</td>
<td>106</td>
<td>107</td>
</tr>
<tr>
<td>5000</td>
<td>103</td>
<td>104</td>
</tr>
<tr>
<td>6300</td>
<td>101</td>
<td>101</td>
</tr>
<tr>
<td>8000</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td>10000</td>
<td>98</td>
<td>95</td>
</tr>
<tr>
<td>Overall SPL</td>
<td><strong>134.5</strong></td>
<td><strong>130.1</strong></td>
</tr>
</tbody>
</table>
5. REM PAYLOAD INTEGRATION

The following section describes what is expected to be the typical, standard process for integrating experiments into the New Shepard vehicle. Blue Origin may require other procedures, depending on the nature of the experiment and payload.

5.1 Roles and Responsibilities

Each experiment will be assigned an integration manager at the time of flight contract initiation. This person will be the Blue Origin contact for coordinating all aspects of flight planning, integration, and execution, including post-flight inquiries up to 30 days after the last flight in a contract.

5.2 Required Payload Documentation

Each researcher flying a payload on the New Shepard vehicle will complete the following documents and submit them to Blue Origin. Templates for these documents are in the appendix of this User’s Guide.

- Payload Data Package
- Payload Safety Package
- Launch Site Integration Package

Blue Origin will develop and deliver the following documents to the researcher:

- Payload-Specific Interface Control Document (ICD) based on Payload Data Package (this document will then be jointly reviewed)
- Post-Flight Data Report
- Process Feedback Report

5.3 Payload Integration Milestones and Schedule

The typical New Shepard payload integration process involves the milestones and schedule shown in Table 11 below. Such a timeline is anticipated to be typical for the first flight of an experiment of moderate complexity for demonstration payloads and early operations. Payloads with custom interface needs or extensive development remaining at contracting are likely to require additional time.
Table 11: Standard Payload Integration Milestones

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Typical Number of Months from Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Contract Signed</td>
<td>-6.0</td>
</tr>
<tr>
<td>Kickoff Teleconference (or meeting)</td>
<td>-6.0</td>
</tr>
<tr>
<td><strong>Payload Data Package Due</strong></td>
<td><strong>-5.0</strong></td>
</tr>
<tr>
<td>Payload Data Package Review (teleconference)</td>
<td>-4.5</td>
</tr>
<tr>
<td><strong>ICD Draft Delivery by Blue Origin</strong></td>
<td><strong>-4.0</strong></td>
</tr>
<tr>
<td>ICD Sign-Off</td>
<td>-3.5</td>
</tr>
<tr>
<td><strong>Locker and BPC Hardware Delivered from Blue Origin to Customer</strong></td>
<td><strong>-3.0</strong></td>
</tr>
<tr>
<td>Payload Safety Package Due</td>
<td>-3.0</td>
</tr>
<tr>
<td>Payload Safety Review (teleconference)</td>
<td>-2.5</td>
</tr>
<tr>
<td><strong>Launch Site Integration Package Due</strong></td>
<td><strong>-1.0</strong></td>
</tr>
<tr>
<td>Launch Site Integration Review (teleconference)</td>
<td>-0.75</td>
</tr>
<tr>
<td><strong>Payload Delivery to Launch Site</strong></td>
<td><strong>-0.5</strong></td>
</tr>
<tr>
<td>Customer Returns Locker and BPC Hardware to Blue Origin After Final Flight</td>
<td>+0.5</td>
</tr>
<tr>
<td><strong>Post Flight Report</strong></td>
<td><strong>+0.5</strong></td>
</tr>
</tbody>
</table>

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

### 5.4 Payload Processing and Flight Operations

The Payload Facility, described in Section 2.4.2, will be used for pre-flight and post-flight processing of experiments. Teams will receive a visitor briefing on the regulations and protocol of operating and traveling on-site while launch operations are underway. Payload teams will be assigned a Blue Origin liaison who will be responsible for assisting them while at the launch site.

Customer personnel will be permitted access to the Payload Facility typically for up to two days prior to and one day after launch. This time period can be extended as a special service for experiments that have more extensive processing requirements. The Payload Facility will have office furniture, tables, telephones, U.S. standard 110 AC power, first aid kit, fire extinguishers, and Internet access. Some basic hand tools, electronic supplies, and research supplies will be available on site; however, we recommend that teams bring all necessary items with them to
Texas to ensure timely payload readiness. General chemical handling may be supported with advance arrangement with Blue Origin.

Payloads will undergo a Payload Locker Receiving and Checkout, ensuring that the payload’s as-built condition is in accordance with the ICD, that workmanship levels are sufficient to not raise safety concerns, and that benchtop performance is as expected.

Installation of payloads into the CC will typically occur two or three days prior to launch. Blue Origin personnel will take possession of the Payload Lockers and transfer them to the VPF for installation onto the vehicle. These standard payloads will remain unpowered until launch day and will undergo multiple reorientations during horizontal mating of the crew capsule and propulsion module. If special installation procedures are required, researchers may request access for vehicle loading; however, access is limited to US Citizens and permanent resident aliens (also known as ‘Green Card’ holders).

As a non-standard service, payloads requiring late access to power, those unable to withstand reorientation, and those necessitating late integration for science purposes may request that Blue Origin install Payload Lockers after the vehicle has been rotated vertically at the pad on the day of launch, approximately 4 hours ahead of the nominal launch. A Power-On Test will be performed to ensure proper communication between the Payload Locker and the Payload Support Enclosure. After these checks are performed successfully, the hatch will be sealed. For standard integrated payloads, this is expected to be the last access available to experiments until after flight.

Prior to payload integration, any payload found not in flight configuration or not fully operational and requiring significant troubleshooting may be removed from the manifest and reassigned to fly at a later date. In order to properly manage vehicle weight and CG limits, payloads becoming non-responsive during or after integration may be powered off but they will remain onboard for flight.

Customers not able or interested in participating in flight operations at the West Texas Launch Site in person may be able to ship their launch-ready payloads directly to Blue Origin for a flight campaign. In this case, Payload Locker Receiving and Checkout will generally be conducted by phone or video conference. Remote operation of hardware will not be supported in flight. Payload contents will be shipped back to customers within one week after flight.

5.5 Post Landing Operations

Following the mission and CC recovery, the CC will be craned onto a flat-bed truck and transported back to the VPF before the hatch is opened and experiments can be accessed. First post-landing experiment access and data retrieval is expected within no more than 8 hours of landing. The Payload Stacks will be disassembled at this time and Lockers will be returned to the Payload Facility for customer unloading.

If the experiment requires access to their payload in fewer than 8 hours, Blue Origin can provide early access as a non-standard service by opening the hatch and accessing the Payload Stacks soon after reaching the CC landing site, approximately 30 minutes after landing and safing. This challenging field operation is discouraged unless critical for mission science.

Blue Origin personnel will query each Payload Controller and download log files as programmed in the XML script. Customers requiring even tighter control over their files may discuss independent data storage options as a special service. Blue Origin does not currently provide
data on in-cabin environments, such as temperature, humidity, and vibration. Customers requiring such data are encouraged to include the relevant sensors in their payload.

When no further re-flights of the payload are planned, the team may either return the Payload Locker, Benchtop Payload Controller, cables, and cameras at the launch site, or ship them back to Blue Origin within two weeks.

5.6 Payload Test Requirements

Except as noted in Section 6 below, there are no predetermined test requirements for payloads to fly on a New Shepard vehicle unless specifically identified during a Safety Review. The Payload Lockers are designed to contain the experiments in the event experiment hardware comes loose, protecting other experiments and the CC vehicle. However, Blue Origin recommends that researchers verify their payloads can execute the mission when exposed to the environments described in Section 2 to promote mission success. In some cases, testing may be the most effective means to accomplish this verification. Blue Origin can recommend some testing levels based on the experiment design, but these may not be exhaustive. Ultimately it is up to the researcher to investigate and decide what level of testing is appropriate.
6. SAFETY

A Safety Review for each payload will be conducted using data from the Payload Data Package and Payload Safety Package, as described in Section 5.3. The Safety Review will seek to identify all potential hazards and develop mitigations for any hazards deemed unacceptable. A Hazards and Operability (HAZOP) review method may be utilized to perform the Safety Review, involving a safety board consisting of Blue Origin representatives from the research team. Hazards include those that pose potential harm to ground crew as well as those that pose potential harm to other experiments or the New Shepard vehicle.

The purpose of this section is to provide general guidelines to researchers for what hazards Blue Origin seeks to identify and analyze in greater detail during the Safety Review. Following these guidelines will simplify the payload Safety Review. These guidelines are not meant to be exhaustive given the range of potential payloads and accompanying hazards that might be present. Researchers should be proactive in identifying any potential safety concerns to Blue Origin as early in the integration process as possible.

6.1 General Payload Safety Requirements

6.1.1 Explosives Safety

Explosives may be flown in the Payload Stack if they are classified by the U.S. Department of Transportation/United Nations Organization as Class 1.3 or 1.4, have a cumulative explosive weight of less than 250 mg per Payload Locker, are fully contained and pass a Blue Origin safety review. A list of Class 1 explosives is available by clicking on the 'Hazardous Materials Table (HMT)' link at http://www.phmsa.dot.gov/hazmat/library.

6.1.2 Electrical Safety

Generally, high voltage batteries (greater than 32V peak voltage) will not be allowed to fly on the Payload Stack. All batteries present in the payload, regardless of voltage, must be identified by manufacturer and model number in the Payload Safety Package.

Each switch or device used to disconnect the circuit from the power source must be clearly labeled to indicate the circuit’s function unless it is located and arranged so the purpose is evident. All labels and marking must be durable enough to withstand the environment to which they may be exposed.

6.1.3 Electromagnetic/RF Emission Interference

It is critical that payload EMI emissions not interfere with Crew Capsule Avionics and that they not create performance hazards to crew or other payloads in the CC. A limit band is expected at a future date to bound emission power versus frequency.

6.1.4 Flammability

All material used in the payload, 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 (MAPTIS). If any materials are present on the payload that do not exhibit this behavior, a more thorough analysis is required (including fault tree analysis) to characterize the potential hazard.
6.1.5 Pressurized Systems

Any payload systems storing positive pressure (e.g., pressure bottles) or negative pressure (e.g., vacuum chambers) must be identified. Blue Origin will apply limits to the stored energy of pressurized systems such that loss of pressure containment will not result in any deleterious effects outside the Payload Locker containing the pressurized system.

In addition, any pressure vessel containing stored energy in the experiment should be made by a recognized manufacturer and used within its defined safe operating limits. If this is not the case, the researcher must explain the method of verifying the integrity of the pressure vessel prior to flight. This method of verification will be subject to Blue Origin approval and audit.

6.1.6 Hazardous and Liquid Material Containment

As described in Section 3.2.7, all payloads containing liquids or hazardous materials must have a primary and secondary means of containment in the event of a leak. In addition, the Payload Locker will provide a tertiary means of spill containment. The type and quantity of all liquids or hazards must also be disclosed along with Safety Data Sheets (SDS) for further evaluation of potential hazard. Hazardous materials may not be shipped to Blue Origin prior to the completion of the safety evaluation, and all hazardous shipments must be coordinated through the Blue Origin payload integration manager.

6.2 Fault Tolerance

6.2.1 Safety-Critical Fault Tolerance

For potential hazards in the payload that could result in ground crew death or major injury during pre-flight processing or post-flight processing, the payload must be designed to be two-fault safe, i.e., any credible combination of two faults must not result in major injury or death. It is allowable for the Payload Locker itself to serve as a level of fault tolerance. Blue Origin will work with researchers to perform fault tree analysis if such hazards exist. The simplest way to meet fault tolerance requirements is to remove all sources of potential hazard if possible.

Fault tolerance requirements apply to the following types of faults, in any credible combination:

- Hardware faults
- Software faults
- Human error

6.2.2 Mission-Critical Fault Tolerance

For potential hazards in the payload that could result in significant damage to the New Shepard vehicle or other experiments on the vehicle, the payload must be designed to be one-fault safe. Blue Origin will work with researchers to perform failure modes analysis if such hazards exist. All the guidelines pertaining to mitigation of faults described above also apply in this case. The simplest way to meet fault tolerance requirements is to remove all sources of potential hazard if possible.
Appendix A: PAYLOAD DATA PACKAGE QUESTIONNAIRE

The following appendix describes the information Blue Origin requires to evaluate compatibility of proposed experiments with its standard Payload interface as described in this document and prepare a payload-specific ICD. Experiments should provide the requested data to Blue Origin as described in Section 5.2 of the Payload User’s Guide.

Date Submitted: ___________________

<table>
<thead>
<tr>
<th>Name and Position</th>
<th>Institution/Department</th>
<th>Email and Telephone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Principal Investigator (PI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-Investigator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Manager</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Add additional sheets as necessary.)

Are any of the team members above NOT a U.S. Citizen or Permanent Resident Alien? If so, please indicate citizenship.

GENERAL INFORMATION

1. Provide an updated abstract of the experiment, describing scientific objectives (not to exceed one page).
2. Provide updated schematics, drawings, 3-D models, and/or photographs of the experiment to help improve Blue Origin’s general understanding of the experiment function. An electrical circuit diagram should be provided.

MECHANICAL INTERFACES

(Reference Payload User’s Guide Section 3.2)

3. List the number of Single and Double Payload Lockers requested for the experiment. For each Payload Locker requested, provide an estimated payload mass to be installed.
within. Note that the payload weight limit for each Single Payload Locker is 25.0 pounds (approximately 11.34 kilograms) and for each Double Payload Locker is 50.0 pounds (approximately 22.68 kilograms). If the payload mass is not yet determined, please provide an expected range. Present this information in the form of a table that provides a unique alphabetical identifier for each Locker. Include the mass of any Blue Origin provided cameras (see Section 3.3.3 of the Payload User’s Guide for a weight estimate). For example:

<table>
<thead>
<tr>
<th>Payload Identifier</th>
<th>Payload Size</th>
<th>Payload Weight (lbs)</th>
<th>Payload Weight Margin (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Single</td>
<td>18.3</td>
<td>+/- 2 lbs</td>
</tr>
<tr>
<td>B</td>
<td>Single</td>
<td>21.5</td>
<td>+/- 2 lbs</td>
</tr>
<tr>
<td>C</td>
<td>Double</td>
<td>37.9</td>
<td>+/- 5 lbs</td>
</tr>
</tbody>
</table>

4. If applicable, describe a requested geometric arrangement of stacked Payload Lockers within a Payload Stack and explain the rationale. If there is no preference, state so.

5. Describe substantial sources of heat (i.e., >50 W) from each Payload Locker that arise from sources other than use of power services provided by Blue Origin. For example, these sources of heat may include power use by batteries that are internal to the experiment, or exothermic chemical reactions in the experiment. For each of these heat sources, identify the Locker containing the output and provide the total energy output (W-hr) and peak heating rate (W) during the mission, including terminal countdown and post-launch recovery phases.

6. If the experiment is expected to generate significant acoustic noise (greater than 70 dB), describe by Locker Identifier the source, peak intensity (in dB), and expected duration. If no significant acoustic source exists, please state that explicitly.

7. Describe in detail any requested deviations from the standard experiment mechanical interface as described in Section 3.2 not previously described.

8. Detail any ways in which the experiment might affect adjoining Lockers (vibration, shock, thermal, electromagnetic interference, etc.).

9. Describe briefly how the experiment will be mounted within the Payload Locker. For example, will a separate attachment plate be used, or will components be mounted individually to the Locker?

**ELECTRICAL INTERFACES**

(Reference Payload User’s Guide Section 3.3)

10. Each Payload Locker contains two connectors that can carry the signals described in Table 4 of the Payload User’s Guide to and from a Flight Payload Controller, plus up to four 26 +/- 4V power services. Provide a table with the following information that lists the requested signal allocation and requested power usage of each Payload Locker. Data and power interfaces for Blue-provided cameras need not be included.
11. List the requested data sampling rate for each of the signals.

12. For each Locker that a Flight Payload Controller will be recording data from, describe:
   a. The planned peak data rate to be written to the SD card in Mbps (Megabits per second), not MBps (Megabytes per second). Do not include the data rate of any video cameras provided by Blue Origin, which will have their own separate connection and microSD card.
   b. The total expected usage of drive memory per mission (in GB). Do not include the memory usage of any video cameras provided by Blue Origin, which will have their own separate connection and microSD card.

13. For each requested 26 +/- 4V power service provided by Blue Origin, provide the total W-hr usage and peak wattage a) during flight, b) pre-flight, and c) post-flight, for each Locker.

14. Indicate whether the researcher requests Blue Origin provide modified GoPro video cameras (see Section 3.3.3 of the Payload User’s Guide), and if so, the number requested by Locker Identifier (up to 2 cameras per Locker).

15. Does the payload team request that Blue Origin provide camera lenses, and if known, which ones? Otherwise, is a lens selection guide requested?

16. Describe briefly the experiment's grounding provisions.

17. Describe in detail any requested deviations from the standard experiment electrical interface as described in Section 3.2.7 of the Payload User’s Guide not previously described.

**EXPERIMENT ENVIRONMENTS**
(Reference Payload User’s Guide Section 2.6 and Section 4)

18. Describe the minimum required continuous microgravity environment (in G’s) and duration (in seconds) to accomplish mission objectives. Is this compatible with the expected microgravity environment as described in Sections 2.6 and 2.7?

19. Does the researcher plan to design to the acceleration environments for nominal, 1-chute failure, or other case described in Table 8? What factors of safety will be applied? What is the method of verification (analysis or test)? Given the possibility that the experiment may be damaged or destroyed by the expected launch and landing loads, please describe the ways in which the design ensures that the experiment will fail safely.

20. Does the researcher plan to perform vibration testing on the experiment, and if so, for what duration and margin above the predicted levels described in Payload User’s Guide?
21. Does the researcher plan to perform acoustic testing on the experiment, and if so, to the level (dB) as described in Payload User's Guide Table 10?

22. Does the researcher plan to perform shock landing load testing on the experiment?

23. Are there any known issues with the experiment functioning when subjected to any environments described in Section 4 of the Payload User's Guide?

SAFETY

24. As described in Payload User's Guide Section 6, a detailed safety review will be conducted for each experiment, and safety related data will be requested in the Payload Safety Package. However, to provide early identification of potential issues, please answer the following questions:

   a. Will the experiment incorporate any materials classified as a U.S. Department of Transportation/United Nations Organization Class 1 explosive hazard, either within the Payload Locker or used during pre-flight and post-flight processing at the launch site? If so, list the type, quantity, mass, and stored energy of all materials by Locker Identifier if known. How will these explosives be contained? If no explosives will be included, please state that explicitly.

   b. Will the experiment incorporate any high voltage batteries (peak voltage>32 V)? If so, list the voltage and energy capacity of all high voltage batteries by Locker Identifier. Include make and model number of all high voltage batteries if known. If no high-voltage batteries are to be included, please state that explicitly.

   c. Will the experiment incorporate any materials classified as flammable as defined in Payload User's Guide Section 6.1.4? If so, list all the materials and specify estimated mass of each material by Locker Identifier. If no flammable material is to be included, please state that explicitly.

   d. Will the experiment store gas at a pressure other than ambient pressure? If so, list the type of stored gas, the expected operating pressure (in psia), and volume by Locker Identifier. If no pressurized system is planned, please state that explicitly.

   e. Does the payload contain anything that is EMI susceptible or is an RF oscillator (e.g., Wi-Fi)? If so, provide details (e.g. power spectrum versus frequency, etc.).

   f. Does the payload contain lasers? If so, provide details (e.g. class level, beam modifications, etc.).

   g. Does the payload produce loud noises (>70dB) or contain a significant heat source (>30W)? If so, provide details.

   h. If the experiment will contain liquids and/or hazardous materials, then fill out the information below. If none are included, please state that explicitly.

      i. Describe the types of liquids and/or hazardous materials planned including their total mass and volume (liquids only). Include a separate list for each Payload Locker.

      ii. Provide Safety Data Sheets for all hazardous materials that will be contained in the experiment.
iii. Describe the method of primary and secondary containment of the liquid in the event of a spill.

EXPERIMENT OPERATIONS

25. As described in Payload User’s Guide Section 5.4, Blue Origin expects the typical researcher will request use of the Payload Facility three days prior to payload installation and one day post-flight. What access is requested for this payload?

26. How many experiment team personnel will be present at the launch site for the test? Identify the planned team by name and for each person indicate the citizenship and residency status of each person.

27. Does the experiment require any special provisions for cleanliness in the Payload Facility beyond what is possible for the team itself to provide?

28. Does the experiment require any special provisions for ventilation in the Payload Facility beyond what is possible for the team itself to provide?

29. Does the experiment require any special provisions for humidity or temperature in the Payload Facility beyond what is possible for the team itself to provide?

30. In addition to the available services and equipment in the Payload Facility described in Payload User’s Guide Section 2.3, list:
   a. Any special equipment the researcher requests Blue Origin provide.
   b. Any special services the researcher requests Blue Origin provide.
   c. The requested area (preferably in square feet) of floor space for experiment processing.
   d. Any additional communication services required over and above one VOIP phone line and four wireless Internet connections.
   e. Requested provisions for storage of experiments before and after a launch, including the volume of storage requested and if any climate control is requested.

31. Multiple researchers from different organizations may be making use of the Payload Facility simultaneously before and after launch. Indicate whether there are any special concerns that would preclude performing pre-flight or post-flight experiment processing in the same room as other research teams (e.g., safety, security, etc.).

32. Provide a conceptual timeline for each Payload Locker during pre-flight, flight, and post-flight, using the following example as a guide. As described in Payload User’s Guide Section 3.4, Blue Origin will provide researchers with the REMConfig software tool, for researchers to program to control the experiment by building a list of events, where each event encapsulates all the settings for which port/power services to use, how to use it, what to do with data that is read/written, when to start using it, and when to stop using. The timeline is requested to give Blue Origin an idea of whether the existing REMConfig configurable settings can accommodate the experiment. An example timeline is as follows:
Locker Identifier: A

<table>
<thead>
<tr>
<th>Event ID</th>
<th>Event Time or Event Condition</th>
<th>Triggered Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sensed acceleration (&lt;10^{-2}) g for (&gt;5) seconds</td>
<td>Start recording data on all channels</td>
</tr>
<tr>
<td>2</td>
<td>Event #1 +5 second</td>
<td>Enable all 26 +/- 4V power services</td>
</tr>
<tr>
<td>3</td>
<td>Event #2 + 90 seconds</td>
<td>Disable all 26 +/- 4V power services</td>
</tr>
<tr>
<td>4</td>
<td>Event #3 + 2 seconds</td>
<td>Stop recording data on all channels</td>
</tr>
</tbody>
</table>

Also include a timeline of events not directly controlled by the REMConfig software, such as an automated sequence that is triggered once a power service is activated.
Appendix B: PAYLOAD SAFETY PACKAGE
QUESTIONNAIRE

Safety is of highest priority to Blue Origin. The following appendix describes the minimum information Blue Origin requires to evaluate potential hazards to personnel and equipment from both the payload and its Ground Support Equipment (GSE). Hazard assessment will address all phases from the time a payload is delivered to Blue Origin until it is returned to the research team after flight. This includes ground shipping receipt and storage, pre-flight preparation and testing transport, installation in the CC, pre-launch checks, flight, de-integration from the CC, and shipment back to the payload team. Given the range of potential hazards, researchers should be proactive in describing any omitted hazards that were not addressed in the following questionnaire.

The accumulated safety information will be used in conjunction with the Payload Data Package to perform a detailed Payload Safety Review of the experiment prior to flight, as described in Payload User’s Guide Section 5.3 and Payload User’s Guide Section 6. Experiments should provide the requested data to Blue Origin as described in Section 5.2.

If more than one Payload Locker will be used for an experiment, then individual hazards must be called out by their Locker Identifier. The same Locker Identifiers should be used as referenced in the Payload Locker Identifier. The same Locker Identifiers should be used as referenced in the Payload Data Package submittal.

DOCUMENTS

Please provide the following documents (attached or submitted electronically):

- Final electrical schematic/wiring diagram
- Final mechanical schematic (CAD mechanical drawing or equivalent)
- SDS (Safety Data Sheets) for all material that pose a potential safety risk
- Photo views of the assembled experiment or 3-D model and photos of any safety-related items (e.g., containment vessels, fragile items, etc.). Please add any labels or call-outs you think would be helpful to our review.
- Bill Of Materials (BOM) for the payload

ELECTRICAL SAFETY

BATTERIES

1. Will the experiment incorporate any batteries (other than batteries provided by Blue Origin), whether for flight or for ground operations? If so, include the make and model number of all batteries, along with their maximum expected voltage level, energy capacity, chemistry (e.g., lead-acid, lithium, etc.) and Locker Identifier.

2. If batteries (other than batteries provided by Blue Origin) are included, describe how these batteries will be charged in the Payload Facility or discharged post-flight. Will this step be conducted by launch site personnel or by the research team?
GROUNDING PROVISIONS

3. How will electrical components be grounded during both ground operations and flight? Describe how grounding wires and power cords will be restrained for anticipated g-loading. Will grounding connections be visually obvious to an operator?

4. How will structural components be connected to ground (electrically bonded)?

ELECTRICAL HAZARD MITIGATION

5. How will electrical loads be current-limited or over-current protected (e.g. fusing, circuit breakers, etc.)?

6. What is the gauge and intended peak current draw across all power cables?

7. Describe any precautions required to isolate electrical connectors from possible fluid conductors.

8. In the event of electrical power loss, describe how the experiment fails to a safe configuration. For example, does a vent valve open automatically in event of power failure, thereby preventing possible pressure build-up of a pressurized system?

EXPOSED LEADS, CONTACTS, ETC.

9. Identify any known exposed/bare contacts or locations where abrasion could expose bare contacts.

10. How will live parts of electric equipment, operating at 50V or more, be guarded against accidental contact? If no equipment operates above this level, please state that explicitly.

ELECTROMAGNETIC/RF EMISSION LEVELS

11. Provide a published data sheet on any hardware that intentionally emits radio-frequency emission, along with their Locker Identifier. Of special importance are any wireless communication devices intended to be flown (e.g., Bluetooth, Wi-Fi, cell modem, etc.).

12. For any known radio-frequency oscillators, complete the following table:

<table>
<thead>
<tr>
<th>Oscillator Description</th>
<th>Supplier and Part Number</th>
<th>Frequency (Hz)</th>
<th>Power Level (dBμV/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. Define any EMI (Electromagnetic Interference) susceptibility requirements that the experiment may have.

14. If applicable, provide the gauss rating and Locker Identifier of any magnets.
HAZARDOUS MATERIAL SAFETY

MATERIAL IDENTIFICATION (SDS) RISKS AND CONTROL MEASURES

15. Will your experiment contain hazardous materials of any type?

16. If applicable, describe how hazardous chemicals in or associated with your experiment will be labeled. Describe any special storage or disposal precautions and procedures anticipated on site. What is the expected maximum quantity of each chemical (a) to be stored at the launch site and (b) to be flown in the experiment?

17. Describe any special transportation measures for each hazardous material.

18. Identify any materials brought to the launch site that have outgassing properties which could pose a health risk at ambient room or anticipated flight temperatures. List the material by mass and by Locker Identifier or ground support equipment function. What temperature is the experiment expected to reach under nominal flight conditions?

19. Identify the type, mass, and Locker Identifier of any cryogens to be used in the experiment. Describe their fill/drain and containment methods.

20. Identify the type, quantity, and Locker Identifier of any radioactive materials brought to the launch site. What is the proposed plan to limit exposure of these materials to personnel?

21. Are any of the materials brought to the launch site considered carcinogenic or toxic? If so, describe the material and note its Locker Identifier or ground support equipment function.

22. In the case of an accidental release, does the affected person require immediate access to an eye wash, shower, or other substances?

23. If containment of the chemical is compromised, what would be the effect on the equipment internal to the Payload Locker along with the Locker itself?

24. If applicable, list any special clean-up chemicals or materials that need to be on-site in case a spill occurs.

25. Explain any preparation steps that need to be conducted in a specialized facility (e.g., clean room, chemical lab, fume hood, etc.).

FIRE SAFETY

FLAMMABLE MATERIALS ASSESSMENT

26. Will the experiment incorporate any materials classified as flammable as defined in Payload User’s Guide Section 6.1.4? If so, list all the materials and specify estimated mass of each material by Locker Identifier.

27. When burned or heated, does any flammable material become a significant source of smoke or toxic fumes? Describe.
IDENTIFICATION OF IGNITION SOURCES

28. Detail what parts of the payload or its ground support equipment may inadvertently act as an ignition source.

29. List any materials with an auto-ignition temperature less than 200°F and any ignition sources that are in close proximity to heating sources above 50W.

MECHANICAL SAFETY

FAILS TO SAFE CONFIGURATION

30. Describe how, in the event of electrical power loss, the experiment fails to a safe configuration. For example, does a vent valve open automatically in event of power failure, thereby preventing possible pressure build-up of a pressurized system?

ACOUSTIC SOURCES

31. If the experiment or its ground support equipment is expected to generate significant acoustic noise (greater than 70 dB), describe by Locker Identifier the source, peak intensity (in dB), and expected duration. If no significant acoustic sources exist, please state that explicitly.

HEAT SOURCES

32. Do any potentially exposed surfaces inside the Payload Locker reach an inadvertent touch temperature greater than 122°F (50°C)? Describe. Are there any backup measures to prevent heating sources from exceeding safe limits?

STRUCTURAL ASSESSMENT PLAN

33. List the mechanical Factor of Safety and Margins of Safety for each major flight hardware structural component as a whole (include Locker Identifier). The analyses should reference the peak design loads listed in Payload User’s Guide Table 8 for a nominal mission. Refer to the Design Guide for more information on performing this analysis. If analysis is NOT to be undertaken, describe how testing will demonstrate that all components within the Payload Locker can withstand peak design loads with an ultimate safety factor of 2.0.

34. Detail how mounting attachments and containment systems have been verified to structurally withstand flight vibration, g-loads, and shock. Refer to Payload User’s Guide Section 4 for a detailed breakdown of expected Payload experiment environments.

FLUID CONTAINMENT

35. Describe the types of payload and ground support equipment liquids or gases (other than air) planned, including their composition, total volume, and mass for each type. Include a separate list identifying the liquid stored in each Payload Locker, referencing the Locker Identifiers.

36. Describe the method of primary (in contact with fluid) and secondary containment.
PARTICLE CONTAINMENT

37. Explain how potential dust, dirt, splinters, shavings, and other particulates will be stored securely inside the payload.

HANDLING ISSUES

38. Describe the mounting and fragment containment provisions for fragile items that can easily shatter (e.g., glass, cathode ray tubes, gauges, windows).

LASER SAFETY

39. What class of lasers or laser systems, if any, will be used in the payload or ground support equipment brought to the launch site? Reference lasers by their Locker Identifier. If none, please state that explicitly.

40. If lasers are used, describe safeguards that minimize the risk of eye damage from the lasers. For example, does the laser housing have an interlock switch to prevent inadvertent operation of the laser when the enclosure is accessed? Is it physically difficult to orient one's eye in-line with the laser beam?

EXPLOSIVE SAFETY

CHEMICAL

41. Will the payload incorporate any materials classified as a U.S. Department of Transportation/United Nations Organization Class 1 explosive hazard, either within the Payload Locker or used during pre-flight and post-flight processing at the launch site? If so, list the type and quantity of all materials by Locker Identifier if known. Refer to Section 6.1.1 for a linked list of US DOT/UNO Class 1 explosives.

42. At the expected payload pressures, do any materials within the Payload Locker have a flash point less than 200°F? If so, detail the active thermal and pressure controls which are required to keep the chemical from entering such a condition.

PRESSURIZED SYSTEMS

43. Will the payload store gas or liquid at a pressure other than ambient pressure? If so, list the type of stored material, the expected operating pressure (in psia), and pressurized volume by Locker Identifier. Ensure that mechanical safety calculations (Factors of Safety) were performed for the combined loading from both landing and atmospheric pressure.

44. Describe how the pressurized state will be achieved pre-flight. For example, will a chamber be pumped to vacuum prior to insertion into the Payload Locker or instead pumped down during the countdown or in flight?

45. Describe the method of and plans for pressure relief for the pressurized containers. Details should include whether the relief is manual or autonomous, the location of the vent ports relative to the operator, the circumstances under which pressure is reduced, and the out-of-range percentage at which pressure relief is required.
46. List the type, range, and accuracy of any sensors that will be used to monitor the state of the pressure vessel. Will the pressure vessel include a visual gauge in addition to electronic sensors?

OPERATION SAFETY

PERSONAL PROTECTIVE EQUIPMENT PLAN

47. What special precautions (Personal Protective Equipment or PPE, awareness of content hazards, etc.) will be needed for each of the following mission phases? Examples of available PPE include, but are not limited to, various types of gloves (chemical, high-temp, cut-resistant), safety glasses, respirators (dust mask, chemical half-face, chemical full-face), face-shield, chemical resistant boots and aprons, hearing protection, etc. Please explain any discrepancies between the requested PPE and the SDS-recommended PPE.

a. Initial handling/receiving at the launch site
b. Ground preparation/test
c. Transport to the CC
d. Installation in the CC
e. Pre-launch
f. Flight
g. Post-flight inspection in the CC
h. De-integration from the CC
i. Transport back to the Payload Facility
j. Disposal of materials
k. Return shipping

SAFETY TRAINING/AWARENESS NEEDS FOR CC GROUND PERSONNEL

48. Describe any safety training or general directions that need to be given to Blue Origin ground personnel.

49. Will a member of the research team or Blue Origin staff need to be present at the landing site in order to safe the system following touch-down (e.g., de-pressurizing or re-pressurizing the pressure vessel) or prior to de-integration from the CC?

50. In the scenario that a flight is scrubbed for the day, will a member of the research team need to safe the system at any time upon rollback to the VPF?
Appendix C: LAUNCH SITE INTEGRATION PACKAGE TEMPLATE

This section contains a questionnaire for gathering necessary information to perform a Launch Site Integration Review of the payload prior to flight, as described in Section 5.3. Questions relate to shipment itineraries, requested services, and anticipated schedule. Some questions are repeated from previous questionnaires to ensure that nothing has changed during payload development.

Review the Launch Site Visitor’s Guide prior to filling out this document. Please provide a response in turn after each question. Provide the anticipated date when an answer will be determined if it is currently unknown.

PERSONNEL and EQUIPMENT

1. Fill out the following table for all individuals from the payload team who may be at the launch site. If integrating into the Crew Capsule at standard load-in on L-3 day, and your team needs to be present for that operation, identify which two personnel will serve in that role. The list should also identify any backup or contingency personnel who could be pressed into service.

<table>
<thead>
<tr>
<th>Full Name &amp; Position</th>
<th>Institution and Mailing Address</th>
<th>Cell Phone</th>
<th>E-mail</th>
<th>Citizenship</th>
<th>Days On Site</th>
<th>Integration Rep? (Yes/No/Backup)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

2. Do any personnel have special needs (e.g., handicap access, vegetarian diet, etc.)?

3. Complete an anticipated packing list of all equipment to be shipped to the launch site. A form is provided at the end of this document as well as the Launch Site Visitor’s Guide.

4. Provide a best-estimate for the basic infrastructure requested inside the Payload Facility.

<table>
<thead>
<tr>
<th>Floor Space (sq. feet)</th>
<th>Number of 6 foot x 2.5 foot Tables</th>
<th>Number of Chairs</th>
<th>Number of Power Outlets</th>
<th>Air Temp Range (deg F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Provide a list of any requested equipment or services that are not already listed as standard in the Launch Site Visitor’s Guide.
SCHEDULE

6. Outline your payload’s schedule of major activities at the launch site in the following table. Provide a day-by-day list of major activities (e.g. shipment arrival at the launch site, team arrival, specific payload checkout tests prior to installation in the Crew Capsule, tests once integrated, payload recovery tasks, payload return shipments, etc.). Detail any tasks that require assistance from Blue Origin personnel. Please be specific and comprehensive.

<table>
<thead>
<tr>
<th>Day</th>
<th>Activities</th>
<th>Personnel Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-1</td>
<td>Payload Locker and equipment arrives at launch site</td>
<td>N/A</td>
</tr>
<tr>
<td>L-0</td>
<td>Payload Locker and equipment arrives at launch site</td>
<td>N/A</td>
</tr>
<tr>
<td>L-0</td>
<td>(Early Pad Install and Launch)</td>
<td>N/A</td>
</tr>
<tr>
<td>L-1</td>
<td>Payload Locker and equipment arrives at launch site</td>
<td>N/A</td>
</tr>
<tr>
<td>L-2</td>
<td>Payload Locker and equipment arrives at launch site</td>
<td>N/A</td>
</tr>
<tr>
<td>L-3</td>
<td>Payload Locker and equipment arrives at launch site</td>
<td>N/A</td>
</tr>
<tr>
<td>L-4</td>
<td>Payload Locker and equipment arrives at launch site</td>
<td>N/A</td>
</tr>
<tr>
<td>L-5</td>
<td>Payload Locker and equipment arrives at launch site</td>
<td>N/A</td>
</tr>
</tbody>
</table>

7. Describe all payload tests to be performed while checking the Payload Controller-Locker interface connections in the Payload Facility.

8. Describe all payload checkouts to be performed in the Crew Capsule at the time of integration. How much time are these checkouts expected to individually take?

9. Describe all payload activities required while the payload is sealed in the crew cabin during ground preparations through the end of the launch count.

10. Describe all payload activities required while the payload is in the crew cabin during flight.

11. Describe all payload activities required after landing through payload removal from the crew cabin.

12. Approximately how soon after the payload is returned can an assessment be made on whether the experiment gathered good data?
TESTING and SAFETY

13. Describe each hazardous operation planned to be conducted at the launch site, if any.

14. Have there been any changes in the quantity, required Personal Protective Equipment PPE, storage and disposal procedures and supplies, hazard types, or hazard levels of substances at the launch site? If so, submit a revised Payload Safety Package with these revisions clearly identified.

15. Have there been any changes to the safety training or general directions given to Blue Origin ground personnel regarding Payload Locker handling, installation, and removal, whether pre- or post-flight? If so, submit a revised Payload Safety Package with these revisions clearly identified.

16. Will any payload checkout, maintenance, or preparation activities require other teams to leave the Payload Facility or interrupt their activities?

17. In the table below, summarize any environmental/attitude constraints on the Crew Capsule once your experiment is installed. If not applicable, write ‘None.’

<table>
<thead>
<tr>
<th>Constraint Category</th>
<th>Constraint Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabin Temperature</td>
<td></td>
</tr>
<tr>
<td>Cabin Humidity</td>
<td></td>
</tr>
<tr>
<td>Cabin Pressure</td>
<td></td>
</tr>
<tr>
<td>Cabin Attitude on Ground</td>
<td></td>
</tr>
<tr>
<td>Cabin Attitude in Flight</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

OTHER

18. Is there any information not included in the Launch Site Visitor’s Guide that you request?

19. The flight manifest and location assignment of the payloads inside the CC will be discussed during the LSIP review. Have there been any changes to your placement preferences listed in Section 4.1 of the Interface Control Document (ICD)? If so, describe.

20. Are there any special requests for privacy and/or security of the payload and equipment while at the launch site?
PAYLOAD PACKING LIST

Complete one form per box or shipping crate.                      Form ____ of ____
                                                                                        (e.g., 1 of 3)

1. Payload Team: _____________________

2. Locker Identifier(s): ____________________

3. Box Weight (lbs): ____________________

4. Box Dimensions (in): _________________

5. Hazardous Materials (e.g. high voltage equipment, highly flammable materials, and stored energy sources including batteries, chemicals, and pyros):

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

6. Safety Data Sheets (SDS) Included in Box (Y/N): __________

7. Open Immediately Upon Receipt? (Y/N): __________

   6a. If so, provide specific directions on how the contents should be handled (e.g. PPE, no stacking, no tipping, etc.) and stored. Attach SDS to this form.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

   6b. Otherwise, describe where and how the box should be stored (e.g., Store at room temp in Payload Staging Facility, store flat, etc.):

________________________________________________________________________