GALACTIC

PAYLOAD USER'S GUIDE

VIRGIN GALACTIC IS EXCITED TO PARTNER WITH YOU FOR AN OUT OF THIS WORLD MISSION!

At Virgin Galactic we believe in the power of curiosity. It is the driving force that compels us to wonder, to constantly ask questions, and to relentlessly seek the answers. We cannot wait to see how your research team uses curiosity to drive your experiments onboard our suborbital space lab!

This document describes the main ways to conduct research using our Spaceship, our autonomous payloads and human-tended research offerings. It includes dimensions for middeck lockers, power availability, and other safety requirements. Please use this document as a guide as you design your experiment and seek out humanity's greatest mysteries!

WE ARE A GO FOR LAUNCH!

Due to practical and regulatory restrictions, some of the detailed technical data will be provided at a later time within other documents. These additional documents will be provided in compliance with the Arms Export Control Act (Title 22, U.S.C. Sec 2751 et seq.) and the Export Administration Act of 1979, as amended (Title 50, U.S.C., App. 2401, et seq.).

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OUR MISSION: TAKE YOUR PAYLOADS TO SPACE SAFELY, AFFORDABLY AND OFTEN.

Virgin Galactic is an aerospace and space travel company, pioneering human spaceflight for private individuals and researchers with its advanced air and space vehicles. We developed a spaceflight system designed to connect the world to the love, wonder, and awe created by space travel and to offer customers a transformative experience. You can find more information at https://www.virgingalactic.com/.

Our spaceflight system consists of Mothership, the high-altitude carrier aircraft, and Spaceship, an air-launched spaceplane providing an extended period of microgravity in suborbital space. These vehicles have been designed to set new standards for spaceflight frequency, safety, flexibility, and cost.

With multiple researchers and dozens of payloads flown to space, Virgin Galactic has successfully demonstrated the ability to use its vehicles as suborbital space labs for governments, researchers, and commercial industry. Virgin Galactic will be conducting regular flight to space, providing multiple opportunities to fly research throughout the year. Within our Spaceship cabin, researchers are able to fly autonomous payloads or fly with their experiments to conduct human-tended research in space. Our goal is to fly you to space within six to twelve months of contract signature and can work with even shorter timelines. We seek to make space accessible to everyone—whether for conducting world-class research, or for the spaceflight experience of a lifetime.

SUMMARY OF KEY PERFORMANCE ATTRIBUTES

Mothership and Spaceship are unique vehicles with unmatched mission capabilities. They will be used for scientific experiments, educational programs and research programs that we have only begun to imagine. We look forward to hearing your ideas on how you plan to use our spaceflight system's capabilities.

Our system's key services and advantages[1] include:

- Suborbital spaceflight payload capacity of **1,000+ lbs**. (450+ kg) onboard Spaceship.
- Matching pressurized usable payload volumes of **500 cubic feet** (14 m^3) including over 50 cubic feet (1.4 m^3) of rack space with shirt-sleeve environments onboard Spaceship.
- Spaceship cabin seating up to six researchers or an equivalent amount of payload racks using a **flexible payload mounting system**
- Exposure to **3 minutes** of a reduced gravity environment
- **Frequent and responsive flight access**, allowing for maximum flexibility and series measurements taken on several flights in rapid succession
- Quick recovery of payloads, with **pre-flight and post-flight access** within minutes of launch and return for time-sensitive missions
- Flight opportunities for both **autonomous and human-tended research**
- Flight from a state-of-the-art Spaceport, where favorable weather conditions and secure access to airspace allow a **maximum number of flight days**
- **Gentler g-loading** than sounding rockets

[1] The performance information described in this Payload User's Guide is based on previous flights, simulation, and modeling. Actual performance may vary, and Virgin Galactic does not guarantee performance and makes no representations or warranties as to the accuracy of such information.

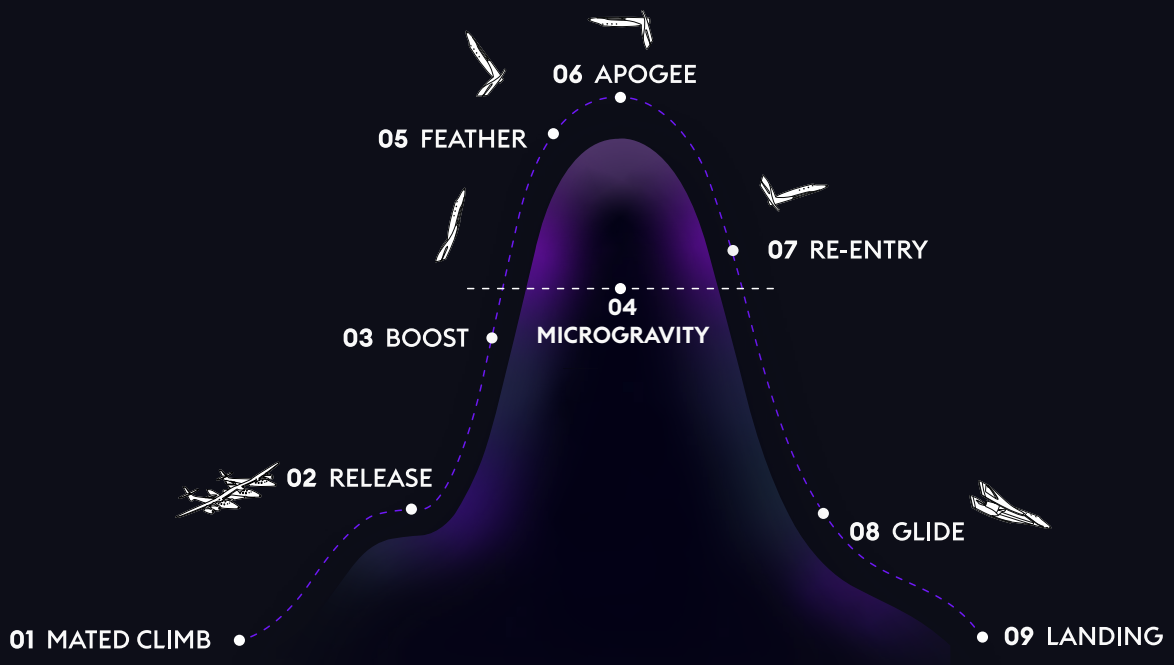


Figure 1: Typical Flight Profile

FLIGHT PROFILE

Virgin Galactic's spaceflight system is designed to routinely and safely carry two pilots and up to six passengers, or the equivalent mass in payloads, on a suborbital flight to space altitudes. A typical flight to space onboard Spaceship takes about 60-75 minutes from takeoff to landing. The standard flight profile is shown above in Figure 1.

For a standard flight, the mated pair of the Mothership and Spaceship takeoff from Virgin Galactic's hangar at Spaceport America in New Mexico. Under the power of Mothership's four jet engines, the two mated vehicles take about 60 minutes to climb to an altitude of approximately 45,000 feet. After completing appropriate vehicle checks, Spaceship is released from Mothership, free falling for a few seconds before igniting its rocket motor. Spaceship boosts upward under the power of the rocket motor for approximately 60 seconds, eventually reaching its peak apogee of at least 80 km. People and payloads in the cabin experience 3 minutes in a high quality microgravity environment before beginning their return to Earth.

While coasting in space, Spaceship 'feathers' its wings and tail booms to achieve a safe reentry. In Spaceship's feathered configuration, the entire tail structure rotates upward about 60 degrees, creating high drag as spaceship reenters the atmosphere. This method allows re-entry into the atmosphere in a manner that minimizes the stress on the vehicle and manageable heating profiles. After reentry, Spaceship resumes its original configuration at approximately 50,000 feet and glides safely back to a smooth, runway landing at its spaceport.

RACK-MOUNTED PAYLOAD SPECIFICATIONS

Spaceship's cabin has up to six seats and each seat can be replaced with a rack of payloads. This enables researchers to fly autonomous rack-mounted payloads or conduct human-tended research by interacting with their rack-mounted payloads during flight.

For rack-mounted payloads, our **flexible cabin** can accommodate a variety of configurations based on the total mass and volume a specific experiment requires. A payload locker's size is determined based on a combination of the maximum volume, mass, and power. A payload rack, as shown in Figure 4, can accommodate up to four single middeck locker equivalents (MLEs). Virgin Galactic has single middeck lockers available for your use. You may also provide your own single middeck locker equivalent, which fits in the same physical parameters. For double, triple, and quad lockers, you need to provide your own locker. We're happy to explore custom locker shapes and weights that exceed these limits as non-standard services. Table 1 outlines the rack-mounted payload locker specifications.

The single middeck locker's dimensions are 18.50" W x 11.25" H x 21.50" D. Virgin Galactic uses Space Shuttle Middeck Lockers as single lockers. It weighs approximately 14lbs, and the total payload weight may not exceed 50lbs. Figure 2 shows the dimensions for our single middeck locker and Figure 3 shows our lockers in use. Figure 5 shows how your locker will be installed with the other research customers on your flight.

Table 1: Rack-mounted payload lockers)

LOCKER SIZE	DIMENSIONS	VOLUME (MLEs)	MAX WEIGHT	MAX POWER
SINGLE	18.50"W x 12.25"H x 21.50"D	1	50 LBS	50 W
DOUBLE	18.50"W x 23.00"H x 21.50"D	2	100 LBS	100 W
TRIPLE	18.50"W x 34.75"H x 21.50"D	3	150 LBS	150 W
QUAD	18.50"W x 46.50"H x 21.50"D	4	200 LBS	200 W

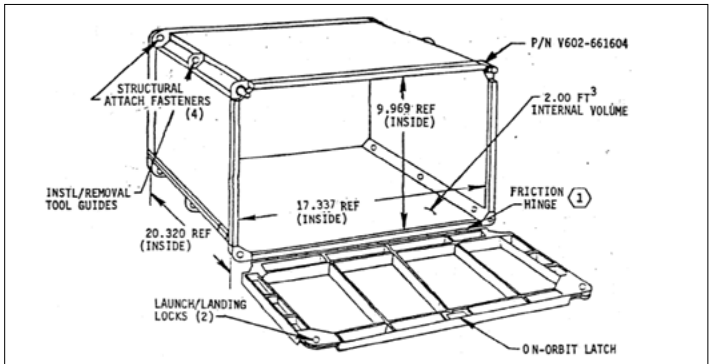


Figure 2: NASA Space Shuttle middeck locker dimensions (SOURCE: NSTS-21000-IDD-MDK)

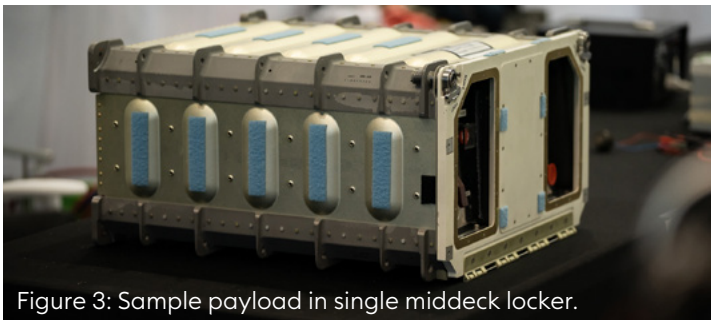
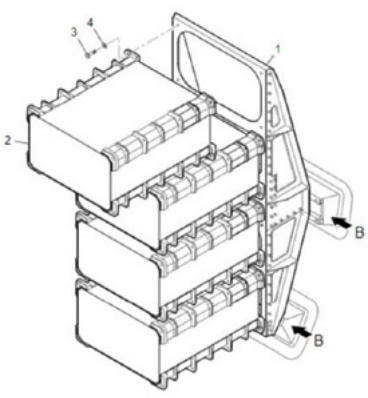


Figure 3: Sample payload in single middeck locker.

Figure 4: Double locker from the University of Louisville flying with Virgin Galactic in 2021.



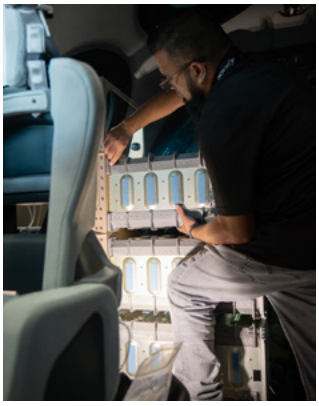


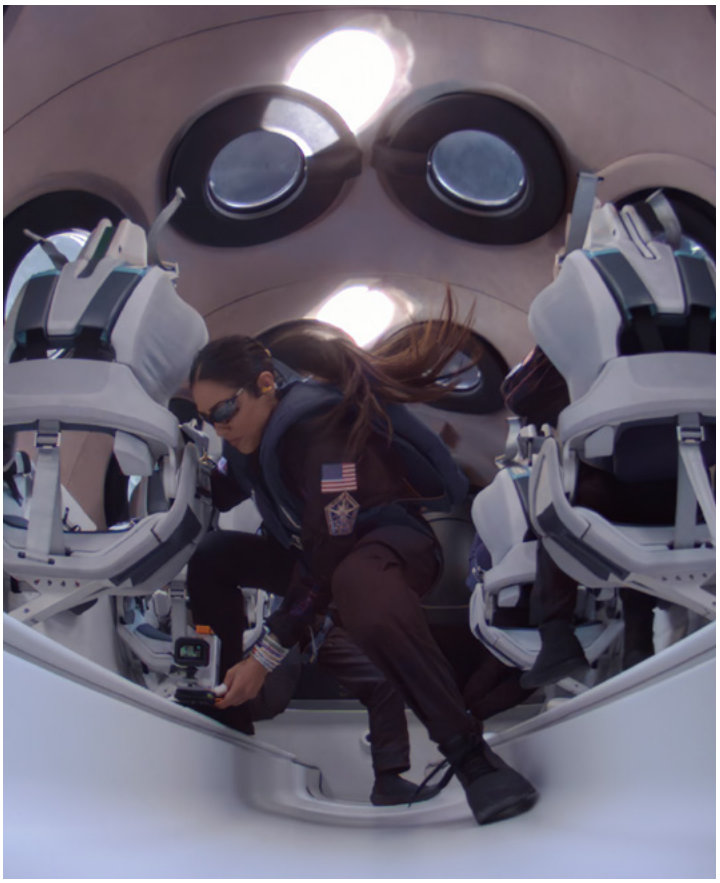
Figure 5: Payload rack with four middeck lockers installed

HUMAN-TENDED RESEARCH

Our Spaceship's modular cabin can accommodate up to six seats and a mixture of seats and racks to enable human-tended research to be conducted during the flight. Researchers who are flying with their experiments can either **interact with a rack-mounted payload or fly with wearable payloads** stored on their person. Wearable payloads may be stored in pockets, strapped to the researcher, or a sensor worn on the body, such as a heart monitor. Each researcher can fly with two wearable payloads and more may be added as a non-standard service. There is no power available for wearable experiments, but researchers receive a flight data report and cabin video after the flight.

The longer mission time and gentler g-loading of our spaceflight system allows researchers to engage with wearable payloads and **collect data during the entire flight profile**. Additionally, by taking off and landing at the same facility, researchers can collect time-sensitive medical data, with previous researchers collecting blood, saliva, ultrasounds, and other samples within minutes of takeoff and landing.

Researchers flying aboard Spaceship receive extra training ahead of their flight to ensure they take full advantage of every second they're in microgravity. You'll work closely with our Astronaut Training and Medical team, in addition to the Payload Integration Engineer. Although there are a few physical parameters to fly, we are committed to opening Space for All and will work with you to make your human-tended research mission a success.



VEHICLE DATA

Spaceship and Mothership are both instrumented to collect large amounts of data during a flight, most of which is collected and stored within our Data Acquisition Units (DAUs) for post-flight download. This data includes vehicle accelerations (including microgravity granularity), inertial rates, cabin temperatures and pressures, and three-dimensional position data. In preparation for your upcoming flight we will provide flight profile data from previous flights and/or simulated practice runs. When your flight is complete, you will have access to a standardized set of data from your actual flight. Please understand that some of this data falls under export control regulations, so a formal process will be established to ensure proper compliance.

The Spaceship cabin has multiple cameras installed that take high resolution video during flight. While the standard video views do not concentrate on individual payloads, some of these videos may be available for post-flight analysis.

POWER, BATTERIES, AND EMI

Spaceship is capable of providing electrical power to rack-mounted payloads. It is strongly recommended to use Spaceship's onboard power whenever possible to make the best use of your mass/volume and to avoid the need to conduct additional safety analysis on a custom power system.

The vehicle-provided payload power is made available to payloads during pre-takeoff checks and operates until after landing. For your flight, a Virgin Galactic Payload Integration Engineer will be available to carry out necessary payload activation steps soon before takeoff and deactivate payloads soon after landing.

All rack-mounted payloads have access to the vehicle-provided 24-28 V DC power source if required. You will be limited to approximately **50 Watts per single middeck locker.**

If your payload uses Spaceship vehicle-provided payload power, you will need to provide and install a D38999/24FD35PN connector to interface with the Payload Power System. When connected to the Payload Power System, Pin 1 is V+ and Pin 2 is ground.

Large and custom-built batteries are likely to impact mission cost and schedule, and may ultimately be rejected from flight if safety concerns cannot be adequately retired or mitigated. Small commercial off-the-shelf (COTS) battery units, such as those commonly found in GoPros or other digital camera systems, are likely acceptable.

Whether you are using the vehicle-provided power or your own battery power, your payload needs to have an **easily accessible and identifiable shutdown switch** that will de-energize all power sources. Should there be an obvious safety issue with your payload while in flight, our Payload Specialist will need to be able to quickly shutdown payload functions. On flights where there is no onboard Payload Specialist, the pilots will maintain the ability to cut power to all payloads should the need arise for safety reasons.

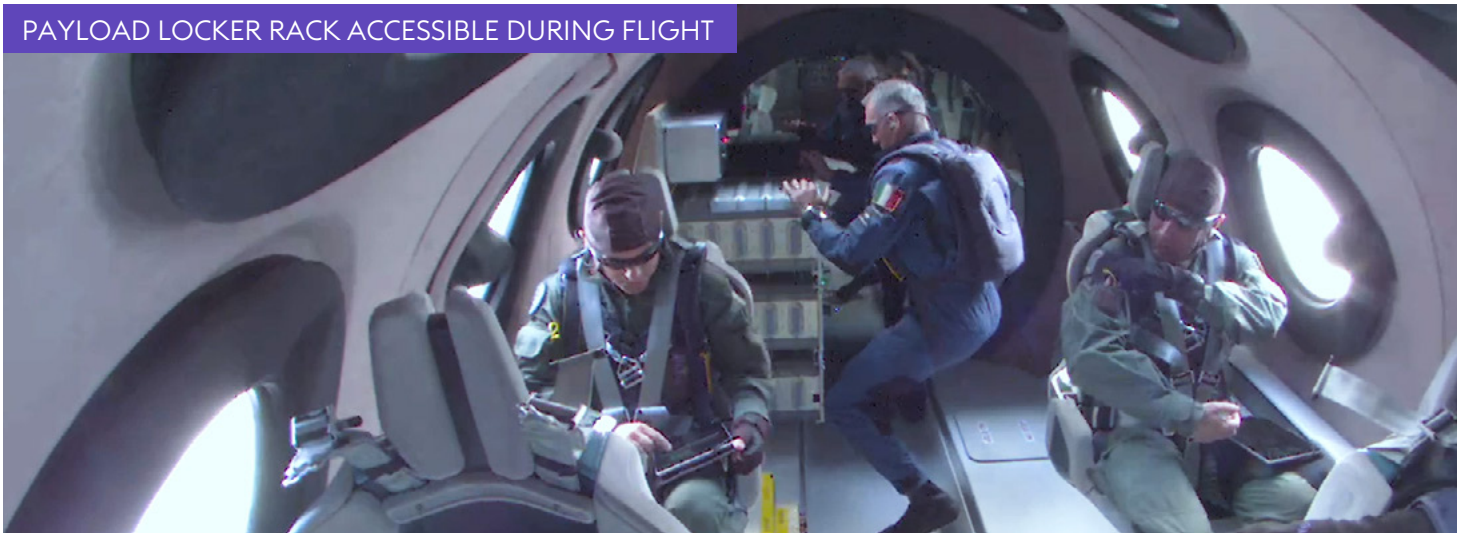
Any electrical wires and/or contacts that are exposed to the cabin must be covered by an **appropriate insulating material**. In addition, each payload should be **properly electrically grounded** to the Spaceship vehicle ground.

Each payload is required to have the proper **wire gauges** for maximum expected currents. Please refer to AC43.13-1B (Acceptable Methods, Techniques, and Practices – Aircraft Inspection and Repair, Chapter 11 Aircraft Electrical Systems)[2] for wire gauge compliance guidelines.

When you are designing your payload, you must verify that all payload functions will automatically **fail to a safe configuration** in the event of complete or partial power loss. You should assume that a power loss can occur at any time during any phase of flight.

In order to prevent interference with vehicle systems the payload must operate within the **electromagnetic interference (EMI)** limits of Spaceship and Mothership. If you anticipate the payload to have an EMI signature that may be a concern, we can provide more information about the requirements. Payloads that require the use of a **radio transmitter or receiver** must be designed not to interfere with vehicle systems. All payloads will undergo a functional check once integrated into the vehicle to test for interference issues prior to flight. Virgin Galactic reserves the right to shut down any payload that demonstrates vehicle interference while in flight.

PAYLOAD LOCKER RACK ACCESSIBLE DURING FLIGHT



THERMAL MANAGEMENT

If your payload requires a **heating element**, it must be designed to automatically prevent overheating. In addition, heating systems need to be located away from any materials that may pose a smoke or fire hazard.

Any kind of **thermal control must be autonomous** and not require intervention from our Payload Specialist as a mitigation method.

To keep cabin temperatures at a reasonable level, each middeck locker location is allowed no more than a **100 W heat load**.

[2] https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/99861

OTHER CABIN INTERFACES

During flight, Spaceship's cabin is pressurized to between 5,000 and 6,000 ft of equivalent altitude, although it may drift outside of this range after atmospheric re-entry on some flights. While mated to Mothership, the cabin interior is actively controlled for pressure (+/- 2 psi relative to ambient atmospheric pressure), temperature (0C to 30C with measures taken to heat the cabin before launch on colder days), and humidity to maintain a shirt-sleeve environment. Prior to release, Spaceship isolates itself from Mothership and switches to its integrated dry air pressurization system. No active heating, cooling, or carbon dioxide scrubbing is necessary to maintain a shirt-sleeve environment within Spaceship during the flight.

CONTAINMENT OF LIQUIDS, POWDERS, AND OTHER HAZARDS

If the payload includes a fluid, it must have at least two independent levels of containment which ensure the fluid will not enter the vehicle cabin when experiencing flight accelerations.

Similar to fluids, all **powders and small particles** must also have at least two independent levels of containment, conforming to the same requirements as above.

In addition, **frangible items** such as glass or polycarbonate and all **moving parts** must be entirely contained and unexposed to the vehicle. For large amounts of frangible material or high energy moving parts, extra levels of containment may be necessary.

A payload using a middeck locker in absence of an internal support structure is required to use protection isolation material (Pyrell Foam or similar material) with a minimum thickness of 0.5" and be compressed by about 24 percent. The isolation material is required to fill gaps between the payload and the interior of the locker and prevent any movement that may cause damage to the internal payload locker structure.

HAZARDOUS MATERIALS

The Hazardous Materials Table found within 49 CFR 172.101 outlines different types and levels of hazardous materials. If the fluid or powder you plan to use is considered a hazardous material, you must use three independent levels of containment. We understand this requirement may be overly restrictive in some cases (i.e. the use of extremely small volumes), so we will work with you to arrive at an agreeable solution for your specific situation. We are here to help, not hinder your work!

If a payload contains an Other Regulated Material (ORM-D), highlighted in yellow in Table 2, it will be addressed on a case-by-case basis.

Table 2. Hazardous Materials Classes

Class No.	Division No. (if any)	Name of class or division	49 CFR reference for definitions
None		Forbidden materials	173.21
None		Forbidden explosives	173.54
1	1.1	Explosives (with a mass explosion hazard)	173.50
1	1.2	Explosives (with a projection hazard)	173.50
1	1.3	Explosives (with predominately a fire hazard)	173.50
1	1.4	Explosives (with no significant blast hazard)	173.50
1	1.5	Very insensitive explosives; blasting agents	173.50
1	1.6	Extremely insensitive detonating substances	173.50
2	2.1	Flammable gas	173.115
2	2.2	Non-flammable compressed gas	173.115
2	2.3	Poisonous gas	173.115
3		Flammable and combustible liquid	173.120
4	4.1	Flammable solid	173.124
4	4.2	Spontaneously combustible material	173.124
4	4.3	Dangerous when wet material	173.124
5	5.1	Oxidizer	173.127
5	5.2	Organic peroxide	173.128
6	6.1	Poisonous materials	173.132
6	6.2	Infectious substance (Etiologic agent)	173.134
7		Radioactive material	173.403
8		Corrosive material	173.136
9		Miscellaneous hazardous material	173.140
None		Other regulated material: ORM-D	173.144

MISCELLANEOUS

All payload **hardware must be thoroughly cleaned to Visually Clean Level** specified in SN-C-0005[3] before integration into the vehicle. We don't need a mirror finish on your surfaces, but there should be absolutely no debris present.

In order for our flight crew to stay focused on vehicle systems to ensure a safe flight, a payload that **emits sound** must stay below 85 dB for both continuous and intermittent noises.

REQUIRED DOCUMENTATION

Documentation: we all hate it, but it is a necessary evil in the world of spaceflight. Our goal is to make the required documentation as painless as possible for everyone involved—for you and for us.

Each payload provider is required to submit a **Payload Information Package (PIP)** to Virgin Galactic to obtain an approval for flight. This document will include a description of payload components and interfaces, hazards and mitigations, results from testing and analysis, descriptions of pre- and post-flight activities and other miscellaneous items. Virgin Galactic will provide a PIP submission template and work with you every step of the way. The PIP submission timeline will be defined by your contract to ensure we all stay on schedule for a successful flight!

SAFETY APPROVAL PROCESS

Our engineering, safety and operations teams will use the information provided in the PIP to assess your payload for any safety or programmatic concerns. We will then work to mitigate any issues identified and iterate as needed in an effort to achieve final PIP approval.

The payload approval process includes the following:

- PIP submission by payload provider
- PIP review by Virgin Galactic Payload Integration Engineer
- Virgin Galactic Discipline Engineer approval (Integration, Structures, Electrical, Fluids Systems, Systems Safety, etc.)
- Safety Review/Management Review Board Approval

Final payload approval will occur when you bring your payload on-site for flight week. We will conduct a detailed comparison of your payload to the description in the PIP. Any differences, deviations or discrepancies will be challenged, so please be sure to notify us of any changes. We encourage you to keep an open dialogue with us to prevent any problems or delays. Most importantly, we want you to fly promptly so communication is key!

[3] SN-C-005 Revision D, July 20, 1998 – Space Shuttle Contamination Control Requirements

We hope this guide has been a useful introduction to our capabilities.
If you'd like to learn more, we have a more detailed Payload Users Guide available to ensure you're ready for flight. To receive a copy or reach us with any other questions, please contact us at **research@virgingalactic.com**.

We look forward to working with you!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