Payload Users' Guide

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Thank you for your interest in using SpaceShipTwo, Virgin Galactic's privately built spacecraft, for your research flight.

This document will provide a general guide to the capabilities of SpaceShipTwo, including a top-level description of experience offered on board SpaceShipTwo as well as the requirements payloads must accommodate in order to fly.

It should be noted that this Payload Users' Guide is a working document, and that revisions or additions will periodically be made. Users are encouraged to check the Virgin Galactic website, where the latest version of this document can always be found.

Additionally, it should be noted that a more detailed edition of this Payload Users' Guide will soon be made available upon request to US Persons as defined in the International Traffic in Arms Regulations (ITAR). Interested parties are encouraged to submit requests to research@virgingalactic.com.

"I get extremely excited thinking about what the scientists and researchers of the world will do with WhiteKnightTwo and SpaceShipTwo. It is so critical that researchers have the opportunity to send payloads to space, or even to fly themselves. I can't wait to see what great new ideas emerge and which of life's biggest questions will be solved using data gathered on board our vehicles."

- Sir Richard Branson
Founder of the Virgin Group
Virgin Galactic Future Astronaut

1.0 Introduction

Virgin Galactic is the world's first commercial spaceline. Founded by Sir Richard Branson, we are currently conducting flight testing for a new generation of privately build spacecraft. Based closely on the historic SpaceShipOne program—which safely carried human beings into space in 2004, thereby claiming the $10M Ansari X PRIZE—these vehicles have been designed to set new standards for spaceflight safety, frequency, flexibility, and cost. Ultimately, we seek to make space accessible to everyone.

Our spaceflight system consists of two vehicles, both pictured above. **WhiteKnightTwo (WK2)** is a four engine jet aircraft that is capable of high altitude heavy lift missions including but not limited to its role as a launch platform for **SpaceShipTwo (SS2),** an air-launched, suborbital spaceplane capable of routinely reaching a 110 kilometer apogee. Between them, these two vehicles allow access to space and to regions of the atmosphere ranging from the troposphere to the thermosphere, and provide extended periods of microgravity before re-entering the atmosphere and gliding to a conventional runway landing.

Virgin Galactic has already signed up more than 475 astronauts eager to fly to space onboard SpaceShipTwo, so we are often considered a space tourism company. While space tourism is a key part of our company, we at Virgin Galactic are extremely excited to offer these new vehicles to scientists and engineers as a novel research platform from which a wide variety of experiments can be conducted. Our **High-altitude Payload and Science System (HighPASS)**—an end-to-end offering that includes the use of SpaceShipTwo and/or WhiteKnightTwo, along with their payload racks and the processes and facilities that go along with them—offers routine, reliable, responsive, and affordable access to the upper atmosphere and space. With vehicles designed to carry six human passengers and two pilots into space, these research platforms allow for suborbital flights of experiments that cannot be carried by any other system: both vehicles offer cabins approximately the same size as that of a Gulfstream G200, providing ample room for experimentation.

Virgin Galactic is taking refundable deposits for flights of autonomous payloads or of research personnel now. Eventually, we expect that WhiteKnightTwo will also be made available for researcher and payload flights With its unique capabilities, including the ability to carry large payloads and to loiter at altitudes greater than 50,000 feet (15 km) for extended durations, WhiteKnightTwo is an attractive research platform. Additionally, WhiteKnightTwo may prove to be a useful stepping stone for researchers planning flights aboard SpaceShipTwo; with the cabins being functionally identical, including the rack systems. More information about research flights on WhiteKnightTwo will be made available in the future. Inquiries and requests are welcomed via email sent to research@virgingalactic.com.

This document provides an introduction to the capabilities of SS2 and the process of securing flight opportunities to meet your research needs. It includes a top level description of the key information you need to start planning your research flight on board SS2.

> *"An enormous range of disciplines can benefit from access to space, but historically, such research opportunities have been rare and expensive. At Virgin Galactic, we are fully dedicated to revolutionizing access to space for scientists, researchers, engineers, educators, and students."*
>
> \- *George Whitesides*
> *President and CEO*
> *Virgin Galactic*

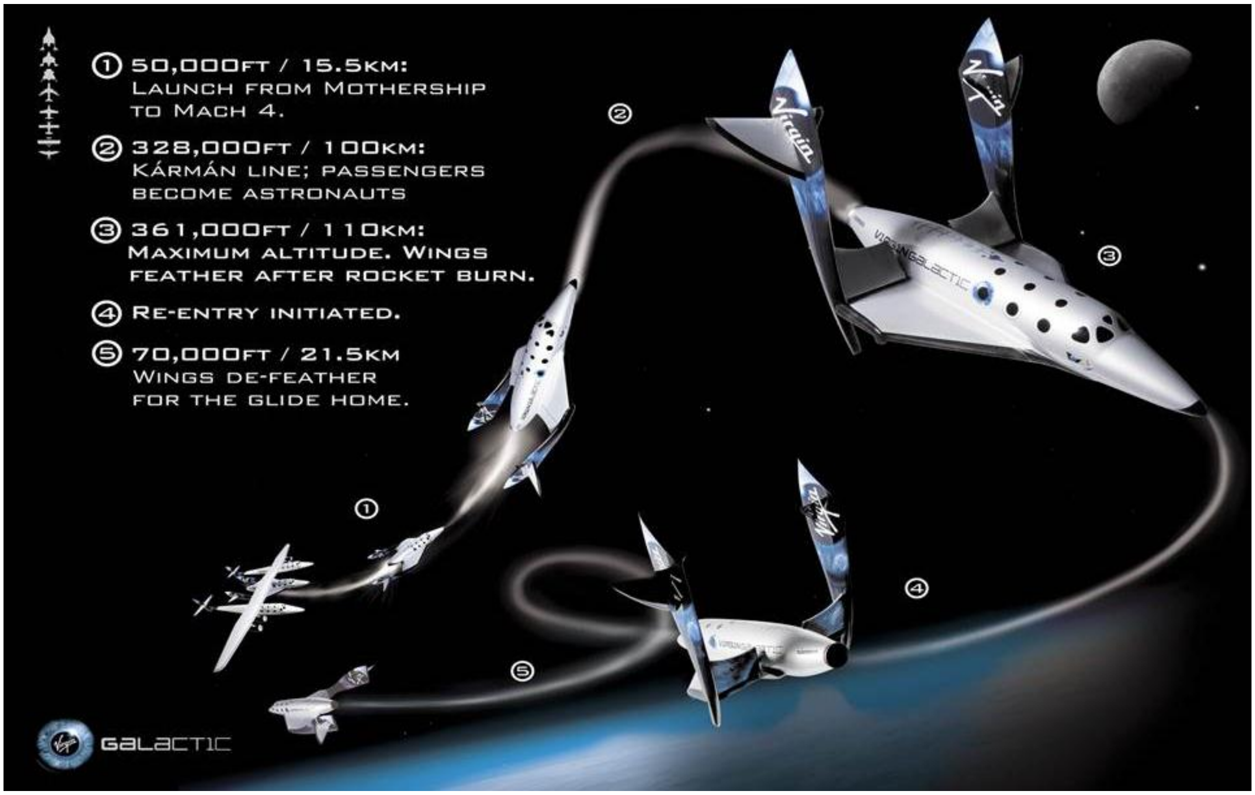
2.0 Summary of Key Performance Attributes

WhiteKnightTwo and SpaceShipTwo are unique vehicles with unmatched mission capabilities. We believe that these vehicles will be used for scientific experiments, educational programs, and research programs we have not even begun to imagine. Rather than our trying to lay out those research applications for you, we'll simply tell you what our vehicles can do and how you can use them—and we look forward to hearing how you plan to use them.

As a research customer, given appropriate regulatory clearance and safety reviews, you will enjoy the following key services and advantages:

- Suborbital spaceflight payload capacity of **1,300 lbs** (600 kg) aboard SS2
- High altitude payload capacities of **30,000 lbs** (13,600 kg) aboard WK2
- Matching pressurized payload volumes of **500 cubic feet** (14 m^3) with shirt-sleeve environments on board both SS2 and WK2
- Exposure to **3-5 minutes** of **high quality microgravity** per flight aboard SS2
- Rapid vehicle turnaround and high flight rates drive **frequent and responsive flight access**, allowing for maximum flexibility and opening the way for 'science of opportunity' missions and series measurements taken on several flights in rapid succession
- Quick recovery of payloads, with pre-flight access to the payload until only hours before flight and with post-flight access to the vehicles within 3 hours after a conventional runway landing
- Flight opportunities for both autonomous payloads and research personnel
- Launch windows tailored to the individual researcher and/or the experiment
- High pointing accuracy aboard both high altitude and suborbital flights

3.0 A Typical Flight



A flight to space onboard SpaceShipTwo lasts about 90 minutes in total. The flight profiles for astronaut and for autonomous payload flights will be the same. First, the mated pair of WK2 and SS2 will take-off from the 10,000 foot runway at Spaceport America in southern New Mexico. Under power of WhiteKnightTwo's four jet engines, the two vehicles will climb to an altitude of approximately 50,000 feet. After completing appropriate vehicle checks, SpaceShipTwo will be released from WhiteKnightTwo, free falling for a few seconds prior to igniting its rocket motor. SS2 will boost upward under the power of its rocket motor, reaching peak speeds of approximately Mach 3.6, and then continue to coast upward, reaching a peak apogee as high as 360,000 feet (110 km), which is above the Kármán line. The following approximate flight times can be expected during a typical flight:

- Mated Climb: ~60-90 minutes
- Boost: ~60 seconds
- Coast: ~240 seconds
- Re-entry: ~80 seconds
- De-feather: ~30 seconds
- Glide to Land: ~15 minutes

The vehicle was designed with human passengers in mind, so the flight will be relatively gentle compared to other launch vehicles. Occupants and payloads will be exposed to a maximum of

3.5g longitudinal (N_x, or “eyeballs in”) acceleration during the boost phase of flight. During reentry, the vertical (N_z, or “head to toe”) loading slowly increases and peaks at around 5.5g. The time spent at an elevated N_z is relatively short in duration (less than 30 seconds above 3g). To ensure safety in both nominal and off-nominal situations, payloads and their mounting hardware shall be designed to withstand transient peak loads of 18.0g forward, 4.5g upward, and 4.5g sideward and sustained loads of 10.2g downward; however, likely observed loads are as indicated in the table below.

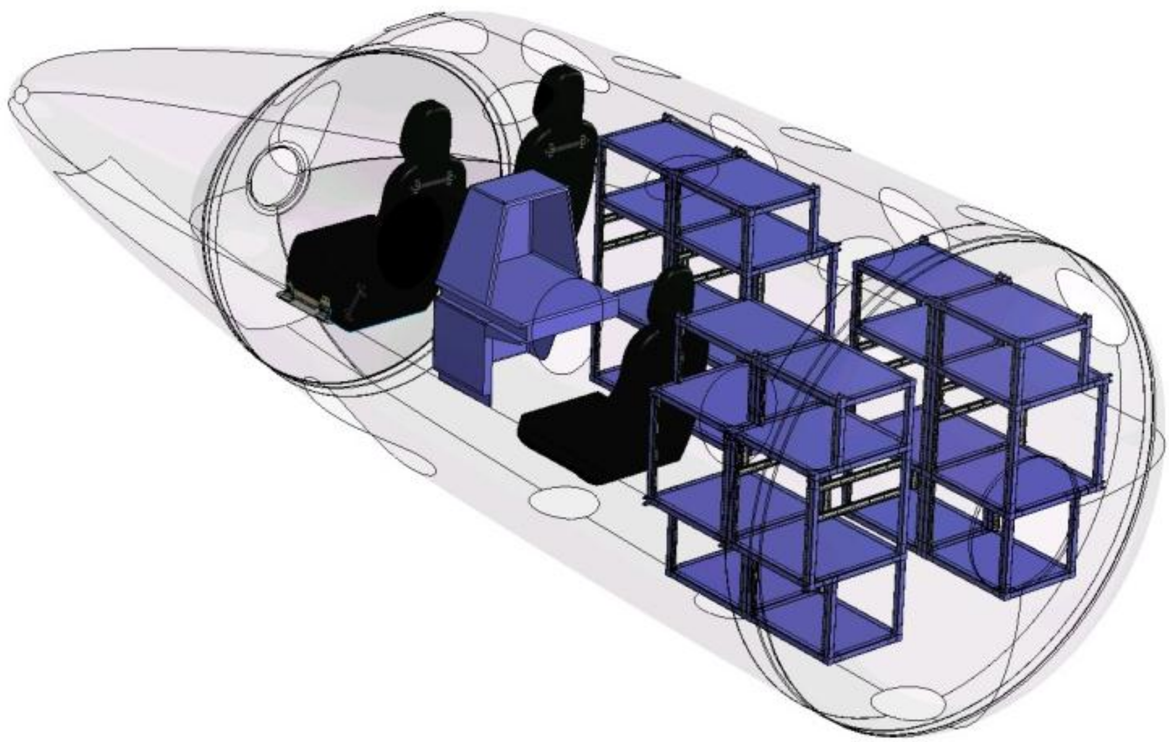
G-Levels

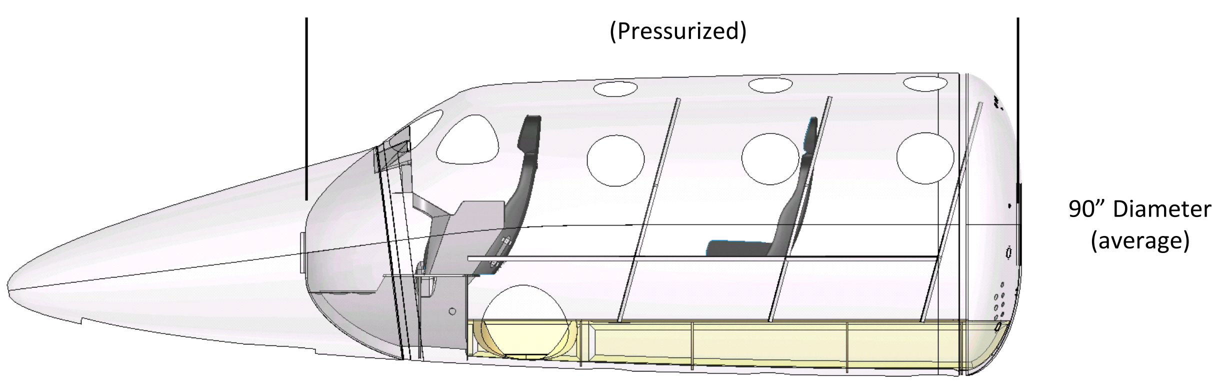
Phase	Maximum G-Level	Direction	Duration (seconds)
Pull up to vertical	~3.4G	Down	~40
Boost	~3.6G	Backwards	~70
Entry	~5.4G	Down	~90
Entry	~2.2G	Left/Right	~90

The duration and quality of microgravity on a flight of SpaceShipTwo is dependent on a variety of factors, including apogee, gross liftoff weight, exact motor burn duration, passenger activity, activation of the various flight systems, and pilot technique. On a typical flight, passengers and payloads will experience between 3 and 4.5 minutes of microgravity.

During flight, the cabin of SS2 is pressurized to a 5000 ft. equivalent altitude. While mated to WK2, the cabin interior will be actively controlled for temperature and humidity to maintain a shirt-sleeve environment (relative humidity less than 75%, air pressure between 12.2 and 15.8 psi). No active heating, cooling, or carbon dioxide scrubbing systems are required to maintain this shirt sleeve environment during the remainder of flight.

4.0 "Your Payload Goes Here": Racks, Doors, and Other Specs





Virgin Galactic has designed a set of payload racks meant to provide support and structure for a wide variety of payloads during flights to space on board SpaceShipTwo. Prototypes of these racks will be installed into and flown onboard WK2 and SS2 in early 2012; any further data or design improvements that result from these tests will be incorporated into further versions of this Payload Users Guide.

Although other flight configurations are possible, during a standard flight dedicated research payloads, SS2 will be fitted with five to nine standard payload racks. The racks are securely attached to the airframe; the graphic above illustrates a notional typical configuration.

On such a standard flight, a Flight Test Engineer designated by Virgin Galactic will fly aboard SS2 and be available to monitor payloads for anomalous behavior that could place the vehicle and/or crew at undue risk. In some instances, this Flight Test Engineer may be available to interact with payloads in a limited fashion, such as by activating an experiment in flight.

The standard SS2 payload rack has a basic 19” component width, and varies in depth and height. The depths vary dimensionally at the top, mid rack and bottom to accommodate the internal curvature of the vehicle. These racks were designed with a specific intention to easily accommodate standard 19” server type payloads as well as 1U and 3U CubeSat form factors, among others. Additionally, SS2 can readily accommodate a large number of standard NASA Shuttle Middeck Lockers; as many as 36 Middeck Lockers could be accommodated on a standard payload flight.

If you do not wish to use the standard payload racks or the Middeck Locker, custom fabrication of racks or mounting systems to meet the needs of special test components or requirements is possible on commercially reasonable terms.

Electrical power (28V, 50A) may be supplied to payloads while SS2 is mated to WK2, but all payloads must be self-powered during SS2 free flight. Power may either be internal to the payload or external and mounted to the associated rack. Payload wiring shall adhere to industry standard wiring sizes.

Additionally, payload users may have the option to access vehicle data and flight instrumentation through an Ethernet interface. Data from the Inertial Navigation System (INS), the Global Positioning System (GPS) and the Air Data System (ADS) can be provided to the payload on that bus. Air data rate is currently 14Hz, and INS data rate is 50Hz. Hundreds of channels, along with several video feeds, are recorded and may be available post flight upon request. However, no data storage is currently provided for payload-generated data.

Installation of the racks allows rack placement anywhere along its length on both the left and right side of the cabin; however, racks cannot be positioned in locations that might impede egress from the vehicle, such as near the right side emergency exit.

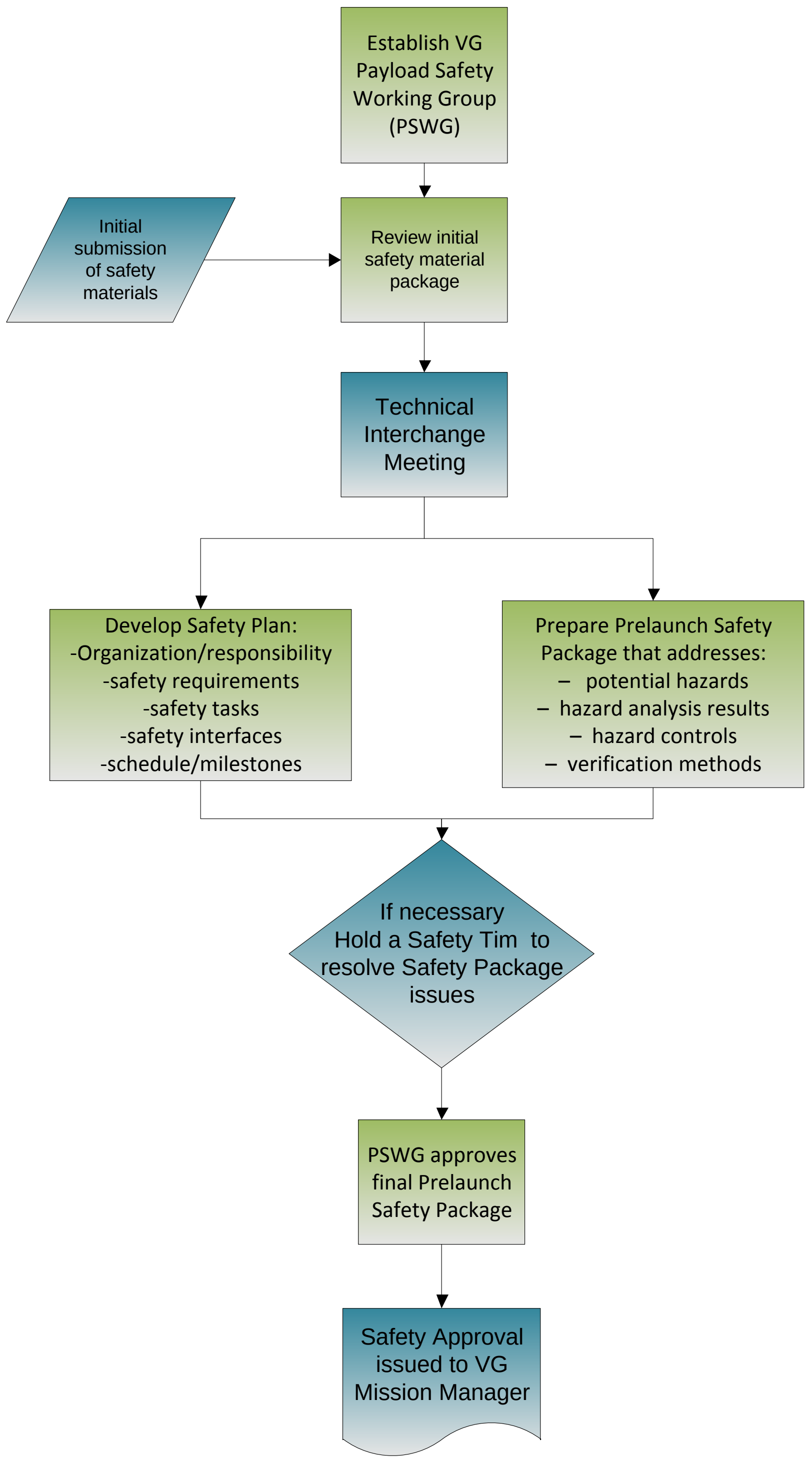
Payload and racks are loaded into SS2 through an elliptical main hatch with a major diameter of 33 inches (~84 cm) and a minor diameter of 26 inches (~66 cm). The bottom of SS2’s main hatch is located 2.5 feet above the ground when SS2 is resting on the ground.

Payloads may also be loaded into SS2 via the circular emergency exit hatch, which has a diameter of 26 inches (~66 cm). The emergency hatch is located 6.8 feet total distance above the ground. SS2 is a low wing aircraft; the wing is located directly under the emergency exit hatch.

In the future, additional payload mounting options may be provided, including racks that provide electrical or computing power or mounting locations on the exterior of the spacecraft.

5.0 Processes and Controls

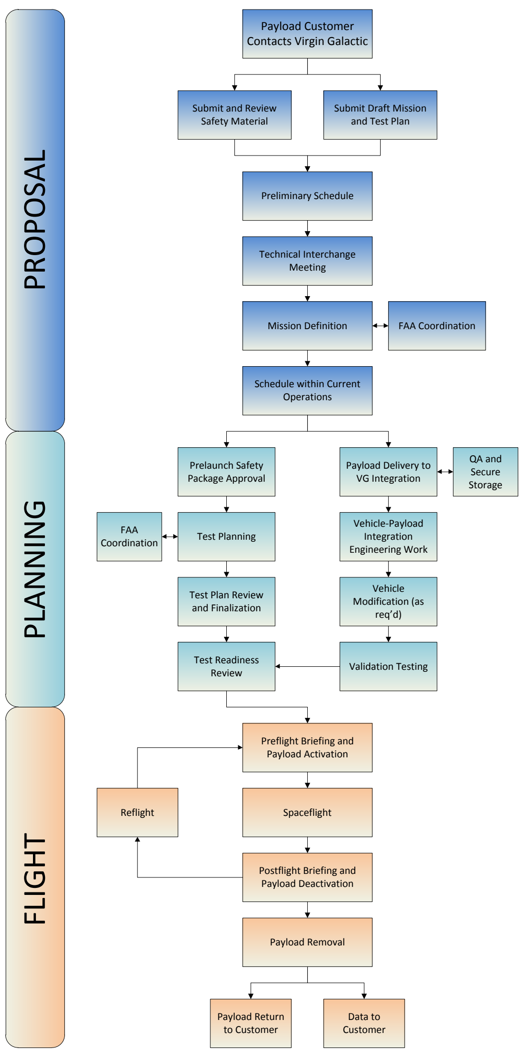
All payloads are subject to Virgin Galactic safety review; these reviews are designed to ensure that neither nominal nor off-nominal operations of the payload could endanger the flight crew or the aircraft/spaceship. The flow diagram below depicts the typical VG safety approval process.



In the initial payload Safety Material submission, the payload provider must identify any known hazardous systems and/or hazardous operations of the payload. Hazardous systems include such items as: hazardous chemicals/materials, bio-hazards, pressure vessels/bottles, stored mechanical energy, and high voltage power. Hazardous operations include such activities as: exposing the crew/craft to ionizing or non-ionizing radiation, venting of payload chemicals or contents into the cabin environment, extreme temperature variations (both hot and cold), known vibration frequencies which may be induced into the equipment mounting racks, and any emergency shutdown procedures requiring crew actions.

Prior to each flight, the payload customer will be granted access to the payload. All payload customer access will be monitored and logged. At the conclusion of each flight, personnel designated by Virgin Galactic will perform a visual inspection of the cabin and other areas containing experiments or payloads directly after the vehicle has been secured for approach. Digital images will be recorded at this time. Payload customers will have access following these post-flight inspections. All payload customer access will be monitored and logged. Unless otherwise requested by the payload customer, the payload may be removed immediately after flight.

Overall, the process experienced by a typical payload customer will be as illustrated in the flow chart below.



6.0 For More Information

As noted previously, a more detailed edition of this Payload Users' Guide will soon be made available upon request and, due to ITAR constraints, only to US Persons as defined in the ITAR. Interested parties are encouraged to submit requests to research@virgingalactic.com

Prospective payload customers interested in placing a reservation for flight are encouraged to send the following information to:

William Pomerantz
Vice President, Special Projects
Virgin Galactic
william.pomerantz@virgingalactic.com
[+1] 626-463-0600

To ensure the fastest and most detailed response, please feel free to include any applicable information, including the categories suggested in Section 7, below. Please be sure any proprietary information is clearly labeled.

Thank you for your interest in flying your research personnel or payloads on board SpaceShipTwo!

7.0 Suggested Information to Include in Requests for More Information

- **Payload Name**
- **Payload Provider Name and Institution**
- **Points of Contact Information (Name, Position, Phone Number, Email)**
- **Approximate Flight Date(s) Desired**

- **Description of Mission**
- **Timeline Constraints**
- **Number of Flights Desired**

- **Payload Mass (lbs)**
- **Payload Dimensions**
- **Desired Location and Orientation within Vehicle**
- **Payload Attachment Method**

- **Payload Allowable Environment (Storage and Operational) – (Max/Min)**
    - **Temperature (F)**
    - **Pressure (psi)**
    - **Humidity (%)**
    - **Air Cleanliness (ISO Level)**
    - **Acoustic Sound Level (dB)**
    - **Vibration (Grms)**
    - **Shock (g)**
    - **Acceleration (g)**

- **Description of Mission Operational Requirements (Pre-Flight, Flight, Post-Flight)**
    - **Personnel**
    - **Timeline**
    - **Tools/GSE**

- **Payload Scale Drawing Showing Dimensions**

- **Security of Payload**
- **Additional Requirements**

- **Safety Materials**
    - **Known Safety Issues with Payload**
    - **Hazardous Systems**
    - **Hazardous Operations**
    - **Power Systems of Payload**
    - **Pressure Vessels of Payload**
    - **RF Systems of Payload**
    - **Hazardous Materials**
    - **Bio-Hazards**

Hazardous Systems (in no particular order):

- Flammable/combustible material, fluid (liquid, vapor, or gas)
- Toxic/noxious/corrosive/hot/cold material, fluid (liquid, vapor, or gas)
- High pressure or evacuated container (explosion, implosion)
- Stored energy device (i.e., mechanical spring under compression)
- Frangible material
- Stress corrosion susceptible material
- Inadequate structural design (low safety factor)
- High intensity light source
- Ionizing/electromagnetic radiation
- Rotating device
- Extendible/deployable/articulating experiment element (collision)
- Stowage restraint failure
- Heat transfer
- Over-temperature explosive rupture (including electrical battery)
- High/Low touch temperature
- Hardware cooling/heating loss (loss of thermal control)
- Pyrotechnic/explosive device
- High acoustic noise level
- Toxic off-gassing material
- Mercury/mercury compound
- Organic/microbiological (pathogenic) contamination source
- Sharp corner/edge/protrusion/protuberance
- Ignition source (electrical, chemical, mechanical)
- High voltage (electrical shock)
- High static electrical discharge potential
- Software error or computer fault
- Carcinogenic material