SPACEX

STARSHIP USERS GUIDE

Revision 1.0 | March 2020

COMPANY DESCRIPTION

SpaceX was founded in 2002 to revolutionize access to space and enable a multi-planetary society. Today, SpaceX performs routine missions to space with its Falcon 9 and Falcon Heavy launch vehicles for a diverse set of customers, including the National Aeronautics and Space Administration (NASA), the Department of Defense, international governments, and leading commercial companies. SpaceX provides further support to NASA with the Dragon spacecraft by conducting cargo resupply and return missions to and from the International Space Station (ISS). Soon, SpaceX will begin transporting crew to the ISS as well. To offer competitive launch and resupply services, SpaceX has incorporated reusability into the Falcon and Dragon systems, which improves vehicle reliability while reducing cost. The Starship Program now leverages SpaceX's experience to introduce a next-generation, super heavy-lift space transportation system capable of rapid and reliable reuse.

STARSHIP PROGRAM OVERVIEW

SpaceX's Starship system represents a fully reusable transportation system designed to service Earth orbit needs as well as missions to the Moon and Mars. This two-stage vehicle—composed of the Super Heavy rocket (booster) and Starship (spacecraft) as shown in Figure 1—is powered by sub-cooled methane and oxygen. Starship is designed to evolve rapidly to meet near term and future customer needs while maintaining the highest level of reliability.

STARSHIP USERS GUIDE

Starship has the capability to transport satellites, payloads, crew, and cargo to a variety of orbits and Earth, Lunar, or Martian landing sites. Potential Starship customers can use this guide as a resource for preliminary payload accommodations information. This is the initial release of the Starship Users Guide and it will be updated frequently in response to customer feedback.

PAYLOAD CONFIGURATIONS

Starship crew and uncrewed configurations are shown in Figure 2. The uncrewed Starship allows for the transport of satellites, large observatories, cargo, refueling tanks or other unmanned assets. Subsequent sections provide an overview of the preliminary volume and mechanical interfaces available; preliminary payload environments expected; and the preliminary mass-to-orbit capabilities of Starship. Please contact sales@spacex.com to evaluate how Starship can meet your unique needs.

Figure 1: Starship and Super Heavy

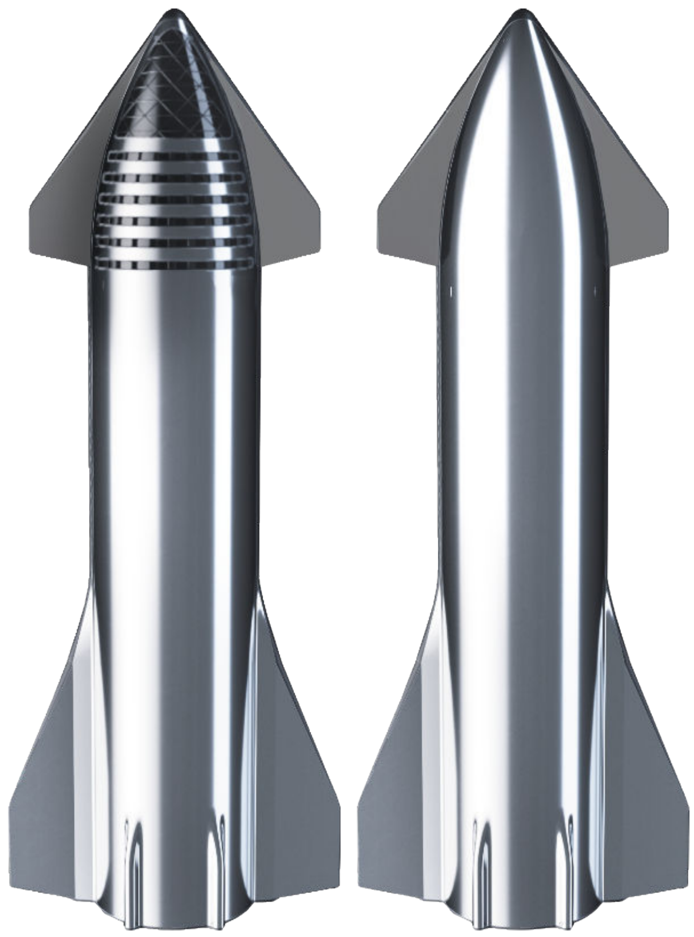

Figure 2: Starship crew (left) and uncrewed (right) configurations

PAYLOAD MECHANICAL INTERFACES

PAYLOAD FAIRING

The standard Starship payload fairing is 9 m in outer diameter resulting in the largest usable payload volume of any current or in development launcher.

The Starship payload fairing is a clamshell structure in which the payload is integrated. Once integrated, the clamshell fairing remains closed through launch up until the payload is ready to deploy. An example sequence of payload deployment is shown in Figure 3. To deploy the payload, the clamshell fairing door is opened, and the payload adapter and payload are tilted at an angle in preparation for separation. The payload is then separated using the mission-unique payload adapter. If there are multiple payloads on a single mission, a rotating mechanism can be provided to allow each satellite to separate with maximum clearance. Once separation is confirmed and the payload(s) have cleared the fairing, the payload fairing door is closed in preparation for Starship's return to Earth.

Figure 3: Starship payload deployment sequence

PAYLOAD VOLUME

Starship's 8 m diameter payload dynamic envelope is shown in Figure 4. This large deployable envelope allows for the design of novel payloads, rideshare opportunities and entire constellations of satellites on a single launch. An extended payload volume is also available for payloads requiring up to 22 m of height.

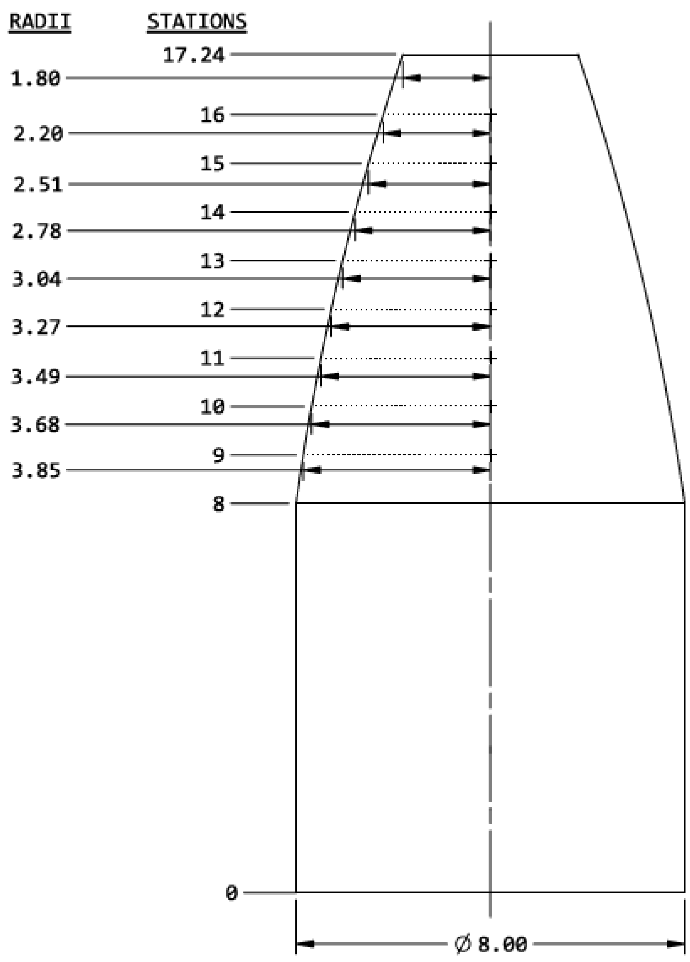

Figure 4: Starship payload volume (dimensions in m)

PAYLOAD MANIFESTING

Satellite customers may be manifested on single or multi-manifest missions. Customers can bring a single spacecraft, coordinate their own rideshares for a single Starship launch, or work with SpaceX to take advantage of a multi-manifest launch. Customer missions do not need to wait for co-passengers in order to fly.

The unique and large geometry of the Starship payload bay also opens new opportunities for payload integration. For payloads requiring additional structural support, Starship has the ability to mount supports along the sidewalls or nose to interface with trunnion-style interfaces on the payloads, similar to those employed on NASA's Space Shuttle orbiters. When large payloads are co-manifested on Starship, they are generally mounted side-by-side on the payload adapter. This reduces technical and schedule dependencies between rideshare participants compared to stacked configurations.

Example single-mission manifests:

- 1-3x geosynchronous telecom satellite(s)
- Full constellation of satellites on a single mission
- 1-2x geosynchronous telecom satellites plus rideshare system of small satellites
- In-space demonstration spacecraft that remains integrated with Starship and returns to Earth
- Cargo and crew configurations

PAYLOAD ADAPTERS

The Starship payload attach fitting is designed to accommodate standard payload interface systems in single- or multi-manifest configurations. SpaceX will either provide and integrate a payload adapter and clampband separation system or will integrate an adapter and separation system provided by the customer. As a baseline, Starship is compatible with heritage Falcon 937-mm, 1194-mm, 1666-mm and 2624-mm clampband interface requirements, including the ability to host multiple payloads side by side given the large diameter available. For customers with alternative interface requirements, SpaceX has a wide breadth of experience designing and manufacturing non-standard adapters and separation systems.

PAYLOAD ELECTRICAL INTERFACES

Starship will replicate common payload power and data interface standards on the flight vehicle in lieu of customer-provided electrical ground support equipment (EGSE) for final pre-launch operations. This will allow the payload to be powered, monitored, and commanded after integration into the fairing without facility located payload EGSE. This covers final pre-launch events in the processing facility and on the launch pad, and some of these electrical interfaces may continue to be available in-flight. Contact sales@spacex.com for more information or other options.

ENVIRONMENTS

Utilizing strong heritage and lessons learned from the development of the Falcon 1, Falcon 9 and Falcon Heavy launch systems, SpaceX is designing Starship and Super Heavy to provide as benign of a payload environment as possible. SpaceX will ensure that Starship environments meet or improve upon those of the Falcon Heavy launch system. To aid in the design of space vehicles capable of flying on Starship, SpaceX is providing the following preliminary payload environments.

LOADS

SpaceX is designing Starship to ensure that acceleration environments are well within industry standard levels. During flight, the payload will experience a range of axial and lateral accelerations. Both the Super Heavy and Starship engines can be throttled to help maintain launch vehicle and payload acceleration limits.

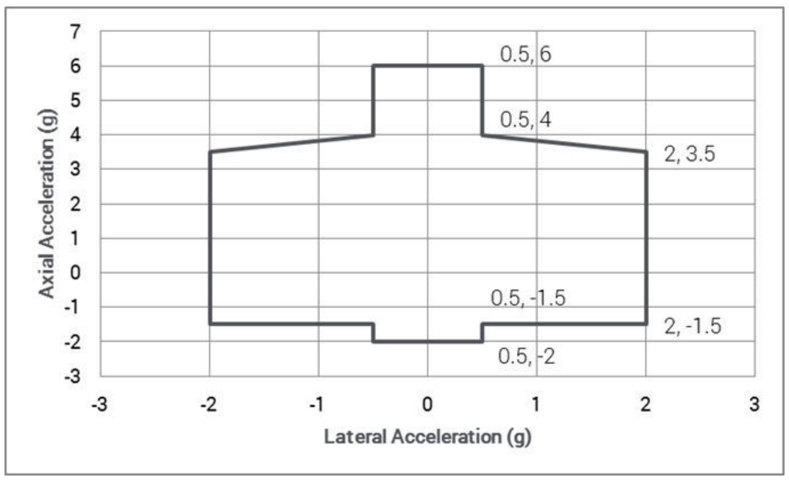

Figure 5: Payload maximum design load factors

The maximum expected design load factors for a single payload mission launching on Starship are shown in Figure 5. Actual payload dynamic loads, accelerations, and deflections are a function of the dynamic coupling between Starship and the payload. These loads can be accurately determined via a coupled loads analysis. For payload specific loads or rideshare loads assessments, contact sales@spacex.com.

ACOUSTICS

During flight, the payload will be subjected to a range of acoustic environments. Levels are highest during liftoff and transonic flight, due to acoustic and aerodynamic excitations. The maximum expected payload acoustic environments are shown in Table 1 and Figure 6 in one-third octave bands. Contact sales@spacex.com for mission specific low frequency acoustic assessments.

Frequency (Hz)	Acoustic Limit Levels 1/3 Octave
100	130
125	130
160	130
200	130
250	129
315	127
400	124.5
500	122
630	118.5
800	115.5
1000	113
1250	111
1600	109.5
2000	108.5
2500	107.5
3150	106.5
4000	105.5
5000	104.5
6300	103.5
8000	102.5
10000	101.5
OASPL (dB)	**137.7**

Table 1: Payload acoustic environment (1/3 octave)

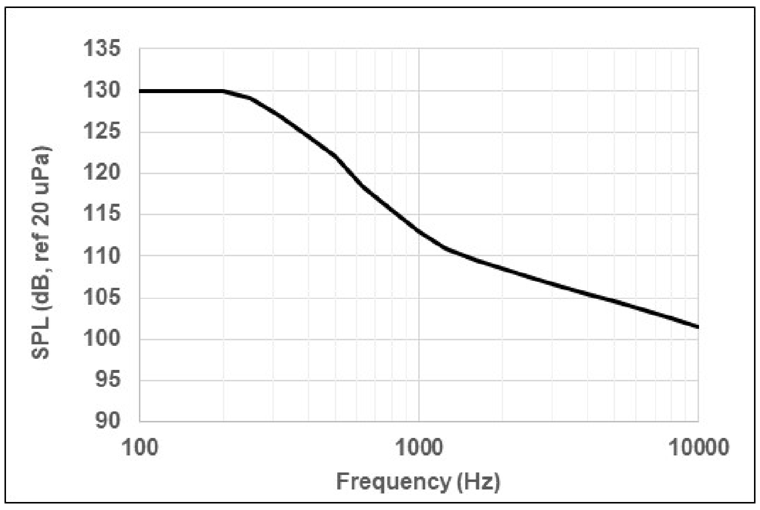

Figure 6: Payload acoustic environment (1/3 octave)

SHOCK

SpaceX is designing Starship to have benign shock environments. Stage separation and payload fairing door opening will generate negligible shock environments at the payload interface. Consequently, the maximum shock environment is typically due to the payload separation system selected for the mission. Typical maximum shock levels at the payload separation plane induced by payload separation systems are provided in Table 2 below.

Frequency (Hz)	Shock SRS (g-peak)
100	20
1000	1000
10000	1000

Table 2: Typical payload separation-induced shock at the payload separation plane

PAYLOAD INTEGRATION

SpaceX is initially planning for two launch sites for the Starship vehicle:

- Kennedy Space Center LC-39A | 28.6082° N latitude, 80.6041° W longitude
- Boca Chica launch pad | 25.9971° N latitude, 97.1554° W longitude

For payloads requiring return to Earth, landing sites are coordinated with SpaceX and could include Kennedy Space Center, FL or Boca Chica, TX.

Payloads are integrated into the Starship fairing vertically in ISO Class 8 (Class 100,000) cleanrooms. Then the integrated payload stack is transferred to the launch pad and lifted onto the Starship vehicle, while maintaining the same vertical orientation throughout the entire process. Conditioned air is delivered into the fairing during encapsulated ground processing while in the processing facility and on the launch pad.

PAYLOAD SEPARATION

SpaceX provides in-flight commanding and monitoring of the payload separation system(s). Starship can perform 3-axis attitude controlled or spin-stabilized spacecraft separation. Note that certain spacecraft separation maneuvers may reduce available payload volume. Collision avoidance maneuvers will be performed as required.

PERFORMANCE

The Starship and Super Heavy system offers substantial mass-to-orbit capabilities. At the baseline reusable design, Starship can deliver over 100 metric tons to LEO. Utilizing parking orbit refueling, Starship is able to deliver unprecedented payload mass to a variety of Earth, cislunar, and interplanetary trajectories. A summary of available Starship capabilities is provided in Table 3 below. The single launch mass-to-orbit assumes no orbital refueling of Starship. The maximum mass-to-orbit assumes parking orbit propellant transfer, allowing for a substantial increase in payload mass. These performance numbers assume full Starship reuse, including Super Heavy return to launch site. For performance estimates to a specific orbit, please contact sales@spacex.com.

Orbit	Mass-to-Orbit Single Launch	Mass-to-Orbit Prop Transfer (t)
LEO[1]	100+	100+
GTO[2]	21	100+
Lunar Surface	N/A	100+
Mars Surface	N/A	100+

[1]Up to 500-km circular orbit at up to 98.9-deg inclination
[2]Assumes 185 x 35,786 km orbit at 27-deg inclination with 1800 m/s ΔV to go

Table 3: Expected Starship Performance

CARGO CONFIGURATION

Starship was designed from the onset to be able to carry more than 100 tons of cargo to Mars and the Moon. The cargo version can also be used for rapid point-to-point Earth transport. Various payload bay configurations are available and allow for fully autonomous deployment of cargo to Earth, Lunar, or Martian surfaces with one example shown in Figure 7.

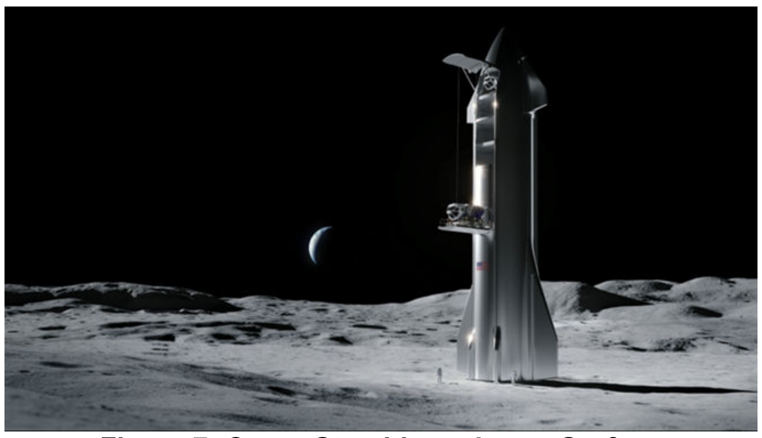

Figure 7: Cargo Starship on Lunar Surface

CREW CONFIGURATION

SpaceX was founded with the goal of making life multi-planetary. The Starship program is realizing this goal with the crew configuration of Starship. Drawing on experience from the development of Dragon for the Commercial Crew Program, the Starship crew configuration can transport up to 100 people from Earth into LEO and on to the Moon and Mars. The crew configuration of Starship includes private cabins, large common areas, centralized storage, solar storm shelters and a viewing gallery.

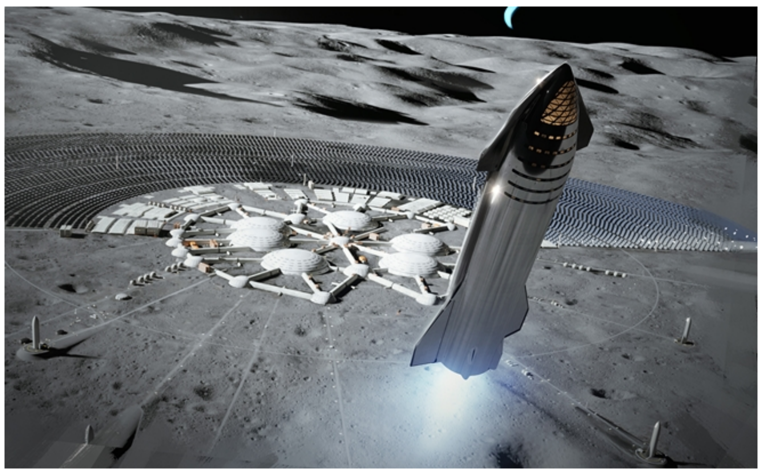

Figure 8: Starship Crew Configuration

ADDITIONAL CAPABILITIES

Fully-reusable Starship and Super Heavy systems are expected to allow for space-based activities that have not been possible since the retirement of the Space Shuttle and Space Transportation System or have never been possible before. With a fully reusable Starship, satellites can be captured and repaired in orbit, returned to Earth, or transferred to a new operational orbit. For more information on additional capabilities or to conceptualize new ideas, please contact sales@spacex.com.