NARRATIVE DESCRIPTION: STA APPLICATION NO. 0983-EX-ST-2021

STARSHIP ORBITAL TEST FLIGHT

SpaceX's Starship spacecraft and Super Heavy booster represent a fully reusable transportation system designed to carry both crew and cargo to Earth orbit, the Moon, Mars and beyond. SpaceX intends to mount Starlink satellite terminals on the Super Heavy booster and orbital Starship for Starship's first orbital test flight and use these terminals to communicate with SpaceX's Starlink satellite constellation. This is a logical extension of SpaceX's existing authorization to demonstrate Starlink operations on Starship suborbital flights.[1]

OBJECTIVES

SpaceX intends demonstrate high data rate communications with Starship and the Super Heavy Booster on the ground at the launch site in Starbase, TX during launch, during booster recovery, in flight, and during reentry. Starlink can provide unprecedented volumes of telemetry and enable communications during atmospheric reentry when ionized plasma around the spacecraft inhibits conventional telemetry frequencies. These tests will demonstrate Starlink's ability to improve the efficiency and safety of future orbital spaceflight missions.

FLIGHT PROFILE

The Starship Orbital test flight will originate from Starbase, TX. The booster stage will separate approximately 170 seconds into flight. The booster will then perform a partial return and land in the Gulf of Mexico approximately 33 km from the shore. The orbital Starship spacecraft will continue flying just south of Florida. It will achieve orbit at a maximum altitude of approximately 250 km before performing a powered, targeted soft landing approximately 100 km off the northwest coast of Kauai.

[1] *See* Space Exploration Holdings, LLC, Experimental Special Temporary Authorization, File No. 0566-EX-ST-2021 (granted June 1, 2021) (call sign WR9XYK).

Figure 1: Super Heavy Booster Launch Profile

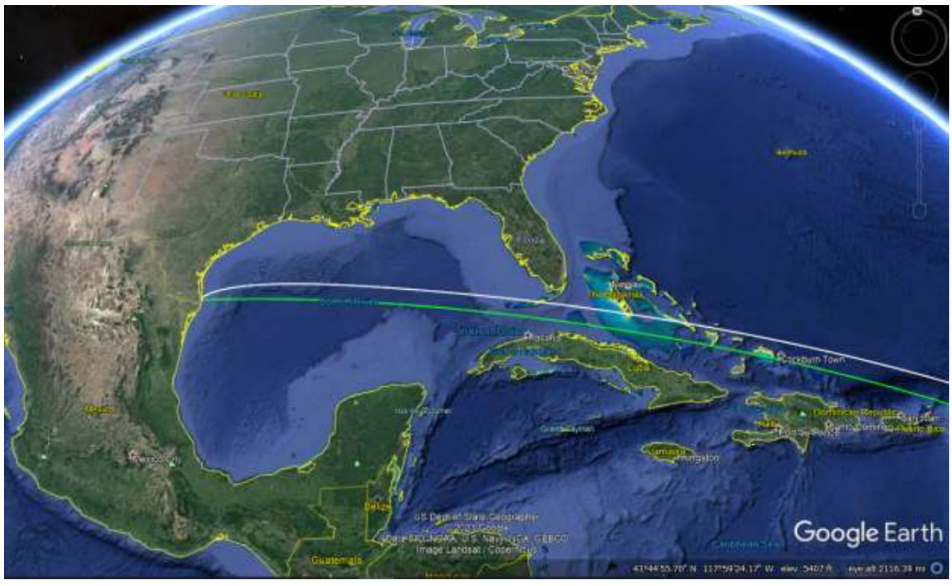


Figure 2: Starship Orbital Launch Profile

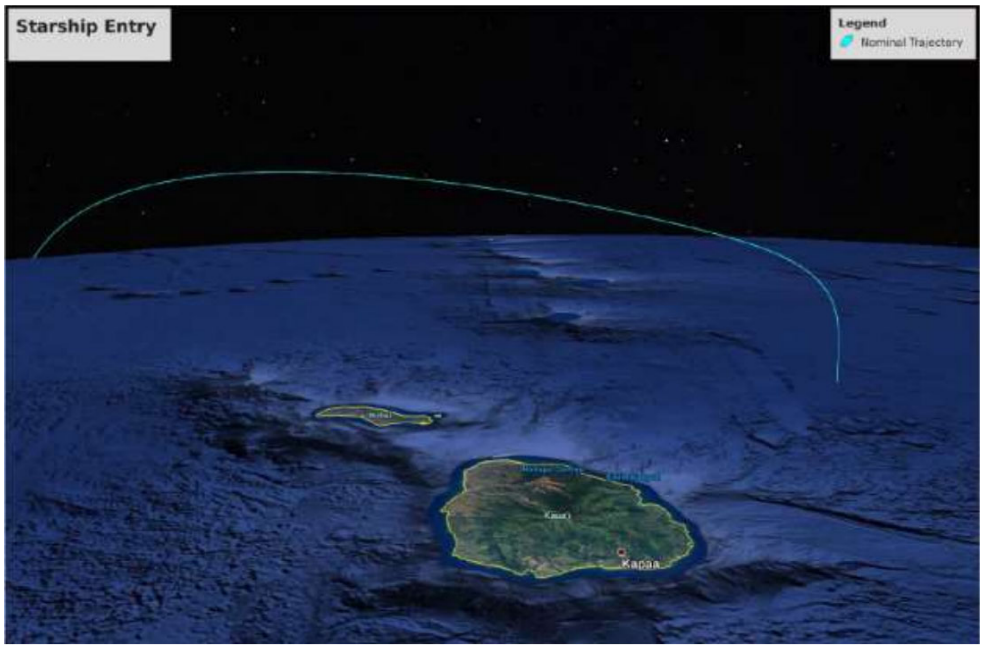


Figure 3: Starship Orbital Reentry Profile

Event T+ time (seconds)	Event T+ time (seconds)
Liftoff	0
Super Heavy Main Engine Cut Off	169
Stage Separation	171
Starship Second Engine Start	176
Super Heavy Touchdown	495
Starship Second Engine Cut Off	521
Starship Splashdown	5420

Table 1 Approximate Flight Timeline

STARLINK TERMINALS

Multiple Starlink terminals will be fitted to each vehicle to ensure a clear view of the Starlink satellite constellation through the Starship flight profile. The terminals will use the same antenna and communications electronics as SpaceX's previously authorized consumer terminals but with a revised enclosure and mounting that is suitable for the mission profile.

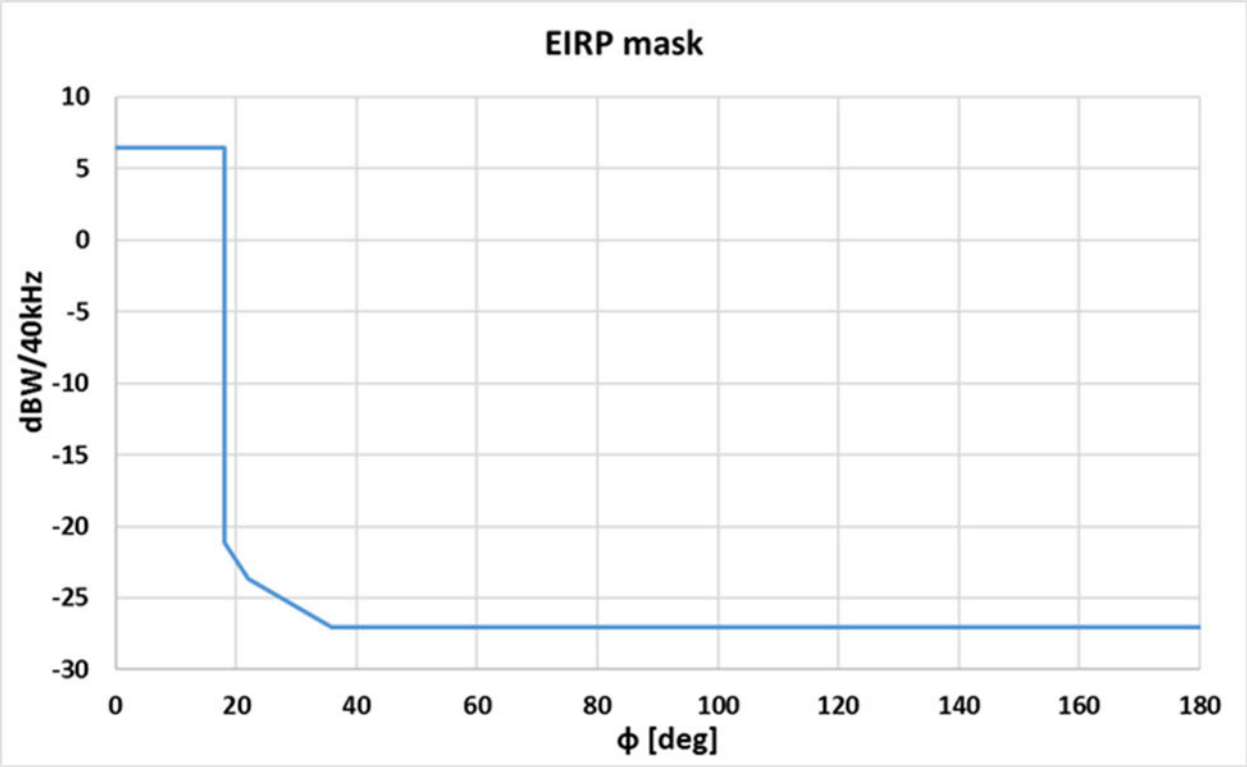
Each user terminal will communicate only with those SpaceX satellites that are visible on the horizon above a minimum elevation angle of 25 degrees and more than 18 degrees away from the Geostationary Orbital ("GSO") arc. The phased array user terminals will track SpaceX's NGSO satellites passing within their field of view. As the terminal steers the transmitting beam, it automatically changes the power to maintain a constant level at the receiving antenna of its target satellite to the extent possible, compensating for variations in antenna gain and path loss associated with the steering angle. At the phased array's equivalent of an "antenna flange," the highest transmit power is 4.06 W and the

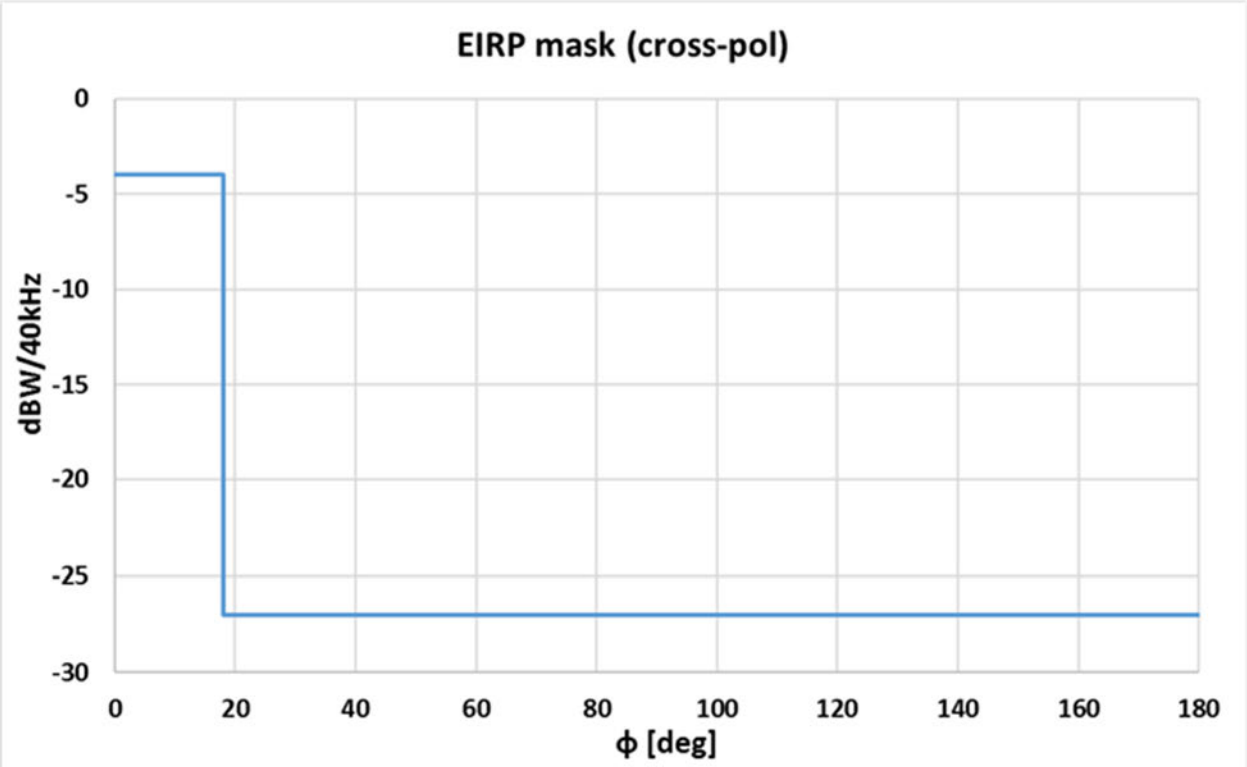
highest EIRP for all carriers is 38.2 dBW. The antenna gain is highest at boresight (33.2 dBi and 34.6 dBi for the receive and transmit antennas, respectively) and lowest at maximum slant (30.6 dBi and 32.0 dBi for the receive and transmit antennas, respectively). For purposes of the STA Form accompanying this application, SpaceX has supplied the highest transmit power figures and lowest gain figures. Table 2 summarizes the technical specifications of SpaceX's proposed earth station terminals.

Link Type	Frequency	Modulation	Emission Designator	Maximum EIRP
Broadband Downlink (space-to-Earth)	10.7-12.7 GHz	Up to 64 QAM	240MD7W	N/A
Broadband Uplink (Earth-to-space)	14.0-14.5 GHz	Up to 64 QAM	60M0D7W	38.2 dBW

Table 2: Starlink Terminal Characteristics

The EIRP masks for these proposed earth stations, for co-polarized and cross-polarized signals, are set forth below. In addition, SpaceX has attached hereto a radiation hazard analysis to demonstrate that these earth stations are compliant with and will not result in exposure levels exceeding the applicable radiation hazard limits established by the Commission.


EIRP mask
10
5
0
-5
-10
-15
-20
-25
-30
dBW/40kHz
0
20
40
60
80
100
120
140
160
180
ϕ [deg]


EIRP mask (cross-pol)
0
-5
-10
-15
-20
-25
-30
dBW/40kHz
0
20
40
60
80
100
120
140
160
180
ϕ [deg]

INTERFERENCE PROTECTION

The Commission has allocated the Ku-band that SpaceX proposes to use for uplink communications (14.0-14.5 GHz) from these blanket-licensed earth stations on a primary basis only to FSS. Certain portions of the 10.7-12.7 GHz downlink band are shared with other commercial and government services. Notably, the proposed earth stations would not transmit in those bands and thus could not cause any interference to other operators using those bands.

Geostationary Satellite Orbit Systems

The proposed operations will protect GSO systems from harmful interference by operating within the ITU EPFD limits that apply to the SpaceX user-terminal network as a whole, which the Commission has concluded "will adequately protect GSO FSS networks."[2] Here, the applicable ITU EPFD limits are provided in Article 22 and Resolution 76 of the ITU Radio Regulations, which require the assessment of a satellite system as a whole to demonstrate that the probabilities of emissions exceeding certain levels remain within specified regulatory limits.

In SpaceX's application for a blanket user-terminal authorization, which the Commission granted in March 2020, SpaceX confirmed that its user-terminal network as a whole will comply with these EPFD limits and such compliance was a condition of the Commission's grant of that authorization.[3] The user-terminals SpaceX seeks to operate in this application are planned to be electrically identical with the 1,000,000 user terminals the Commission has already permitted in that authorization from a radiofrequency perspective, and, in all events, will operate within that previously authorized user-terminal network within those EPFD limits and will not exceed the on- or off-axis EIRP levels of those devices.[4] The Commission has found that compliance with these EPFD limits is sufficient to protect GSO

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[2] *Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range*, 16 FCC Rcd. 4096, ¶ 77 (2000) (concluding that implementation of EPFD limits "will adequately protect GSO FSS networks"). *See also* 47 C.F.R. § 25.289 (NGSO satellite systems that comply with EPFD limits will be deemed not to cause unacceptable interference to any GSO network).

[3] *See* SpaceX Services, Inc., Radio Station Authorization, IBFS File No. SES-LIC-20190211-00151 (granted Mar. 13, 2020) (call sign E190066).

[4] *Id*. Notably, the Commission does not require the submission of antenna patterns for blanket-licensed NGSO earth stations, as the EIRP mask is sufficient to verify compliance with EPFD limits and other interference-protection benchmarks. SpaceX's Part 25 blanket user-terminal authorization was granted on this basis. NGSO user terminals are also not required to comply with the antenna-gain limitations in Section 25.209. The Commission has granted other blanket user-terminal authorizations as well that have not included antenna patterns and which have correctly asserted that "the Commission's antenna performance standards contained in Section 25.209 of the Commission's rules are not applicable to NGSO user terminals." *See* WorldVu Satellites Limited, Radio Station Authorization, IBFS File No. SES-LIC-20190930-01217 (granted Apr. 27, 2021) (call sign E190727).

systems against unacceptable interference.[5] Accordingly, the proposed operations will satisfy the GSO interference-protection requirements that the Commission has adopted for NGSO systems in this band.

SpaceX complies with these EPFD limits by enforcing a 25-degree minimum elevation limit, GSO avoidance angle of 18 degrees, and a transmit EIRP mask on all user terminals, including those described in this application. The minimum elevation angle and the GSO avoidance angle limit the interference geometry from the terminal to the GSO and prevent terminals from transmitting to NGSO satellites that are within 18 degrees of the GSO arc. In addition, when a terminal transmits to an NGSO satellite more than 18 degrees from the GSO arc, the EIRP mask limits the power spectral density of transmissions from the terminal toward GSO satellites. The experimental earth stations in this application will comply with the same operational limits as the terminals covered under SpaceX's blanket license and therefore will not exceed the already authorized EPFD limits for the Starlink system.

In addition, the proposed operations will comply with the FCC's requirements for NGSO Earth Stations in Motion ("ESIMs") in these bands to ensure that motion of the user-terminal will not cause it to inadvertently exceed interference protection limits. In particular, these earth stations will be self-monitoring and, should a condition occur that causes it to exceed EIRP, EIRP density or off-axis EIRP mask limits included in the licensing conditions for the FSS NGSO network that it is using as a point of communication in the 14.0-14.5 GHz band, the terminal will automatically cease transmissions within 100 milliseconds and not resume transmissions until the condition that caused the experimental terminal to exceed those limits is corrected.[6]

The protection of GSO systems is not meaningfully affected by the altitude of the terminal for the proposed test flights. At a maximum altitude of 250 km, the proposed terminals are less than 0.7% closer to the satellites in the GSO, so power reduction of only 0.06 dB is required to maintain the same power flux density at the GSO.

Fixed-Service Systems

Similar to protection of GSO systems, the ITU has adopted PFD limits (codified in Article 21 of the ITU Radio Regulations) that limit the energy of satellite downlink transmissions to protect terrestrial services. The Commission has concluded that compliance with these PFD limits is sufficient to protect terrestrial fixed-service operators from harmful interference.[7] Nothing about the operation of the proposed earth stations will affect that. As mentioned above, the 14.0-14.5 GHz band in which these earth stations transmit is allocated on a primary basis solely to FSS.

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[5] *See, e.g.*, *Updates to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, 32 FCC Rcd. 7809, ¶ 32 (2017) ("*NGSO Update Order*") ("Any NGSO FSS system operating in compliance with these [EPFD] limits is considered as having fulfilled its obligation under Article 22 of the ITU Radio Regulations not to cause unacceptable interference to any GSO network."); 47 C.F.R. § 25.289 (same).

[6] *See* 47 C.F.R. § 25.228(c).

[7] *Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range*, 16 FCC Rcd. 4096, ¶ 42 (2000).

The protection of fixed-service operators is enhanced by the higher altitude of the terminal for the proposed test flights. For example, at a maximum altitude 250 km, the proposed terminals are 20 times further away from the ground than the previously authorized 12.5 km, which will reduce the PFD of their transmissions at the ground by 26 dB.

SpaceX recognizes that the 12.2-12.7 GHz band (the "12 GHz band") is not specifically listed among the bands available for ESIM operations. The Commission did not, however, affirmatively prohibit ESIM operations in this band—though it did so with respect to other spectrum.[8] Rather, the Commission did not include the 12 GHz band because it had not been included in the proceeding and thus "the record is insufficient for us to consider use of these bands for ESIMs communications with NGSO FSS satellites."[9] But, to repeat, the proposed earth stations will only *receive* in this band, and thus cannot cause any interference to other authorized users. Moreover, the Commission's rules specifically contemplate that experimental authorizations may be issued for operations inconsistent with existing frequency allocations so long as they are on a non-interference basis.[10]

NGSO Systems

The SpaceX NGSO FSS system, including operations under the authorization requested herein, will at all times comply with the Section 25.261(c) which governs spectrum sharing between NGSO operators. Beyond the requirements of Section 25.261, the SpaceX system uses steerable and shapable beams as well as satellite diversity, which will often allow SpaceX to choose from multiple satellites capable of serving any one point on the ground. These advanced capabilities will allow SpaceX to minimize the potential for in-line events involving these or any other SpaceX earth stations. The SpaceX terminals described in this application include these same capabilities and flying at higher altitudes does not affect how these capabilities work.

TDRSS and Radio Astronomy

SpaceX will comply with its obligations, pursuant to conditions placed on its blanket user-terminal authorizations, to avoid and/or coordinate with NASA TDRSS and radioastronomy facilities as necessary to avoid harmful interference to these services.[11]

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8 *See* 47 C.F.R. § 25.115(f)(2) (prohibiting ESIM operations in the 28.35-28.4 GHz band).

9 *Facilitating the Communications of Earth Stations in Motion with Non-Geostationary Orbit Space Stations*, 35 FCC Rcd. 5137, ¶ 46 (2020).

10 *See* 47 C.F.R. § 2.102(b)(3) ("Experimental stations, pursuant to part 5 of this chapter, may be authorized [for] the use of any frequency or frequency band not exclusively allocated to the passive services" on a non-interference basis).

11 Section 25.228(j) covers operation with TDRSS and Radio Astronomy. For these experimental operations, SpaceX will not operate within radio line of sight of the listed facilities unless SpaceX has coordinated its operations.