QUESTION 7: PURPOSE OF EXPERIMENT

The Commission has authorized Space Exploration Holdings, LLC ("SpaceX") to launch and operate a constellation of over 4,400 non-geostationary orbit ("NGSO") satellites (call sign S2983/S3018) using Ku- and Ka-band spectrum.[1] SpaceX has launched over 1,300 satellites and continues to deploy its system. The Commission has also granted a blanket license for operation of up to one million end-user customer earth stations that communicate with SpaceX's NGSO constellation.[2] These user terminals employ advanced phased-array beam-forming and digital processing technologies to make highly efficient use of Ku-band spectrum resources by supporting highly directive antenna beams that point and track the system's low-Earth orbit satellites.

The Commission has previously granted experimental authority to test these same user terminals at various locations within the United States.[3] In order to expand its assessment of the end-to-end capabilities of its satellite system, SpaceX seeks authorization to expand these experimental operations to include three additional areas of operation: (1) Aboard recovery vessels (a) anchored in port, (b) in transit to predetermined landing zones, and (c) on station at those landing zone sites in U.S. territorial waters in the Pacific Ocean. Recovery vessels operating in the Pacific Ocean will be anchored at the Port of Los Angeles (33.72°N, 118.27°W). (2) Aboard recovery vessels (a) anchored in port, (b) in transit to predetermined landing zones, and (c) on station at those landing zone sites in U.S. territorial waters in the Gulf of Mexico. Recovery vessels operating in the Gulf of Mexico will be anchored at Port Canaveral, FL (28.41°N, 80.62°W); Port of Brownsville, TX (25.97°N 97.36°W); and Pascagoula, MS (30.34°N 88.51°W). (3) Aboard vehicles within 5 km of Boca Chica Village, TX, (26.00°N, -97.16°W) at altitudes not to exceed 12.5 km. These operations will only occur on the ground in Boca Chica Village, TX or during test flights of durations not to exceed eight minutes. Such authority would enable SpaceX to obtain critical data regarding the operational performance of its user terminals and the SpaceX NGSO system more broadly.

SpaceX will operate no more than ten user terminals under this experimental authorization at any given time, all of which are planned to be electrically identical to those

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1 *See Space Exploration Holdings, LLC*, 33 FCC Rcd. 3391 (2018) ("*SpaceX Authorization*"); *Space Exploration Holdings, LLC*, 34 FCC Rcd. 2526 (IB 2019).

2 *See* Radio Station Authorization, IBFS File No. SES-LIC-20190211-00151 (granted Mar. 13, 2020) (call sign E190066). The Commission's rules specifically contemplate blanket licensing for earth stations operating in these frequency bands. *See* 47 C.F.R. § 25.115(f)(2). Unless otherwise noted, the overall height of these antennas above ground level (or above existing structures) will not exceed six meters.

3 *See, e.g.*, Experimental Authorization, ELS File No. 0388-EX-CN-2019 (granted Aug. 27, 2019); Experimental Authorization, ELS File No. 0517-EX-CN-2019 (granted Aug. 27, 2019).

already authorized under SpaceX's user-terminal blanket license and, in all events, will not exceed the on- or off-axis EIRP levels of those devices.

Consistent with SpaceX's space station authorization, this earth station will transmit in the 14.0-14.5 GHz band and receive in the 10.7-12.7 GHz band. These bands are available for use by earth stations in motion communicating with NGSO FSS systems.[4] The Commission has allocated the Ku-band uplink band (14.0-14.5 GHz) that SpaceX proposes to use for this earth station 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. However, because this earth station would not transmit in 10.7-12.7 GHz, it will not cause any interference to other operators in that band. SpaceX has engineered its satellite system to achieve a high degree of flexibility to facilitate spectrum sharing with other authorized satellite and terrestrial systems. SpaceX is aware of its obligations under its authorization to protect terrestrial and space systems in these shared bands, particularly the applicable equivalent power flux-density ("EPFD") limits set forth in Article 22 and Resolution 76 of the ITU Radio Regulations and the applicable power flux-density ("PFD") limits set forth in the Commission's rules and Article 21 of the ITU Radio Regulations.[5] The Commission has found that compliance with these EPFD and PFD limits is sufficient to protect GSO systems and terrestrial systems, respectively, against harmful interference.[6]

SpaceX will protect these systems from harmful interference primarily by ensuring that its experimental user-terminal operations do not cause the SpaceX user terminal network taken as a whole to exceed these EPFD limits. Each experimental earth station in the 14-14.5 GHz band will be self-monitoring and, should a condition occur that causes them 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, the experimental terminal will automatically cease transmissions within 100 milliseconds and not resume

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4 *See* 47 C.F.R. § 25.202(a)(10)(ii).

5 *See SpaceX Authorization,* ¶¶ 40(b), (d), and (e); 47 C.F.R. § 25.115(f)(1) (incorporating certification requirement in 47 C.F.R. § 25.146(a)(2)).

6 *See, e.g., 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"); 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); *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) (observing PFD limits should protect terrestrial systems in the band). In addition, pursuant to Section 25.115(i), SpaceX Services hereby certifies that it is planning to use a contention protocol (TDMA/FDMA), and such protocol usage will be reasonable.

transmissions until the condition that caused the experimental terminal to exceed those limits is corrected.

In addition, SpaceX recognizes that its earth station operations will be subject to certain sharing conditions.[7] With respect to the requirements in Section 25.228(j), the SpaceX testing in Boca Chica Village, Texas in the 14-14.2 GHz band will not occur within radio line of sight of NASA TDRS facilities at three locations and will not operate in the 14.47-14.5 GHz band within radio line of sight of radio astronomy observatories at sixteen locations.[8]

SpaceX is confident that the highly advanced and flexible capabilities of its NGSO system, including the earth stations proposed by SpaceX herein, will be able to comply with the limitations discussed above. Nevertheless, in the extremely unlikely event that harmful interference should occur due to transmissions to or from its earth stations, SpaceX will take all reasonable steps to eliminate the interference. Should an issue arise, SpaceX can be reached at:

Starlink Network Operations Center
satellite-operators-pager@spacex.com
+1 (360) 780 - 3103

SpaceX's user terminal will communicate only with those SpaceX satellites that are visible on the horizon above a minimum elevation angle of 25 degrees. The proposed flat phased array user terminal will track SpaceX's NGSO satellites passing within its 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, 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 (4.06 W) occurs at maximum slant, while the lowest transmit power (0.76 W) occurs at boresight. Similarly, the highest EIRP for all carriers (38.2 dBW) occurs at maximum slant and the lowest level (33.4 dBW) occurs at boresight. Conversely, 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 Form 442 accompanying this application, SpaceX has supplied the higher transmit power figures and lower gain figures in order to present worst-case conditions.

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[7] *See, e.g.*, 47 C.F.R. §§ 25.115(f)(2); 25.208(o); 101.1409; 2.106 n.5.487A; and 2.106 n.342.

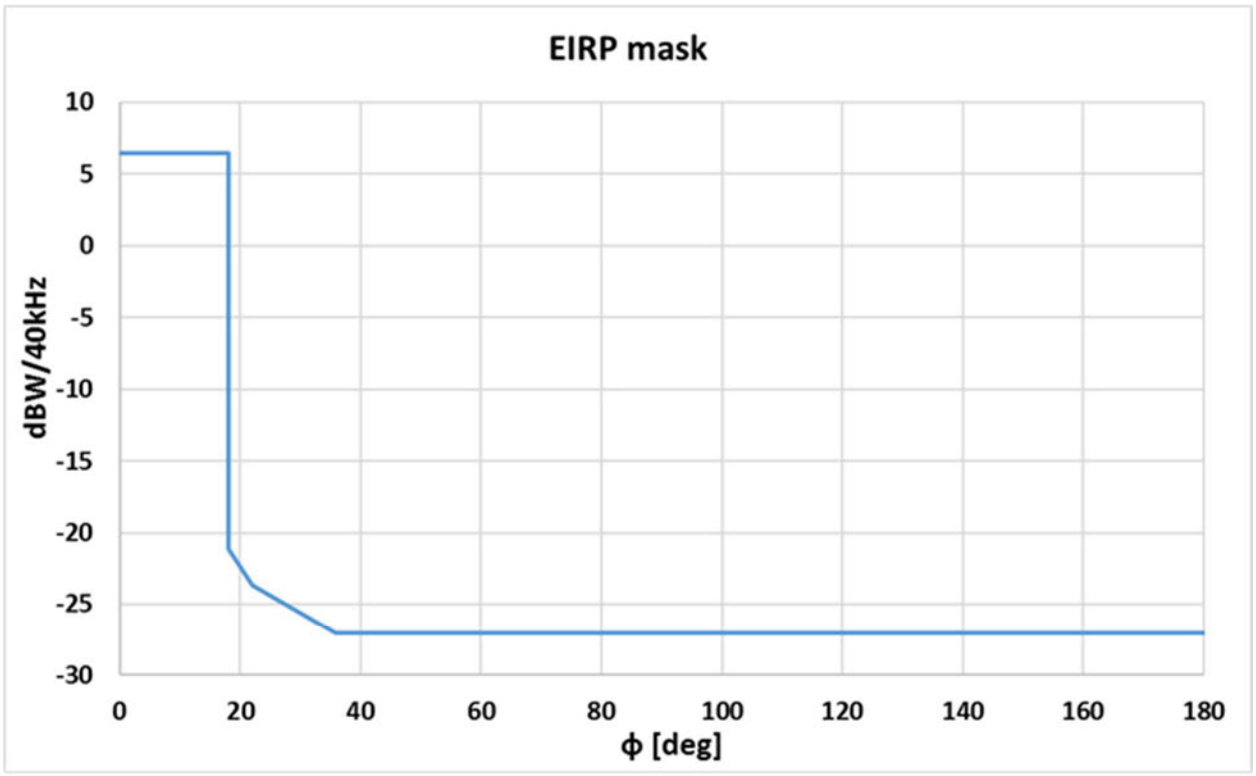
[8] *See* 47 C.F.R. § 25.228(j)(1) and (3). *See also SpaceX Authorization*, ¶ 37 (requiring SpaceX to take note of NASA TDRS facilities at three locations).

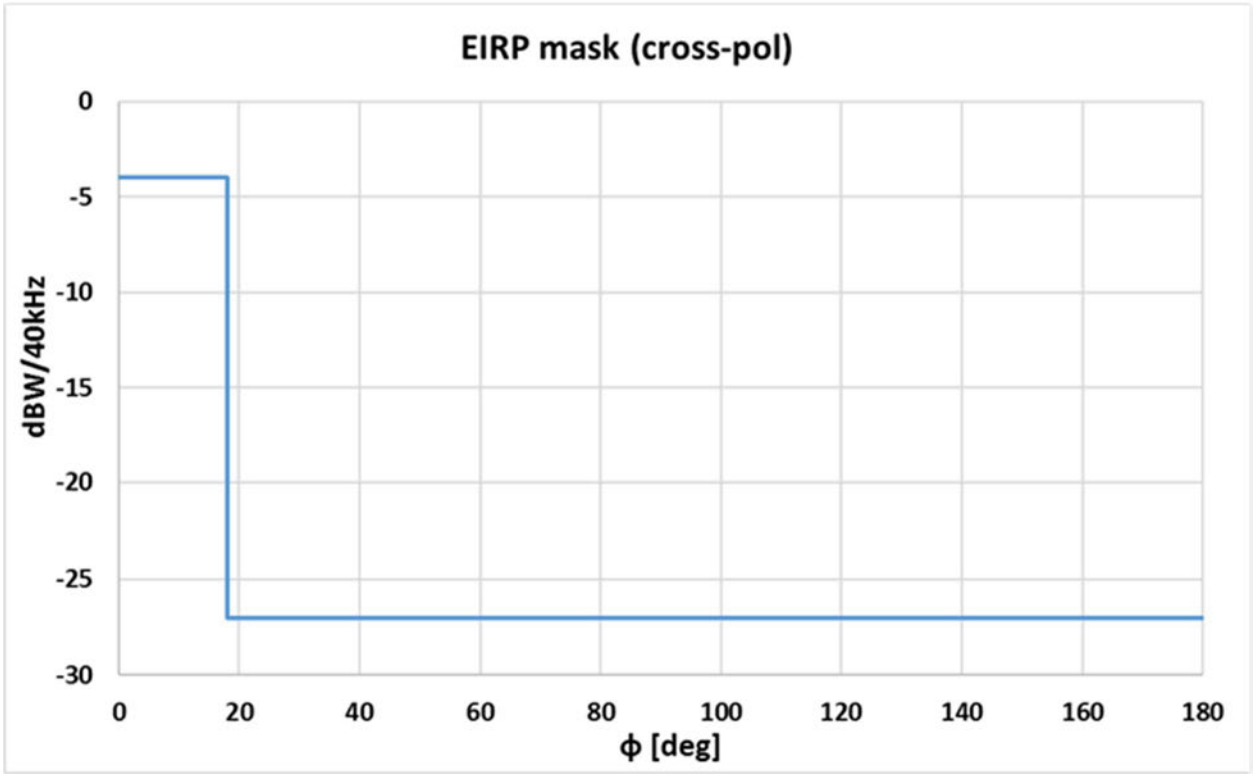
For reference, Table 1 summarizes the technical specifications of SpaceX's proposed earth station terminals.

Link Type	Frequency	Modulation	Emission Designator	Maximum EIRP	Half Power Beamwidth
Broadband Downlink (space-to-Earth)	10.7-12.7 GHz	Up to 64 QAM	240MD7W	N/A	3.5° (boresight) 5.5° (at slant)
Broadband Uplink (Earth-to-space)	14.0-14.5 GHz	Up to 64 QAM	60M0D7W	38.2 dBW	2.8° (boresight) 4.5° (at slant)

Table 1. User Terminal Specifications

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]