QUESTION 7: PURPOSE OF EXPERIMENT

The Commission has authorized Space Exploration Holdings, LLC ("SpaceX") to launch and operate a constellation of 4,425 non-geostationary orbit ("NGSO") satellites (call sign S2983/S3018) using Ku- and Ka-band spectrum.[1] In doing so, the Commission recognized that granting the SpaceX Authorization would "enable SpaceX to bring high-speed, reliable, and affordable broadband service to consumers in the United States and around the world, including areas underserved or currently unserved by existing networks."[2] On May 23, 2019, SpaceX launched the first 60 satellites of its constellation. Those satellites should reach their assigned operational orbits within the next few weeks.

In order to assess the end-to-end capabilities of its satellite system, SpaceX seeks authority to test the earth stations that end-user customers will utilize to communicate with SpaceX's NGSO constellation. A SpaceX affiliate has applied for a blanket commercial license for some of these same customer earth stations.[3] 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. That application is still pending, and SpaceX would like the opportunity to test its consumer terminals for up to one year while the Commission is processing it. In addition, SpaceX would like to test a one meter parabolic antenna with essentially the same performance characteristics as the phased array, since some users may prefer this type of earth station. Consistent with SpaceX's space station authorization, both of these earth stations will transmit in the 14.0-14.5 GHz band and receive in the 10.7-12.7 GHz band. SpaceX seeks authority to deploy and operate these earth stations throughout the United States.[4]

SpaceX seeks experimental authority for two types of testing: (1) a total of 70 user terminals (mixed between the two types of antennas) so that it can test multiple devices at a number of geographically dispersed locations throughout the United States; and (2) up to 200 phased array user terminals to be deployed within the state of Washington at the homes of SpaceX employees for ongoing testing. Such authority would enable SpaceX to obtain critical data regarding the operational performance of these user terminals and the SpaceX

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1 *See Space Exploration Holdings, LLC*, 33 FCC Rcd. 3391 (2018) ("SpaceX Authorization"). The Commission recently modified that authorization so that SpaceX could relocate 1,584 satellites previously authorized to operate at an altitude of 1,150 km to an altitude of 550 km, and to make related changes to the operations of the satellites in this new lower shell of the constellation. *See Space Exploration Holdings, LLC*, DA 19-342 (rel. Apr. 26, 2019).

2 SpaceX Authorization, ¶ 1.

3 *See* IBFS File No. SES-LIC-20190211-00151.

4 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). The overall height of these antennas above ground level (or above existing structures) will not exceed six meters.

NGSO system more broadly. The number of earth station terminals requested is necessary to enable SpaceX to fully evaluate the operational characteristics of its system as it advances its plan to bring high-speed, reliable, and affordable broadband service to consumers in the United States and around the world.

The Commission has allocated the Ku-band uplink band (14.0-14.5 GHz) that SpaceX proposes to use for these earth stations on a primary basis only to FSS. However, certain portions of the downlink band are shared with other commercial and government services. SpaceX has engineered its NGSO 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] In addition, SpaceX recognizes that its earth station operations will be subject to certain sharing conditions.[7] 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 these limitations.

SpaceX's user terminals 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

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[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).

[7] *See, e.g.,* 47 C.F.R. §§ 25.115(f)(2); 25.208(o); 101.1409; 2.106 footnote 5.487A; and 2.106 footnote 342. *See also* SpaceX Authorization, ¶ 37 (requiring SpaceX to take note of NASA TDRS facilities at three locations). 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.

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.[8] 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.

For the parabolic antenna, the transmit power ranges from 0.65 W at maximum slant to 0.21 at boresight, while the maximum EIRP levels are the same as for the phased array. Here again, for purposes of Form 442 accompanying this application, SpaceX has supplied the higher transmit power figure in order to present worst-case conditions. Unlike the phased array, however, the gain of the parabolic antenna does not change as it tracks SpaceX's NGSO satellites.

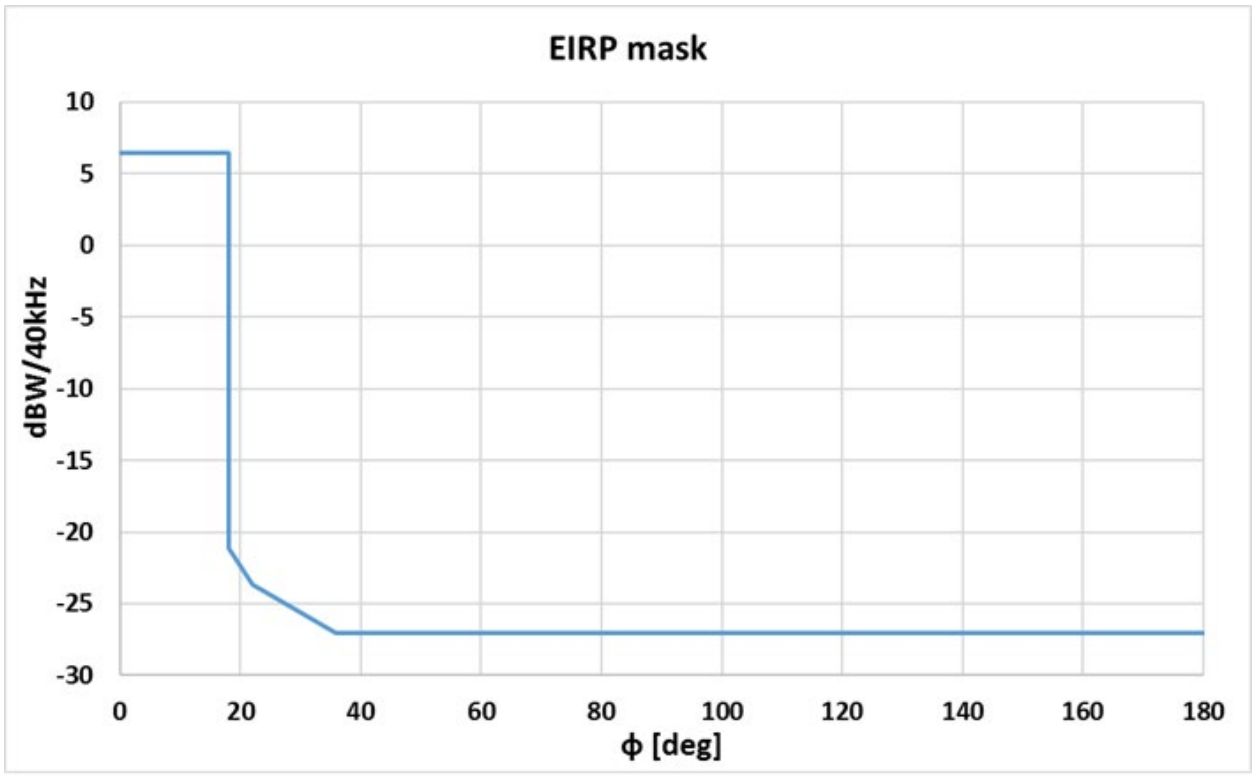
Table 1 summarizes the technical specifications of SpaceX's proposed earth station terminals.

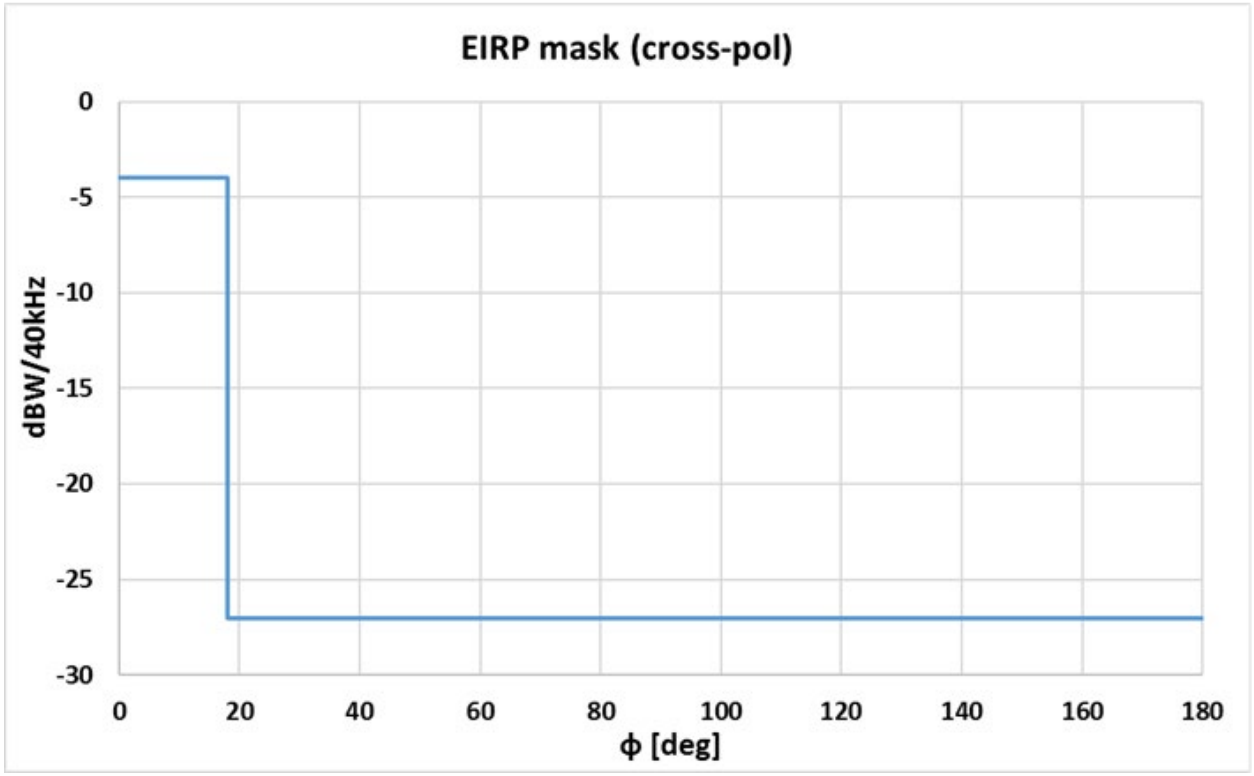
Link Type	Frequency	Modulation	Emission Designator	Maximum EIRP	Half Power Beamwidth
Broadband Downlink (space-to-Earth)	10.7-12.7 GHz	Up to 64 QAM	240MD7W	N/A	3.5° (at boresight) 5.5° (at slant) 1.8° (parabolic)
Broadband Uplink (Earth-to-space)	14.0-14.5 GHz	Up to 64 QAM	63M5D7W	38.2 dBW	2.8° (at boresight) 4.5° (at slant) 1.5° (parabolic)

Table 1. Consumer 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.

[8] For both types of antenna, there is no difference in transmit power between end user terminals at the center or edge of the spot or between clear sky or heavy rain conditions.


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]