QUESTION 7: PURPOSE OF EXPERIMENT

NARRATIVE SUMMARY

Space Exploration Technologies Corp. ("SpaceX") is a U.S. space technology company that designs, manufactures, and launches advanced rockets and spacecraft. The company is headquartered in Hawthorne, California and has over 6,000 employees based in the United States.

On March 29, 2018, the Commission granted SpaceX's application for authority to launch and operate a constellation of non-geostationary orbit ("NGSO") satellites designed to provide high-speed, high-capacity, low-latency broadband services in the United States and around the world.[1] SpaceX successfully launched its first 60 Starlink satellites in May 2019, and to date has launched a total of 420 Starlink satellites. The Commission has previously granted SpaceX an experimental authorization for activities undertaken with the federal government to demonstrate the ability of SpaceX's NGSO system to transmit and receive information between both fixed sites on the ground and airborne earth stations aboard moving aircraft.[2]

In this application, SpaceX seeks an experimental authorization for additional test activities undertaken with the federal government.[3] Like those previously authorized, the tests are designed to demonstrate the ability to transmit to and receive information from (1) two stationary ground sites and (2) one airborne aircraft at one location. Nothing about these experiments will change the operation of SpaceX spacecraft, which will continue to operate as authorized. This application only seeks authority to use an earth station to transmit signals to the SpaceX satellites first from a fixed position on the ground and later from a moving aircraft, and to operate two gateways to complete the link. As discussed below, these proposed operations will not adversely affect any other authorized spectrum user, including geostationary orbit ("GSO") satellite systems.

For this effort, SpaceX is working with Ball Aerospace, a manufacturer of conformal antennas for tactical aircraft, which will provide antennas required for aircraft testing. SpaceX will analyze the data link performance and installation options for user terminals with conformal arrays. In order to complete the link with its satellites, SpaceX will use gateways at Panaca, NV, and Redmond, WA.[4] Information on the aircraft and gateway earth station antennas, including operational parameters and antenna gain patterns, are provided in Exhibit 1 to this application.

---

1 *See Space Exploration Holdings, LLC*, 33 FCC Rcd. 3391 (2018). The Commission has since granted two modifications to the license. *See Space Exploration Holdings, LLC*, 34 FCC Rcd. 2526 (IB 2019); *Space Exploration Holdings, LLC*, DA 19-1294 (rel. Dec. 19, 2019).

2 *See* Experimental Authorization, ELS File No. 0515-EX-CN-2019 (rel. Aug. 26, 2019).

3 The requested authorization would be used in fulfilling the requirements of an agreement with the Air Force Strategic Development Planning and Experimentation Office (SDPE) for Defense Experimentation Using Commercial Space Internet (DEUCSI) program, contract number FA8650-19-9-9320.

4 Applications to license these two gateway earth stations are currently pending and contain complete information on their operational parameters. *See* IBFS File Nos. SES-LIC-20190827-01110 and SES-LIC-20200402-00367.

As shown in Table 1, the locations from which SpaceX seeks authority to operate are all located in CONUS. At each of these locations, SpaceX would perform outdoor ground testing. At the California location, SpaceX would also conduct airborne testing at a maximum altitude of 40,000 feet within a radius of 1000 km of the ground test site. Communications with the satellites will be limited to a minimum elevation of 25 degrees above the horizon at all times during testing.

Location	**Stationary or Mobile**	**Lat/Long**
Redmond, Washington	Stationary	47.6941°N, 122.0327°W
Edwards Air Force Base, California	Stationary	34.9197°N, 117.8877°W
Edwards Air Force Base, California	Mobile: Airborne max altitude 40,000 ft. AGL, within 1000 km radius	34.9197°N, 117.8877°W
Panaca, Nevada	Stationary (gateway)	37° 47' 1.1" N 114° 41' 33.7" W

Table 1: Testing locations

To prepare for the Ground-to-Air testing, SpaceX will first test the SpaceX modem integrated with the inertially stabilized electronically steered array technology as part of the ground testing. This ground testing will take place near SpaceX's Redmond, WA facilities. It will include interfacing the modem RF and antenna steering interfaces to the antennas. SpaceX will not begin Ground-to-Air integration and testing until it has performed sufficient characterization of the airborne antenna configuration with representative motion profiles. SpaceX will perform a series of tests with the integrated airborne prototype terminal, including tests with antenna static angles from 0 to up to 70 degrees from boresight, and then varying motion for representative roll and pitch of an aircraft.

For the Ground-to-Air scenario, an antenna terminal will be integrated onto one aircraft. SpaceX is designing a custom installation kit consisting of mechanical plates for the low-profile antennas and a fairing to reduce wind drag in order to limit the impact to the aircraft for this installation. The antennas will interface with SpaceX test equipment to form a user terminal for the demonstration. The existing antenna design meets the required transmit effective isotropic radiated power and receive gain over temperature for each configuration up to four transmit subarrays and six receive subarrays. SpaceX will test the full range of configurations, from one transmit and one receive subarray up to the operational configuration of four transmit and six receive subarrays to characterize the link performance at each stage.

SpaceX anticipates that the Ground-to-Air testing will require four to six months to complete within the 12 month testing period.

Equivalent Power Flux Density at the Geostationary Satellite Orbit in the Ku- and Ka-Bands

The Commission and the ITU have adopted EPFD limits designed to protect GSO satellite systems against harmful interference from NGSO satellite systems. Section 25.146(a)(2) of the Commission's rules provides that NGSO FSS systems operating in the 10.7-30 GHz frequency range must meet the EPFD limits set forth in Article 22 of the ITU Radio Regulations.[5] In the 12.75-14.5 GHz band, the EPFD in the Earth-to-space direction ($EPFD_{up}$), produced at any point on the GSO arc by the emissions from all co-frequency earth stations in an NGSO FSS system, for all conditions and for all methods of modulation, shall not exceed -160 dBW/m^2 in 40 kHz bandwidth.[6] In the 27.5-30.0 GHz band, the $EPFD_{up}$ shall not exceed -162 dBW/m^2 in 40 kHz bandwidth.[7]

The calculations in Table 2 below demonstrate that the $EPFD_{up}$ produced by the transmissions from the proposed Ball Aerospace earth stations, whether on the ground or operating while airborne, will never exceed the relevant ITU limit. Similarly, Table 3 demonstrates that the $EPFD_{up}$ produced by the transmissions from the proposed gateway earth stations will comply with the applicable limits. For both analyses, an occupied bandwidth of 60 MHz is used. Note that the earth station transmitter is turned off whenever (1) there is no SpaceX satellite in view at an elevation angle of at least 25 degrees, or (2) the direction of the SpaceX earth station transmit beam and the GSO arc is separated by less than 18°. In addition, the sidelobes of the antenna patterns are at least 20 dB down from the main lobe at 18° separation or more.

[5] *See* 47 C.F.R. § 25.146(a)(2).

[6] *See* ITU Radio Regs. No. 22.5D and Table 22-2.

[7] *See id.*

	Earth Station on Ground	Earth Station Airborne
Distance to GSO altitude [km]	35786	35773.8
EIRP @ zenith [dBW]	39.1	39.1
EIRP density @ zenith [dBW/Hz]	-38.7	-38.7
EIRP in 40kHz [dBW]	7.34	7.34
Sidelobe level towards GSO arc [dB]	-20.0	-20.0
Spreading loss [dB]	-162.07	-162.07
$EPFD_{up}$ [dB(W/m^2)/40kHz]	-176.0	-176.0

Table 2. $EPFD_{up}$ for proposed Ball Aerospace earth stations

Distance to GSO altitude [km]	35786
EIRP @ zenith [dBW]	66.5
EIRP density @ zenith [dBW/Hz]	-29.33
EIRP in 40kHz [dBW]	16.6
Sidelobe level towards GSO arc [dB]	-40.0
Spreading loss [dB]	-162.07
$EPFD_{up}$ [dB(W/m^2)/40kHz]	-185.38

Table 3. $EPFD_{up}$ for proposed Gateway earth stations

As demonstrated above, the GSO arc avoidance techniques used by the earth stations ensure the system never exceeds the applicable uplink EPFD limit. Accordingly, SpaceX is confident that the proposed operations will not affect any GSO satellite services. In the wholly unlikely case that there is confirmed interference to a GSO system by SpaceX, SpaceX will cease transmission on the relevant frequency and work with the Commission and other relevant parties to mitigate future occurrences.