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] As a development step towards this initiative, SpaceX applied for and was granted on November 16, 2017, an experimental authorization for the launch and operation of two initial test and demonstration satellites (Microsat-2a and Microsat-2b) over the course of two years.[2] The Commission then authorized a request from SpaceX to modify its experimental authorization to allow testing of two different antennas, both of which were to operate on the ground and one of which was also to operate from a moving aircraft. SpaceX has not received any interference notices from any authorized users in the spectrum bands that SpaceX has been authorized to use for testing in the existing license, including the modification.

The Commission granted on April 26, 2019, SpaceX's request for modification of its commercial license to lower the operating altitude of 1,584 satellites in its constellation from 1,150 km to 550 km.[3] SpaceX successfully launched its first 60 satellites on May 24, 2019.

In this application, SpaceX seeks an experimental authorization to test activities undertaken with the federal government. The tests are designed to demonstrate the ability to transmit and receive information (1) between five ground sites ("Ground-to-Ground") and (2) between four ground sites and an airborne aircraft ("Ground-to-Air"). Nothing about the operation of and transmissions from the satellites will change under this modification. This application seeks only to use an earth station to transmit signals to the SpaceX satellites first from the ground and later from a moving aircraft. For this purpose, SpaceX will use the same antenna used in the earlier experiments with Microsat-2a and Microsat-2b. As discussed below, these proposed operations will not adversely affect any other authorized spectrum user, including geostationary orbit ("GSO") satellite systems.

Proposed Antennas

SpaceX seeks an experimental authorization to allow ground and air testing of an antenna used during the Mircosat experiments, but communicating with the operational satellites under

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1 *See Space Exploration Holdings, LLC*, 33 FCC Rcd. 3391 (2018).

2 *See* Call Sign WI2XTA, File No. 0298-EX-CN-2016 (granted Nov. 16, 2017).

3 *See Space Exploration Holdings, LLC*, DA 19-342 (rel. Apr. 26, 2019).

SpaceX's license. In conducting these experiments, SpaceX would operate under the same technical parameters outlined in its existing experimental license, including the RF output power, frequencies used, and emission bandwidth, but would do so while communicating with the satellites launched under its commercial authorization. Additional information on the earth station antenna, including antenna gain patterns, are provided in Exhibit 1 to this application.

As shown in Table 1, SpaceX seeks authority to operate from up to five locations exclusively in CONUS. At each of these locations, SpaceX would perform outdoor ground testing. At each location other than Redmond, WA, SpaceX would also conduct airborne testing aboard aircraft at a maximum altitude of 35,000 feet within a radius of 1,000 km of the ground test site. Communications with the satellites will be limited to a minimum of 40 degree elevation angle at all times during testing.

Location	**Stationary or Mobile**	**Lat/Long**
Redmond, Washington	Stationary	47.6941°N, 122.0327°W
Hurlburt Field, Florida	Stationary and Mobile	30.4280°N, 86.6935°W
Joint Base Lewis-McChord Field, Washington	Stationary and Mobile	47.0870°N, 122.5834°W
Mountain Home Air Force Base, Idaho	Stationary and Mobile	43.0444° N, 115.8620° W
Harrisburg Air Force Base, Pennsylvania	Stationary and Mobile	40.1928°N, 76.7454°W
Cape Canaveral, Florida	Stationary and Mobile	28.4740° N, 80.5772° W

Table 1: Testing locations

To complete the link with its satellites, SpaceX would also use existing gateway earth stations located in Redmond, WA and Greenville, PA,[4] and will set up experimental gateways at Hurlburt Field, Mountain Home Air Force Base, and Cape Canaveral. Additional information on these earth station antennas is also included in Exhibit 1 to this application.

For this effort, SpaceX is working with a manufacturer of conformal antennas for tactical aircraft, which will provide antennas required for aircraft testing. This will assist SpaceX in analyzing the data link performance and installation options for user terminals with conformal arrays.

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.

[4] Applications to license these two gateway earth stations are currently pending. *See* IBFS File Nos. SES-LIC-20190402-00426 and -00427, SES-AMD-20190410-00520 and -00521.

This ground testing is expected to take place near other planned testing at 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 40 degrees from boresight, and then varying motion for representative roll and pitch rates of a high-performance aircraft.

For the Ground-to-Air scenario, an antenna will be built and integrated onto an aircraft. The antenna manufacturer is designing a custom installation kit consisting of mechanical plates for the low-profile antennas and fairings reducing 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 when using four transmit subarrays and six receive subarrays.

SpaceX anticipates that the Ground-to-Air testing will require four to six weeks to complete.

Example test sequence for new antenna:

1. Wait for satellite to rise to 40 degrees elevation over test site
2. Initiate broadband test from ground
3. Perform broadband test with earth stations (either on ground or airborne)
4. Satellites set below 40 degrees elevation as viewed from test site
5. Satellite disables Ku-band broadband system

Equivalent Power Flux Density at the Geostationary Satellite Orbit in the Ku band (12.75-14.5GHz)

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]

The calculations in Table 2 below demonstrate that the $EPFD_{up}$ produced by the transmissions from the proposed earth stations, whether on the ground or operating while airborne, will never exceed the relevant ITU limit. An occupied bandwidth of 240 MHz is used. Note that the earth station transmitter is turned off whenever (1) there is no SpaceX satellite in view at an elevation

5 *See* 47 C.F.R. § 25.146(a)(2).

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

angle of at least 40 degrees, or (2) the direction of the SpaceX earth station transmit beam and the GSO arc is separated by less than 12°. In addition, the sidelobes of the antenna patterns are at least 15dB down from the main lobe at 12° separation or more.

	Earth Station on Ground	**Earth Station Airborne**
Distance to GSO altitude [km]	35786	35775.3
EIRP @ zenith [dBW]	38.8	38.8
EIRP density @ zenith [dBW/Hz]	-45.0	-45.0
EIRP in 40kHz [dBW]	1.0	1.0
Sidelobe level towards GSO arc [dB]	-15.0	-15.0
Spreading loss [dB]	-162.07	-162.07
$EPFD_{up}$ [dB(W/m^2)/40kHz]	-195.0	-195.0

Table 2. EPFDup for the proposed earth stations

As demonstrated above, the brief transmit times, GSO arc avoidance techniques, and adaptable power levels used by the earth stations ensure the system never exceeds the applicable -160dB(W/m^2)/40kHz 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.