

APPLICATION FOR TT&C EARTH STATION

I. OVERVIEW

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 SpaceX intends to begin launching satellites to populate its constellation later this year.

This application, filed by a sister company, SpaceX Services, Inc. (“SpaceX Services”), seeks authority to operate an earth station that SpaceX will use to perform telemetry, tracking, and control (“TT&C”) functions for its NGSO system. Consistent with SpaceX’s space station authorization, this earth station will transmit in the 13.9-13.95 GHz band and receive in the 12.2-12.25 GHz band.

Below, we discuss certain spectrum sharing issues relevant to the operation of these earth stations. We then demonstrate that grant of this application would serve the public interest. Lastly, we provide technical information to supplement the information provided on Form 312. To support its ambitious timetable for launching satellites and deploying broadband services, SpaceX Services requests that the Commission grant the requested license as expeditiously as possible.

¹ See *Space Exploration Holdings, LLC*, 33 FCC Rcd. 148 (2018) (“SpaceX Authorization”). SpaceX recently filed a modification application in which it proposes to 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 Application, IBFS File No. SAT-MOD-20181108-00083 (Nov. 8, 2018).

² SpaceX Authorization, ¶ 1.

II. SPECTRUM SHARING ISSUES

The Commission has allocated the Ku-band uplink band (13.9-13.95 GHz) that SpaceX Services proposes to use for this TT&C earth station on a primary basis only to FSS. However, the downlink band (12.2-12.25 GHz) is shared with other commercial and government services. SpaceX has engineered its NGSO system design 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.³ 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.⁴ In addition, SpaceX Services recognizes that its earth station operations will be subject to certain sharing conditions, including those relating to the Multichannel Video and Data Distribution Service.⁵ SpaceX is confident that the highly advanced and flexible capabilities of its NGSO system, including the earth station proposed by SpaceX Services herein, will be able to comply with these

³ 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)).

⁴ 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).

⁵ See, e.g., 47 C.F.R. §§ 25.115(f)(2); 25.208(o); and 101.1409.

limitations.

In addition, the attached Technical Annex includes a demonstration that the proposed TT&C earth station will comply with the criteria established by the Commission for the protection of U.S. Navy shipboard radiolocation operations (RADAR) and NASA space research activities in the 13.75 - 14.0 GHz band against harmful interference.⁶

III. GRANT OF THIS APPLICATION WOULD SERVE THE PUBLIC INTEREST

Granting this application would serve the public interest by helping to speed broadband deployment throughout the United States by authorizing the ground-based component of SpaceX's satellite system. U.S. and worldwide demand for broadband services and Internet connectivity continues to increase with escalating requirements for speed, capacity, and reliability and ongoing adaptations for usage. The volume of traffic flowing over the world's networks has exploded, with one report estimating that annual global Internet protocol traffic reached 1.5 zettabytes in 2017 – meaning that approximately 1,500 billion gigabytes of data were exchanged worldwide last year.⁷

Yet, as the Commission has recognized, many communities across the United States and the world still lack access to reliable broadband connectivity, preventing them from fully participating in economic, social, and civic activities.⁸ To help close this digital divide, SpaceX is

⁶ See *Amendment of Parts 2, 25, and 90 of the Commission's Rules to Allocate the 13.75-14.0 GHz Band to the Fixed-Satellite Service*, 11 FCC Rcd. 11951, ¶¶ 18-22 (1996).

⁷ See Cisco Visual Networking Index: Forecast and Methodology, 2017-2022, at 1 (Nov. 26, 2018), available at <https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html>.

⁸ See, e.g., *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion*, 33 FCC Rcd. 1660, ¶ 50 (2018) (noting that “over 24 million Americans still lack fixed terrestrial broadband at speeds of 25 Mbps/3 Mbps,” and that “the gap in rural and Tribal America remains notable: 30.7 percent of Americans in rural areas and 35.4 percent of Americans in Tribal lands lack access to fixed terrestrial 25 Mbps/3 Mbps broadband”). Internationally, the disparities between broadband access and absence are even greater, with 4.2 billion people (or 57% of the world's population) offline. See BROADBAND COMMISSION FOR SUSTAINABLE DEVELOPMENT, “Open Statement from the Broadband Commission for Sustainable Development to the UN High-Level Political Forum (HLPF)” (July 11, 2016), available at <http://broadbandcommission.org/Documents/publications/HLPF-July2016.pdf>. See also BROADBAND

designing, constructing, and deploying an innovative, cost-effective and spectrum-efficient satellite system capable of delivering robust broadband service to customers around the world. SpaceX has already secured U.S. authority for the space station components of its NGSO system. This application takes the next step by seeking authority for a TT&C earth station that will be used in coordination with others located around the world to ensure that SpaceX has sufficient command and control over its satellite system. Accordingly, an expeditious grant of this application would serve the public interest.

Respectfully submitted,

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COMMISSION FOR SUSTAINABLE DEVELOPMENT, “The State of Broadband 2015,” at 8 (Sep. 2015), *available at* <http://www.broadbandcommission.org/Documents/reports/bb-annualreport2015.pdf> (“A large body of evidence has now been amassed that affordable and effective broadband connectivity is a vital enabler of economic growth, social inclusion and environmental protection.” (footnotes omitted)).

TECHNICAL ANNEX

In this Technical Annex, SpaceX Services provides additional information on the proposed operations of its gateway earth station to supplement the data provided in Schedule B to Form 312 filed with this narrative application.¹

A. Antenna Patterns

Section 25.209 of the Commission's rules imposes reference antenna pattern requirements for certain satellite earth stations. Most of these relate to earth stations communicating with GSO systems, as the rule was developed to facilitate GSO-to-GSO sharing where a constant level of interference is present.² However, Section 25.209(h) specifies performance standards for transmitting antennas in a gateway earth station communicating with NGSO FSS satellites in the 10.7-11.7 GHz and 14.4-14.5 GHz bands.³ For this purpose, the Commission defines "NGSO FSS gateway earth station" as an earth station or complex of multiple earth station antennas that supports the routing and switching functions of an NGSO FSS system and that does not originate or terminate communications traffic.⁴ The TT&C earth station proposed in this application is not such a "gateway."

Accordingly, the Commission's earth station licensing rules that are predicated on antenna performance standards do not apply to this application. For example, Section 25.132 of the Commission's rules provides that applications for transmitting FSS earth stations must include a

¹ To the extent relevant, SpaceX Services hereby incorporates the technical information submitted with SpaceX's space station applications. See IBFS File Nos. SAT-LOA-20161115-00118, SAT-LOA-20170726-00110, and SAT-MOD-20181108-00083.

² See *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, ¶ 81 (2000) ("*Ku-Band NGSO Order*"). But see 47 C.F.R. § 25.209(h) (specifying performance standards for transmitting gateway earth stations operating with Ku-band NGSO systems).

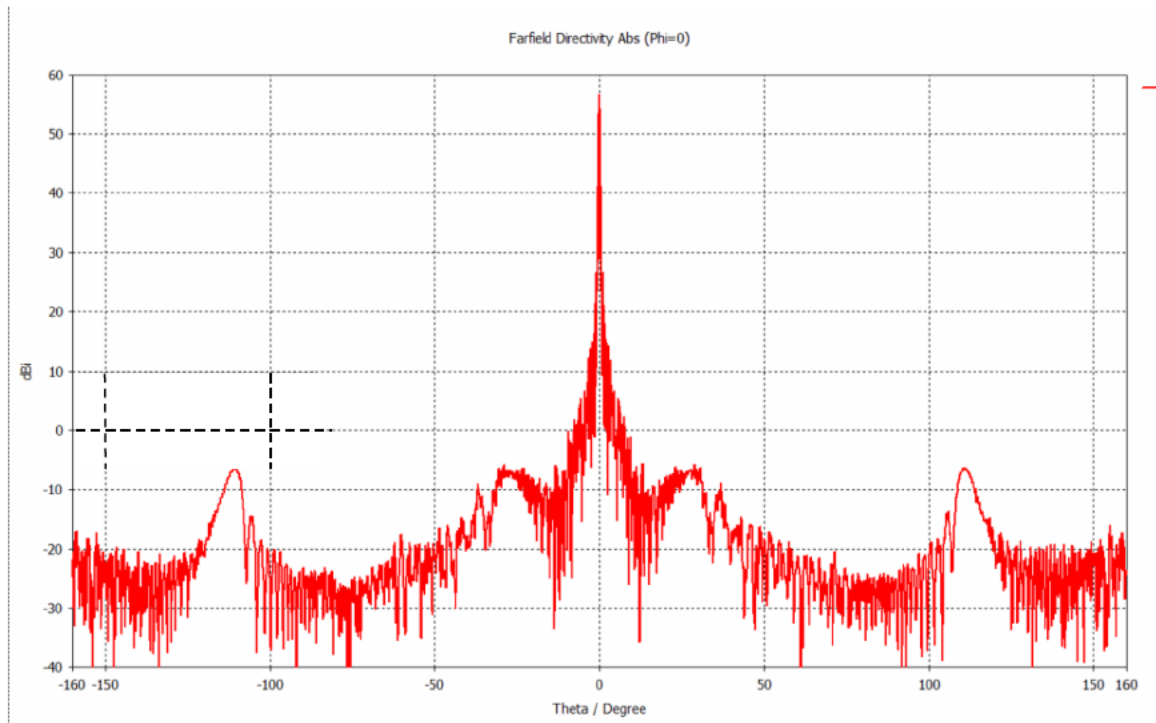
³ See 47 C.F.R. § 25.209(h).

⁴ *Id.* § 25.103.

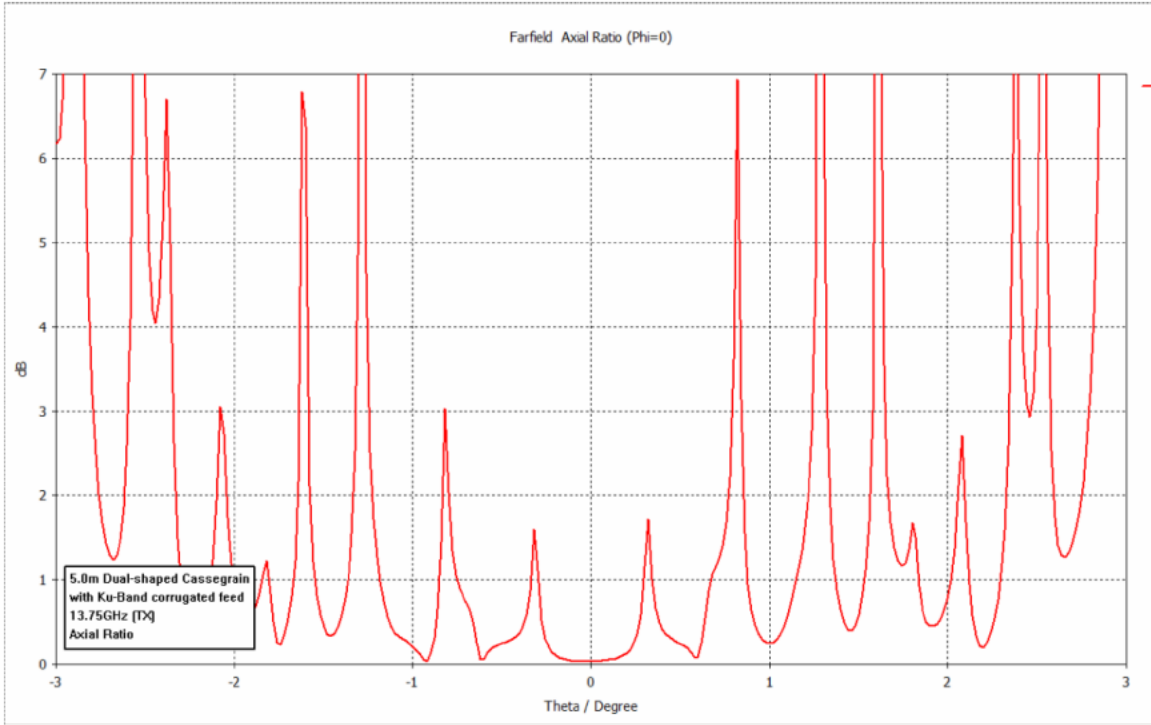
certification that the applicant has reviewed the results of a series of radiation pattern tests performed on representative equipment in representative configurations, and the test results demonstrate that the equipment meets relevant off-axis gain standards in Section 25.209. Since no such standards apply to the TT&C earth station proposed in this application, no such certification is required.

In support of its application, SpaceX Services (1) states that the half power beamwidth for its proposed TT&C earth station is 0.26 degrees at 13.9 GHz, and (2) provides below information on the EIRP mask for its proposed five-meter TT&C antenna.⁵

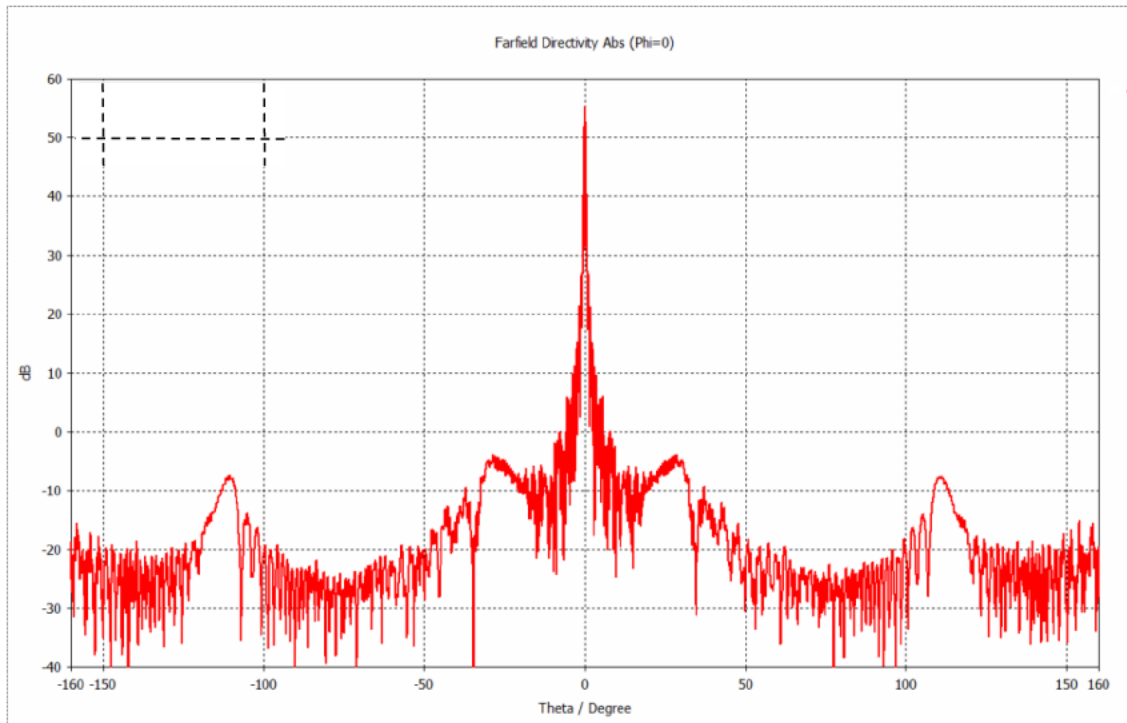
Transmit

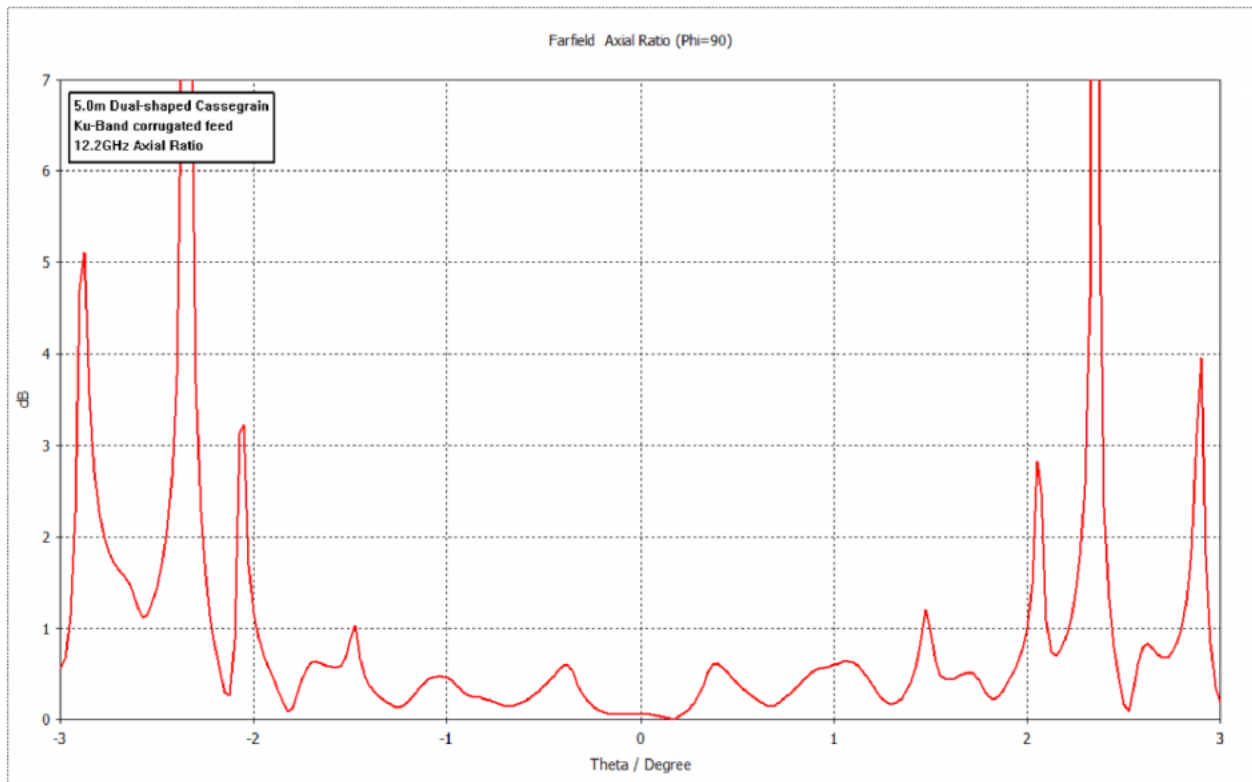
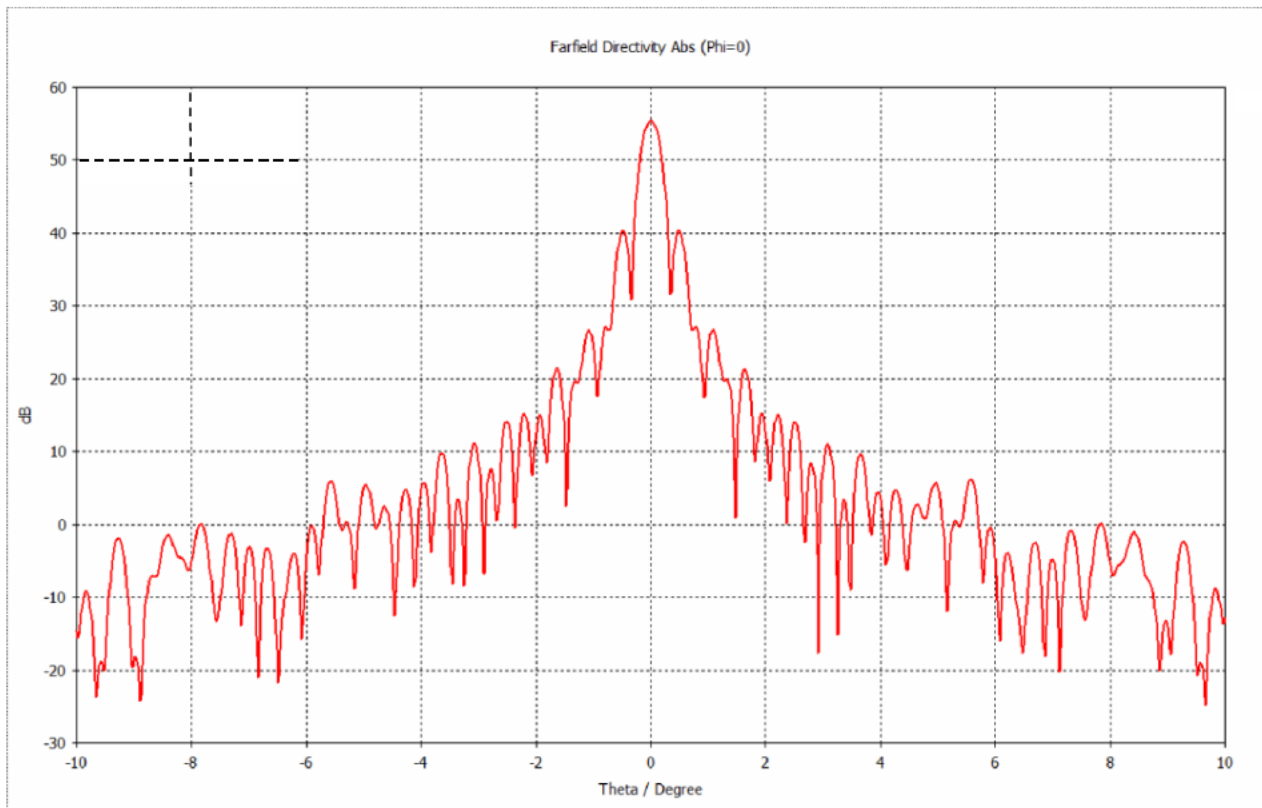


⁵ In addition, consistent with the requirements of footnote US356 to the Table of Frequency Allocations, the antenna for this earth station has a diameter greater than 4.5 meters and the EIRP of its emissions falls between 68 dBW and 85 dBW. See 47 C.F.R. § 2.106, n. US356.



Receive





B. Compliance with Frequency Coordination Requirements for the 13.75 - 14.0 GHz Band

1. Background

The following analysis demonstrates that the TT&C satellite earth station in Brewster, WA proposed by SpaceX Services will comply with the requirements set forth in *Extended Ku-Band Coordination Order*.⁶ Specifically, this analysis addresses the potential interference from the earth station to U.S. Navy shipboard radiolocation operations (RADAR) and the NASA space research activities in the 13.75 - 14.0 GHz band. The parameters for the earth station are:

- Coordinates (NAD83): 48.148621° N, 119.701131° W
- Satellite Location for Earth Station: SpaceX NGSO constellation
- Frequency Band: 13.75-14.0 GHz for uplink
- Polarizations: Circular
- Emissions: 2M7D7W, 13M5D7W, 41M4D7W
- Modulation: Digital
- Maximum Aggregate Uplink EIRP: 70.9 dBW for all carriers
- Transmit Antenna Characteristics
 - Antenna Size: 5.0 meter diameter
 - Antenna Type/Model: CGC Type 4
 - Gain: 55 dBi
- RF power into Antenna Flange:
 - 2.7 MHz modulation:
15.9 dBW or -12.4 dBW/4 kHz (Maximum)
 - 13.5 MHz modulation:
15.9 dBW or -19.4 dBW/4 kHz (Maximum)
 - 41.4 MHz modulation:
15.9 dBW or -24.2 dBW/4 kHz (Maximum)
- Minimum Elevation Angle: 5°
- Side Lobe Antenna Gain: 29 - 25*log(θ), from ITU S.1428 pattern
11.5 dBi at 5° separation

⁶ See Amendment of Parts 2, 25, and 90 of the Commission's Rules to Allocate the 13.75-14.0 GHz Band to the Fixed-Satellite Service, 11 FCC Rcd. 11951, ¶¶ 18-22 (1996) ("Extended Ku-Band Coordination Order").

Because the above uplink spectrum is shared with the Federal Government, coordination in this band requires resolution data pertaining to potential interference between the earth station and both Navy Department and NASA systems. Potential interference from the earth station could affect the Navy and/or NASA systems in two areas: (1) radiolocation and radio navigation, (2) data relay satellites.

2. Potential Impact to Government Radiolocation (Shipboard RADAR)

Radiolocation operations (RADAR) may occur anywhere in the 13.4 – 14.0 GHz frequency band aboard ocean-going United States Navy ships. The Commission has allocated the top 250 MHz of this 600 MHz band to the Fixed Satellite Service (FSS) on a co-primary basis with the radiolocation operations and provides for an interference protection level of -167 dBW/m²/4 kHz.⁷

The closest distance to the shoreline from the Brewster earth station is approximately 185.2 km West toward Marysville, WA. In addition, the Cascade mountain range lies in between the earth station and the shore, with a height of 10,500 ft. The calculation of the power spectral density at this distance is given by:

	2M7D7W	13M5D7W	41M4D7W
1. Clear Sky EIRP (dBW)	70.9	70.9	70.9
2. Carrier Bandwidth	2.7 MHz	13.5 MHz	41.4 MHz
3. PD at antenna input, after losses (dBW/4 kHz)	-12.4	-19.4	-24.2
4. Transmit Antenna Gain	55 dBi		
5. Antenna Gain Horizon	11.5 dBi at 5° separation (ITU S.1428 pattern)		
6. Antenna Elevation Angle	5°		

The proposed earth station will radiate interference toward Puget Sound according to its off-axis side-lobe performance. A conservative analysis, using the ITU S.1428 reference pattern, results in off-axis antenna gain of 11.5 dBi toward the Puget Sound. The signal density at the shoreline, through free space, is:

2.7 MHz Carrier

PF_D = Antenna Feed Power density (dBW/4 kHz) + Antenna Off-Axis Gain (dBi) – Spread Loss (dBW/m²).

⁷ See *id.* ¶ 20.

$$\begin{aligned}
&= -12.4 \text{ dBW/4 kHz} + 11.5 \text{ dBi} - 10 \cdot \log[4 \cdot \pi \cdot (185200)^2] \\
&= -117.2 \text{ dBW/m}^2/4 \text{ kHz} + \text{Additional Path Losses } (\sim 98.3 \text{ dB}) \\
&= -215.5 \text{ dBW/m}^2/4 \text{ kHz}
\end{aligned}$$

13.5 MHz Carrier

PFD = Antenna Feed Power density (dBW/4 kHz) + Antenna Off-Axis Gain (dBi) – Spread Loss (dBW/m²).

$$\begin{aligned}
&= -19.4 \text{ dBW/4 kHz} + 11.5 \text{ dBi} - 10 \cdot \log[4 \cdot \pi \cdot (185200)^2] \\
&= -124.2 \text{ dBW/m}^2/4 \text{ kHz} + \text{Additional Path Losses } (\sim 98.3 \text{ dB}) \\
&= -222.5 \text{ dBW/m}^2/4 \text{ kHz}
\end{aligned}$$

41.4 MHz Carrier

PFD = Antenna Feed Power density (dBW/4 kHz) + Antenna Off-Axis Gain (dBi) – Spread Loss (dBW/m²).

$$\begin{aligned}
&= -24.2 \text{ dBW/4 kHz} + 11.5 \text{ dBi} - 10 \cdot \log[4 \cdot \pi \cdot (185200)^2] \\
&= -129.0 \text{ dBW/m}^2/4 \text{ kHz} + \text{Additional Path Losses } (\sim 98.3 \text{ dB}) \\
&= -227.3 \text{ dBW/m}^2/4 \text{ kHz}
\end{aligned}$$

Our calculations identified additional path losses of approximately 98.3 dB including absorption loss and earth diffraction loss for the actual path profiles from the earth station to the nearest shoreline. This includes the Cascade mountain range, which lies in between Brewster and Puget Sound, with a peak height of 10,500 ft.

The worst-case calculated PFD including additional path losses to the closest shoreline location is -215.5 dBW/m²/4 kHz for 2.7 MHz carrier, -222.5 dBW/m²/4 kHz for 13.5 MHz carrier, and -227.3 dBW/m²/4 kHz for 41.4 MHz carrier. All carriers are a minimum of 48.5 dB below the -67 dBW/m²/4 kHz interference criteria established in the *Extended Ku-Band Coordination Order*. Therefore, there should be no interference to the US Navy RADAR from the Brewster earth station due to the distance and the terrain blockage between the site and the shore.

3. Potential Impact to NASA’s Tracking and Data Relay Satellite System (TDRSS)

The geographic location of the SpaceX Services earth station in Brewster, WA is outside the 390 km radius coordination contour surrounding NASA’s White Sands, New Mexico ground station complex. Therefore, the TDRSS space-to-earth link will not be impacted by the proposed earth station in Brewster, WA.⁸

The TDRSS space-to-space link in the 13.772 – 13.778 GHz band is assumed to be protected if an earth station produces an EIRP less than 71 dBW/6 MHz in this band.⁹ The five-meter earth station antenna will have an EIRP less than 71 dBW/6 MHz for all carriers in this

⁸ See *id.* ¶ 21.

⁹ See *id.* ¶ 34.

band. The total EIRP is 70.9 dBW for all carriers. For the 2.7 MHz carrier, the equivalent EIRP per 6 MHz segment will remain at 70.9 dBW/6 MHz. For the 13.5 MHz carrier the equivalent EIRP is 67.4 dBW/6 MHz. For the 41.4 MHz carrier the equivalent EIRP is 62.5 dBW/6 MHz.

All cases remain below the EIRP threshold of 71 dBW/6 MHz. Therefore, there should be no interference to the TDRSS space-to-space link from any carriers.

4. Coordination Issue Result Summary and Conclusions

The results of the analysis and calculations performed in this exhibit indicate that compatible operation between the TT&C earth station at the Brewster facility and the U.S. Navy and NASA systems space-to-earth link are possible for all proposed carriers. Operations in NASA systems space-to-space link (13.772 – 13.778 GHz) will also be permitted for all carriers.