APPLICATION FOR GATEWAY EARTH STATION

I. OVERVIEW

The Commission has authorized Space Exploration Holdings, LLC ("SpaceX") to launch and operate a constellation of 4,409 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 "allow SpaceX to make efficient use of valuable spectrum resources more safely, quickly, and cost-effectively as it initiates a new generation of broadband services available to customers worldwide, including those in areas previously underserved or even totally unserved by other broadband solutions."[2] In May 2019, SpaceX began launching satellites to populate its constellation.

This application, filed by a sister company, SpaceX Services, Inc. ("SpaceX Services"), seeks authority to operate a Ka-band gateway earth station that SpaceX will use to deliver broadband data between the satellites of its NGSO system and terrestrial Internet exchange points. Specifically, SpaceX Services seeks authority for eight technically identical 1.5-meter antennas in Prosser, Washington (the "Prosser Gateway"). Consistent with SpaceX's space station authorization, these earth stations will transmit in the 27.5-29.1 GHz and 29.5-30.0 GHz bands and receive in the 17.8-18.6 GHz and 18.8-19.3 GHz bands.

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,

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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) ("SpaceX Modification"). These authorizations anticipate that Kaband spectrum would be used for gateway communications.

2 SpaceX Modification, ¶ 1.

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.

II. SPECTRUM SHARING ISSUES

Under the Commission's spectrum allocations and the plan adopted for the Ka-band in particular,[3] SpaceX Services will need to share with a variety of other systems operating in its bands. Below we demonstrate that the proposed Prosser Gateway will comply with all relevant sharing requirements.

A. Uplink Bands

The 27.5-28.35 GHz band has been designated for use by the Upper Microwave Flexible Use Service ("UMFUS") on a primary basis, with a secondary designation for FSS. The Technical Appendix attached hereto demonstrates that the Prosser Gateway will satisfy the criteria set forth in Section 25.136(a)(4) of the Commission's rules such that it may operate without providing additional interference protection to terrestrial UMFUS systems operating in the band.[4]

FSS is primary throughout the 28.35-29.1 GHz band, with NGSO designated as secondary to GSO in the 28.35-28.6 GHz portion and NGSO designated as primary in the 28.6-29.1 GHz portion. FSS is co-primary with Mobile Satellite Service ("MSS") in the 29.5-30.0 GHz band, with NGSO designated as secondary to GSO.[5]

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3 *See Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, 32 FCC Rcd. 7809, App. B (2017) ("*NGSO Update Order*").

4 *See* 47 C.F.R. § 25.146(a)(4).

5 *See id.*

The Comsearch Report submitted with this application confirms that SpaceX Services has coordinated with existing terrestrial licensees in these bands in compliance with the Commission's rules and can operate without causing harmful interference to any such deployments. SpaceX Services makes no claim of interference protection from U.S.-licensed GSO FSS systems in the 28.35-28.6 GHz and 29.5-30.0 GHz bands. In addition, SpaceX Services will comply with the applicable equivalent power flux-density ("EPFD") limits set forth in Article 22 and Resolution 76 of the ITU Radio Regulations, which the Commission has found to be sufficient to protect GSO systems against harmful interference.[6] SpaceX has demonstrated that its NGSO system will comply with these EPFD limits, and doing so is a condition of its Authorization.[7]

B. Downlink Bands

The Commission has allocated the 17.8-18.3 GHz band on a primary basis to the terrestrial fixed service ("FS") and on a secondary basis for FSS. The 18.3-18.6 GHz band is allocated on a primary basis to FSS, with NGSO secondary to GSO and subject to international EPFD limits. The 18.8-19.3 GHz band is allocated to FSS on a primary basis, with NGSO designated as primary.

SpaceX has previously demonstrated that its NGSO system will protect terrestrial fixed stations in the 17.8-18.6 GHz and 18.8-19.3 GHz bands, in compliance with a condition placed on its license.[8] Moreover, the Comsearch report submitted with this application confirms that there

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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). SpaceX believes that the EPFD limits designed to protect GSO FSS systems will also protect GSO MSS systems in the band.

7 *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)).

8 *See* SpaceX Modification, ¶ 29.

should be no additional limitations placed on operations of the Prosser Gateway. Similarly, SpaceX has demonstrated that its NGSO system will comply with the relevant EPFD limits in the 18.3-18.6 GHz band, which the Commission considers sufficient to protect GSO networks from unacceptable interference.[9]

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 that year.[10]

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.[11] To help close this digital divide, SpaceX

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9 *See* SpaceX Authorization, ¶ 9.

10 *See* Cisco Visual Networking Index: Forecast and Methodology, 2017-2022, at 1, CISCO (Nov. 26, 2018), https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paperc11-741490 html.

11 *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), http://broadbandcommission.org/Documents/publications/HLPF-July2016.pdf. *See also* Broadband Commission for Sustainable Development, "The State of Broadband 2015," at 8 (Sep. 2015),

is 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 one of the gateway earth stations that will connect the satellite system to the terrestrial Internet. Accordingly, an expeditious grant of this application would serve the public interest.

Respectfully submitted,

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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 APPENDIX

In this Technical Appendix, 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.[12]

A. Minimum Elevation Angle

SpaceX Service's gateway earth stations will communicate only with those SpaceX satellites that are visible on the horizon above a minimum elevation angle. This angle may be as low as 25 degrees, and thus SpaceX Services has used this minimum elevation angle in its analysis in order to capture the full potential range of service.

B. UMFUS Coordination

1. Section 25.136(a)(4)

Section 25.136(a)(4) of the Commission's rules defines four elements that, if met, permit an earth station licensee to operate without providing additional interference protection to terrestrial systems in the Upper Microwave Flexible Use Service ("UMFUS") operating in the 27.5-28.35 GHz band.[13] As demonstrated below, the proposed Prosser Gateway satisfies these criteria, and the Commission should authorize this earth station without requiring additional protection for future UMFUS systems.

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[12] 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, SAT-MOD-20181108-00083, and SAT-MOD-20200417-00037.

[13] *See* 47 C.F.R. § 25.146(a)(4).

2. Section 25.136(a)(4)(i)

The Prosser Gateway complies with this section of the Commission's rules because there are no other earth stations authorized in the 27.5-28.35 GHz band operating in Benton County, Washington.

3. Section 25.136(a)(4)(ii)

Section 25.136(a)(4)(ii) provides that an earth station operator need not provide interference protection to future UMFUS systems if, in a UMFUS license area with a population between 6,000 and 450,000 people, no more than 450 people will be within the earth station's PFD contour that is equal to or exceeds -77.6 dBm/m^2/MHz. The Prosser Gateway is located in Benton County, which has a population of approximately 175,177 people.[14] As demonstrated below, the Prosser Gateway's PFD contour contains fewer than 450 people.

In order to conduct a technical analysis to determine the region around the Prosser Gateway site that would fall within the PFD contour defined by Section 25.136(a)(4), SpaceX used the Visualyse Professional software tool created by Transfinite Systems Ltd., which implements the standard ITU-R Rec. P.452.16 propagation model.[15] Because each of the eight antennas of the Prosser Gateway would track a different SpaceX satellite, SpaceX first determined the worst-case aggregate EIRP density toward the horizon to be -11.7 dBW/MHz.[16] Next, SpaceX defined a reference antenna at 10 meters height above ground with 50.24 dBi gain pointed toward the Prosser

14 *See* QuickFacts Benton County, Washington, United States Census Bureau, https://www.census.gov/quickfacts/bentoncountywashington

15 Information on this software can be found at https://www.transfinite.com/content/professional.

16 This value is based on eight earth station antennas with -1 dBi gain toward the horizon, each operating at -20.7 dBW/MHz EIRP density toward the horizon, based on -19.7 dBW/MHz input power density. SpaceX notes that the earth station input power spectral density used for this calculation is 3.9 dB lower than the maximum provided in the application since the latter includes maximum uplink power control for rain events.

Gateway. This is necessary because Visualyse performs its calculations using receive power density rather than PFD. The 50.24 dBi gain effectively converts the receive power density value to a PFD value so that Visualyse can display the results in terms of PFD.[17] SpaceX also loaded information on the surrounding terrain at a 3-arc second resolution (approximately 90 meters by 90 meters) from NASA's SRTM Digital Terrain Elevation Data profile. Table 1 below summarizes the Prosser Gateway parameters used for the analysis.

Table 1: Prosser Gateway Parameters	
Site location	Prosser, Washington
County	Benton County, Washington
Antenna coordinates	46°7'38.2" N, 119°41'3.5" W
Simulation Frequency	27.5 GHz
Number of active antennas	8
Antenna sidelobe level toward horizon	-1 dBi
Worst-case aggregate EIRP	-11.7 dBW/MHz

With these inputs and an omni-directional pattern, centered at the gateway site, SpaceX ran the Visualyse software implementing the ITU propagation model to develop a composite (eight antennas) PFD contour with a threshold of -107.6 $dBW/m^2/MHz$[18] at 10 meters above ground, as required under Section 25.136. It does so by moving the reference antenna in small steps all around the area surrounding the Prosser Gateway to measure the value of received power at each location step. The resulting contour can be exported as a .kml file for viewing with a range of GIS mapping software. Figure 1 below shows the PFD contour as calculated by Visualyse superimposed on Google Maps.

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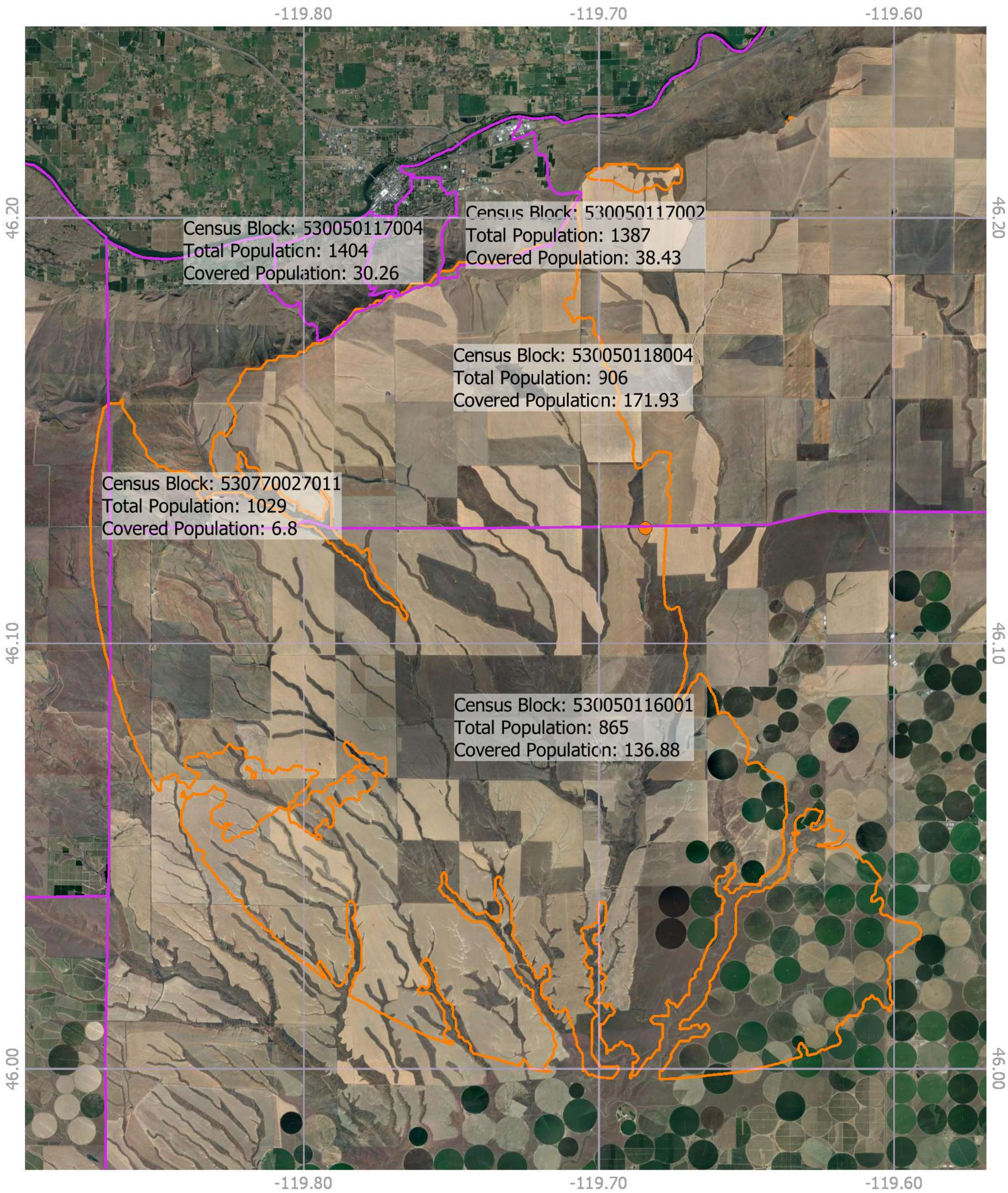
17 This is the gain of a meter square antenna at 27.5 GHz ($G = 10*\log10(4\pi/\lambda^2)$), where λ=1.09 cm at 27.5 GHz). This is a physical quantity corresponding to an antenna with one-meter square effective area, necessary to convert Visualyse's calculation in terms of receive power density into power flux density.

18 This is equivalent to the -77.6 dBm/m2/MHz value used in Section 25.136(a)(4).

Figure 1. PFD Contours for Prosser Gateway



Census Block ID	Total Block Population	Covered Area	Covered Block Population
530050117004	1404	2.16%	30.26
530050117002	1387	2.77%	38.43
530770027011	1029	0.66%	6.80
530050116001	865	15.82%	136.88
530050118004	906	18.98%	171.93
530050117005	1431	1.10%	15.75

Total Covered Population = 400.05

Figure 2. Wide Area View showing Census Block Boundaries

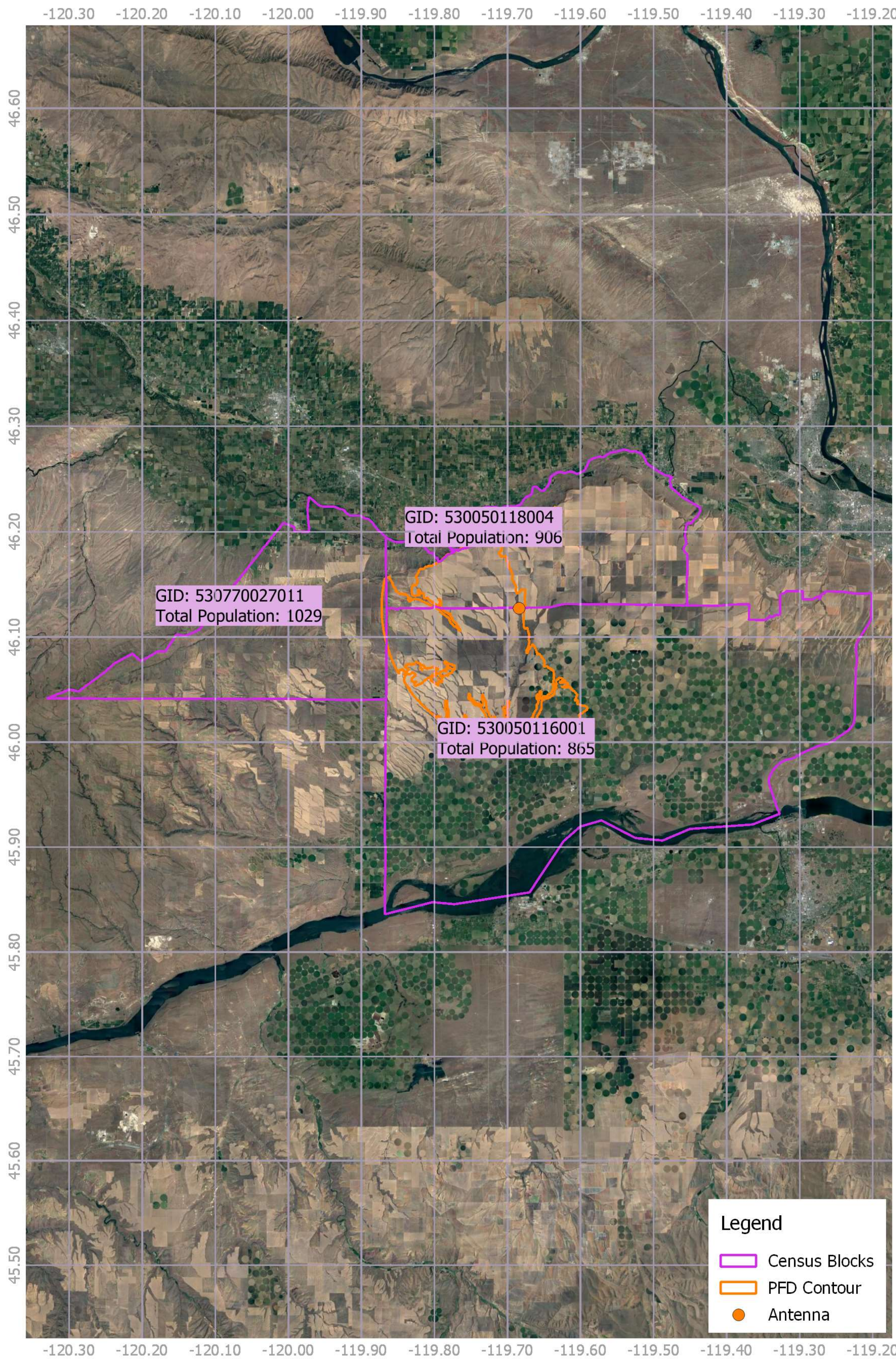
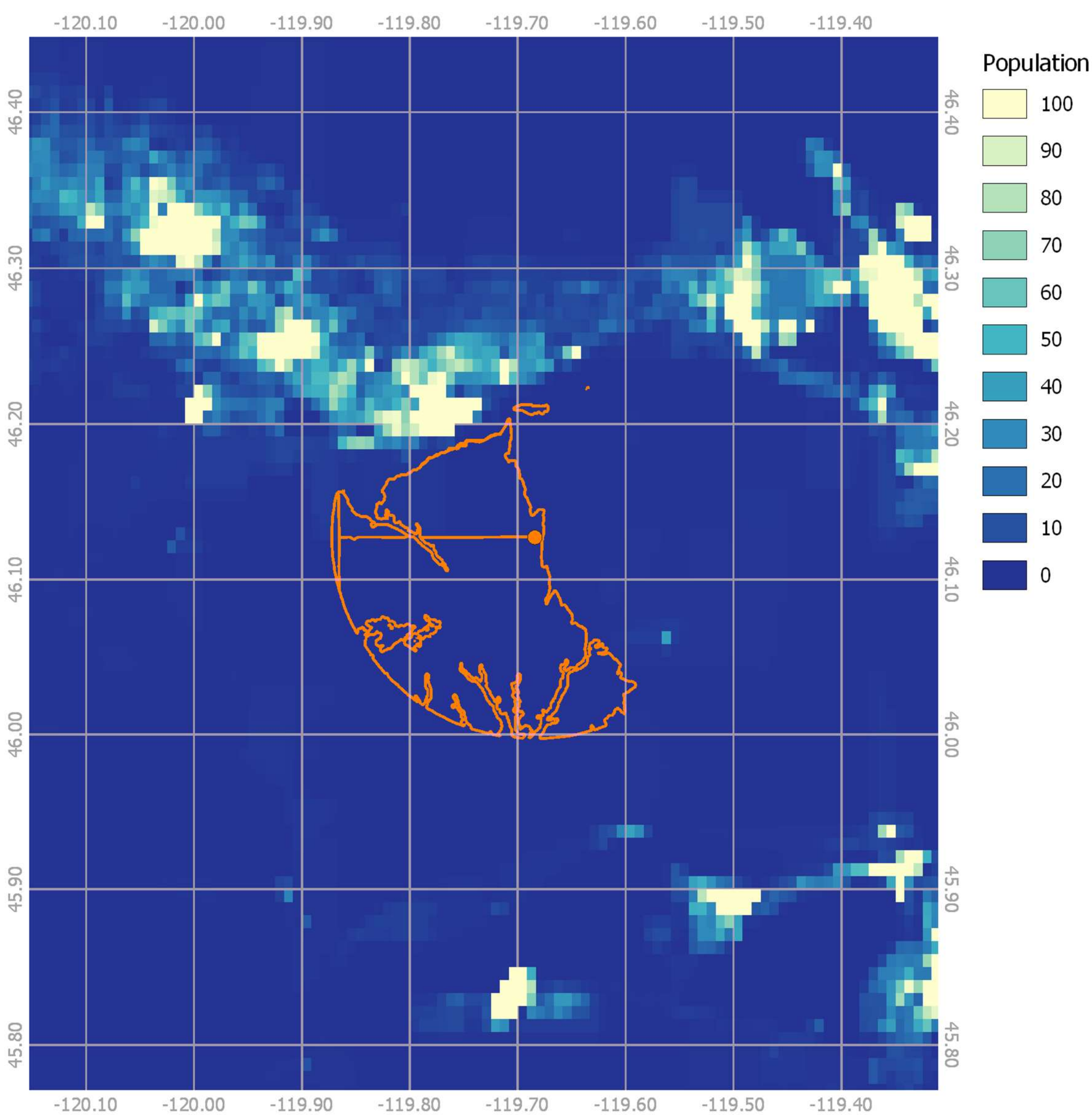


Figure 3. PFD Contour Projected Onto GPWv4 Population Grid



This PFD contour can also be used with other data sources to determine the population that falls within the contour. For this purpose, SpaceX used two sources for input data. First, it used the most recent version of NASA's Socioeconomic Data and Applications Center Gridded Population of the World ("GPWv4").[19] The GPWv4 data is based on population counts collected at the most detailed spatial resolution available from the results of the 2010 U.S. Census, which is also extrapolated to produce population estimates for 2020.

By superimposing the PFD contour on the GPWv4 population distribution grid in Figure 3, SpaceX was able to integrate the population contained within the contour using projected 2020 total population with 30 arc-second resolution. Using this tool, the estimated population within the PFD contour is 103 people – much less than the 450-person limit established in Section 25.136(a)(4)(ii).

Second, SpaceX used data from the 2010 U.S. Census in order to confirm the analysis based on the NASA data above. Here again, SpaceX was able to project the PFD contour onto a map of census blocks as shown in Figures 1 and 2 to determine which ones fall partially or totally within the contour, and then integrate the share of the population covered in each block to reach an aggregate figure. Using this approach, the estimated population within the PFD contour is 400 people – confirming compliance with the 450-person limit.

4. Section 25.136(a)(4)(iii)

Based on a search in Google Maps, there are no major event venues, urban mass transit routes, passenger railroads, or cruise ship ports within the Prosser Gateway's PFD contour. Accordingly, the Prosser Gateway complies with the requirements of this subsection.

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[19] *See* NASA Socioeconomic Data and Applications Center, *Gridded Population of the World: Version 4*, http://sedac.ciesin.columbia.edu/data/collection/gpw-v4/maps/services.

5. **Section 25.136(a)(4)(iv)**

The Comsearch Report submitted demonstrates that SpaceX completed coordination in compliance with the Commission's rules.

C. Antenna Patterns

SpaceX will comply with a mask similar to the one in Section 25.209(a)(3) applicable to earth station antennas operating in the 24.75-25.25 GHz and 28.35-30.0 GHz bands with geostationary satellites but will improve that pattern to -3 dBi (rather than 0 dBi) beyond 25 degrees off-axis. The mask can be stated as follows:

$29-25\log_{10}\theta$	dBi	for $2° \leq \theta \leq 7°$.
8	dBi	for $7° < \theta \leq 9.2°$.
$32-25\log_{10}\theta$	dBi	for $9.2° < \theta \leq 25°$.
-3	dBi	for $25° < \theta \leq 180°$.

Consistent with Section 25.209(a)(3), "[t]his envelope may be exceeded by up to 3 dB in 10% of the range of θ angles from ±7-180°, and by up to 6 dB in the region of main reflector spillover energy."[20] In addition, the half power beamwidth for the proposed antenna is 0.5 degrees at 30 GHz.

[20] *Id.* § 25.209(a)(3).