SPACEX GEN2 DIRECT-TO-CELLULAR SYSTEM

ATTACHMENT A
TECHNICAL INFORMATION TO SUPPLEMENT SCHEDULE S

A.1 Scope and Purpose

This attachment contains information describing SpaceX's non-geostationary orbit ("NGSO") satellite system and use of the 1910-1915 MHz and 1990-1995 MHz bands (the "PCS G Block") for a direct-to-cellular service in cooperative agreement with T-Mobile's primary terrestrial mobile operations, as required under Parts 24 and 25 of the Commission's rules. Because portions of the technical information included below cannot be fully captured by the Schedule S software, SpaceX provides this attachment as a supplement. The accompanying Schedule S generally reflects the system as it will operate once modified and fully deployed.

A.2 Overall Descriptions

Constellation information is generally available in Attachment A ("Technical Information to Supplement Schedule S") to the previous applications related to SpaceX's second-generation NGSO Fixed-Satellite Service ("FSS") system ("Gen2 system").[1] Under the modification proposed herein, SpaceX requests adding a direct-to-cellular Mobile-Satellite Service ("MSS") payload operating in the PCS G Block in the United States (the "SpaceX direct-to-cellular system") on satellites in the Gen2 system, as part of its current authorization.[2] SpaceX intends to provide similar direct-to-cellular operations outside of the United States, subject to cooperation with local terrestrial mobile service providers who are authorized to provide service within a specified

[1] *See* Application for Approval of Orbital Deployment and Operating Authority for the SpaceX Gen2 NGSO Satellite System, IBFS File No. SAT-LOA-20200526-00055 (filed May 26, 2020); Amendment, IBFS File No. SAT-AMD-20210818-00105 (filed, Aug. 18, 2021) (collectively, "Previous Applications"); *see also Space Exploration Holdings, LLC*, FCC 22-91 (rel. Dec. 1, 2022) ("*Gen2 Authorization*").

[2] *See Gen2 Authorization* ¶¶ 6-8.

frequency band and consistent with authorization within each country to reuse that spectrum accordingly. SpaceX's operations will be consistent with its filings at the International Telecommunication Union ("ITU") and, in such instances, SpaceX will provide notice to the Commission of authorizations and operations in other countries, similar to prior orders related to satellite-to-cellular connectivity outside the United States.[3]

Orbital Parameters

The SpaceX direct-to-cellular system is an NGSO satellite system that will consist of a payload deployed on satellites in SpaceX's Gen2 system, subject to the conditions set forth in the *Gen2 Authorization* initially granting SpaceX authority to launch and operate 7,500 satellites.[4] The SpaceX direct-to-cellular system will be deployed on up to 7,500 satellites within the orbital shells at 525 km, 530 km, and 535 km altitudes. Thus, SpaceX's Gen2 system will remain as described in the Previous Applications, which are incorporated by reference, and as initially authorized in the *Gen2 Authorization*.[5] Operation of the SpaceX direct-to-cellular system payload will have no effect on the orbital characteristics of these already licensed satellites.

At full deployment, this hosted payload will enable SpaceX to provide full and continuous coverage of the Earth within ±58° latitude by mid-2024. The Gen2 system will maintain apogee and perigee within an altitude range of -50 km to +45 km,[6] and inclination will be maintained to less than 0.5 degrees of the respective target values, consistent with the *Gen2 Authorization*. The right ascension of the ascending nodes ("RAANs") will precess and span the full range of 0-360

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[3] *See Lynk Global, Inc.,* DA 22-969, ¶ 34 (IB 2022) ("*Lynk*") (authorizing operations in frequency bands for satellite-to-cellular connectivity outside the United States).

[4] *See Gen2 Authorization* ¶¶ 1-2, 18-19.

[5] *See Gen2 Authorization* ¶ 7.

[6] Consistent with the Gen2 authorization, all satellites will operate at or below 580 km. *See Gen2 Authorization* ¶ 135bb.

degrees. These operational parameters should be used in combination with other materials submitted with this application, including the Schedule S and attached .MDB file, to give a complete description of the system.

Technology and Operations

The SpaceX direct-to-cellular system will utilize advanced phased array beam-forming and digital processing technologies onboard each satellite payload in order to make highly efficient use of spectrum resources and share spectrum flexibly with other space-based and terrestrial-licensed users. The SpaceX direct-to-cellular service will be available for residential, commercial, institutional, and governmental users in the entire contiguous United States, Hawaii, Puerto Rico, and some of the most remote corridors of Alaska.

SpaceX seeks to leverage its existing space resources to provide even more ubiquitous connectivity options to Americans, including outside the reach of traditional terrestrial mobile networks, with a goal of global affordable connectivity. To expand into mobile service, SpaceX acquired Swarm Technologies, Inc. ("Swarm"), a company authorized to deploy and operate 150 small NGSO satellites designed to provide narrowband services in the 137-138 MHz and 148-150.5 very-high frequency ("VHF") MSS bands.[7] Swarm has already launched most of its authorized satellites and is offering services to customers in the agriculture, maritime, energy, environmental, and transportation sectors, among others in need of global satellite connectivity for Internet-of-Things ("IoT") devices. With this application, SpaceX's proposed direct-to-cellular system will enable satellite connectivity for LTE devices, which can include cell phones as well as LTE-capable IoT devices. The combination of direct-to-cellular and the Swarm IoT connectivity solutions truly encompass all ranges of data rates and power levels for devices around

[7] *See Public Notice*, 36 FCC Rcd. 14264 (IB 2021) (confirming authority for Swarm transfer of control to SpaceX).

the world.

In the PCS G Block, SpaceX's direct-to-cellular service in the United States would be able to provide voice, messaging, and basic web browsing at theoretical peak speeds of up to either 3.0 Mbps or 7.2 Mbps peak upload (Earth-to-space) over 1.4 MHz or 5 MHz bandwidth channels per beam, respectively, and up to either 4.4 Mbps or 18.3 Mbps on the downlink (space-to-Earth) over the 1.4 MHz channels or the 5 MHz channel per beam, respectively. SpaceX plans to implement 3GPP LTE Layer 2 concepts that allow per-user scheduling as low as one resource block centered at any frequency within the 5 MHz spectrum with appropriate guard bands.[8] Outside the United States, SpaceX anticipates that its system will achieve similar levels of throughput, though the precise channelization used in other bands and jurisdictions may vary.

SpaceX's direct-to-cellular system will include multiple beams per satellite, and beam centers will remain stationary on the ground. SpaceX will compensate and correct for Doppler and time synchronization effects both inside and between beams. An algorithm will place beams such that they meet any single or aggregate power-flux density ("PFD") limit. The algorithm will also support user handoff between two beams and point neighboring beams appropriately to minimize interference from beam-to-beam.

In the United States, user terminals will be unmodified, commercial off-the-shelf cellular phones that can communicate in the PCS G Block, which is part of LTE Band 25. These devices typically have low gain antennas (e.g., -5 dBi) and will already be certified to operate under Part 24 rules within the United States. These "stock" cellular phones will continue to operate under the exact same Part 24 rules and limits when connecting with a direct-to-cellular hosted payload

[8] A resource block of 180 kHz is the smallest bandwidth that can be allocated to a user. *See 3GPP TS 36.101 V17.6.0*, 3GPP (June 2022), https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=2411; *see also 3GPP TS 36.201 V17.0.0*, 3GPP (Mar. 2022), https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=2424.

as described in the narrative accompanying this application.

Spectrum

SpaceX requests authority to provide seamless satellite connectivity in the United States to T-Mobile USA, Inc. (with its subsidiaries, collectively referred to as "T-Mobile") wireless subscribers in the PCS G Block, across which T-Mobile has exclusive, nationwide access.[9]

A channelized frequency plan is provided in the associated Schedule S, encompassing three or four 1.4 MHz downlink channels or one 5 MHz downlink channel and 1.4 MHz channels or one 5 MHz channels on the uplink with center frequency set appropriately within the 5 MHz PCS G Block uplink or downlink band. Satellite downlink transmissions will operate over a range of parameters more fully captured in the Schedule S, with no more than a peak antenna gain of 38 dBi, peak Effective Isotropic Radiated Power ("EIRP") of 58 dBW, and peak EIRP density of -2.33 dBW/Hz (per 1.4 MHz channel). The direct-to-cellular system satellites will transmit with circular polarization using L-band antennas, although the Schedule S lists both right-hand circular polarization ("RHCP") and left-hand circular polarization ("LHCP") for completeness. All uplink operations from certified mobile handsets will conform to Part 24 standards and limits, with vertical polarization, although the Schedule S lists both vertical and horizontal polarization for completeness.

SpaceX certifies that its direct-to-cellular system will operate without causing harmful interference to or requiring protection from any other service duly licensed in these bands. The SpaceX direct-to-cellular system will operate in the United States pursuant to a cooperative

[9] SpaceX anticipates that the system will also employ optical inter-satellite links for communications directly between SpaceX satellites. As the Commission has previously found, "[b]ecause optical ISLs do not involve wire or radio frequency transmissions, the Commission does not have jurisdiction over the use of optical ISLs." *Teledesic LLC*, 14 FCC Rcd. 2261, ¶ 14 (IB 1999) ("*Teledesic*"). Moreover, to the extent that the use of optical ISLs alleviates congestion in radio frequency bands, it is to be encouraged. *Id.*

agreement with T-Mobile's primary terrestrial mobile operations and will protect adjacent band operations from harmful interference. Moreover, SpaceX seeks to operate in the PCS G Block on a non-protected, non-interference basis.

In addition to specific authority for United States operations, SpaceX seeks authority more generally to deploy and operate the direct-to-cellular system for service in other countries over the range of terrestrial frequencies included in its ITU filings described in Section A.12. As described in the narrative accompanying this application, SpaceX will only use this capability to provide service in cooperation with local terrestrial mobile service providers authorized to operate within a specified spectrum band and subject to authorization within each country to reuse that spectrum for service to handsets from satellites.

A.3 Predicted Space Station Antenna Gain Contours

All downlink spot beams on each SpaceX satellite are independently steerable. The intended coverage area for each user beam is a cell inside the -3 and -5 dB contour, as illustrated in Figure A.3-1 below. SpaceX is maintaining optionality for either contour size in the design. At a given center frequency, only a single beam typically would cover a user cell on the ground from a given satellite. SpaceX plans to implement appropriate frequency reuse factors to minimize interference and provide a high-performance experience to the user. Again, domestic operations in the PCS G Block will protect T-Mobile's primary terrestrial mobile operations in accordance with an agreement between the companies. In addition, in the United States, SpaceX will comply with the boundary field strength limit specified in the PCS rules.[10]

[10] *See* 47 C.F.R. § 24.236 (establishing an in-band boundary field strength limit for PCS licensees).

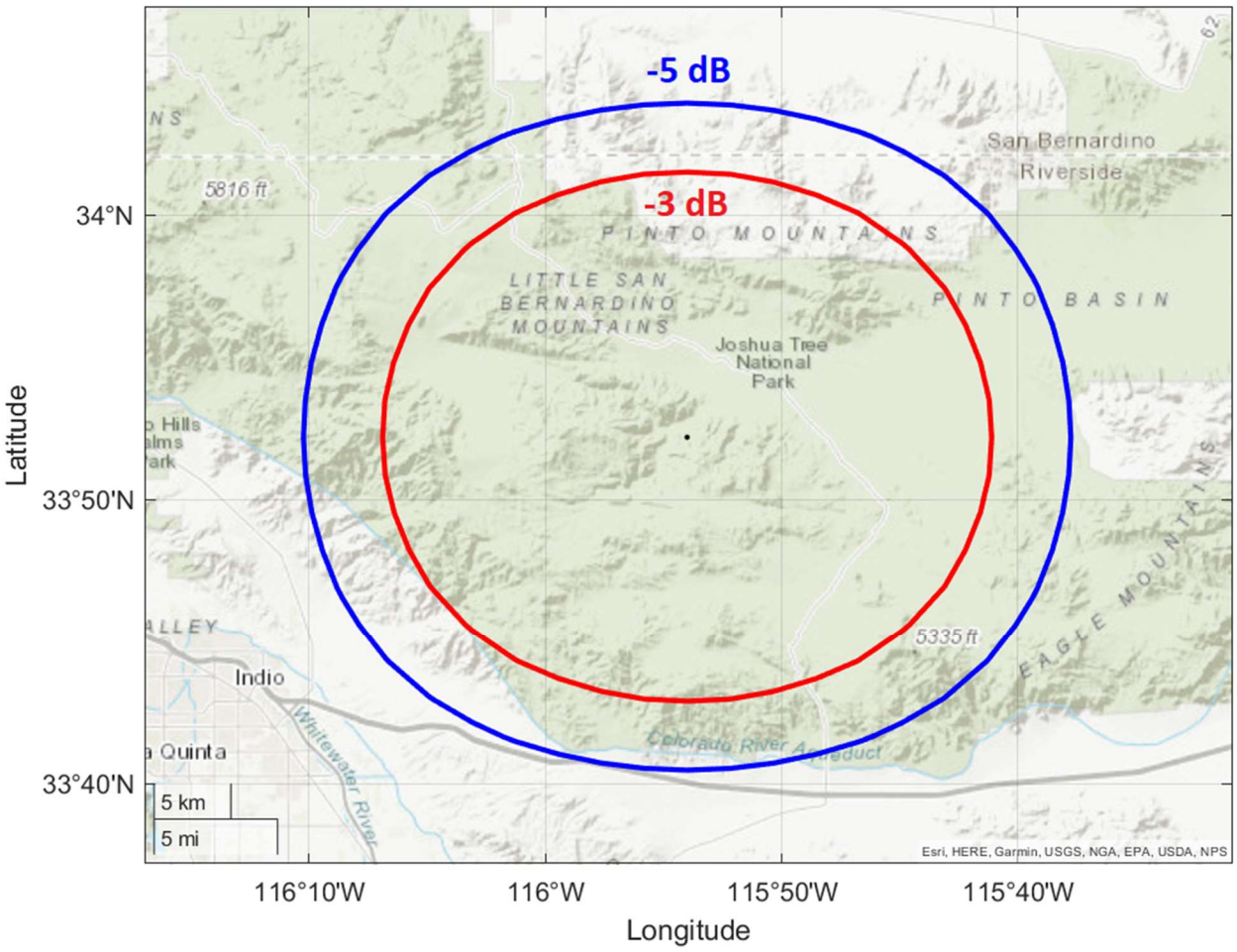

Figure A.3-1: Intended Beam Coverage Area showing -3 dB (red) and -5 dB (blue) contours.

A.4 TT&C Characteristics

SpaceX will use the existing TT&C subsystem on its Gen2 system for communications with the spacecraft during pre-launch, transfer orbit, and on-station operations, as well as during spacecraft emergencies, consistent with the *Gen2 Authorization*. A description of the SpaceX TT&C subsystem is provided in the Previous Applications and incorporated by reference.[11]

A.5 Backhaul Operations

The SpaceX direct-to-cellular system backhaul will use gateway links authorized in Ka-

[11] *See also Gen2 Authorization* ¶ 90 (citing Previous Applications).

band spectrum for the Gen2 system, as well as future E-band links, which remain pending. As discussed in the Previous Applications, the SpaceX Gen2 system will utilize high-gain steered beams to simultaneously communicate with multiple SpaceX satellites from a single gateway site. SpaceX has also deployed optical inter-satellite links and anticipates that they will provide seamless network management and continuity of service while minimizing the spectrum footprint of the system overall and facilitating spectrum sharing with other space-based and terrestrial systems. All backhaul will be consistent with the Gen2 system parameters. A description of the SpaceX TT&C subsystem is provided in the Previous Applications and incorporated by reference.[12]

A.6 Geographic Coverage

The SpaceX direct-to-cellular system will be able to provide full and continuous coverage of the Earth within ±58° latitude. For purposes of the service SpaceX proposes in the United States, the system will provide coverage in the entirety of the contiguous United States, Hawaii, Puerto Rico, and the majority of Southeast Alaska, Kodiak, and the Aleutian Islands—all locations where T-Mobile has exclusive access to the PCS G Block. Once operational, the direct-to-cellular system will instantly serve geographic areas that are unserved or underserved and connect millions of Americans across the country.

[12] *Id.*

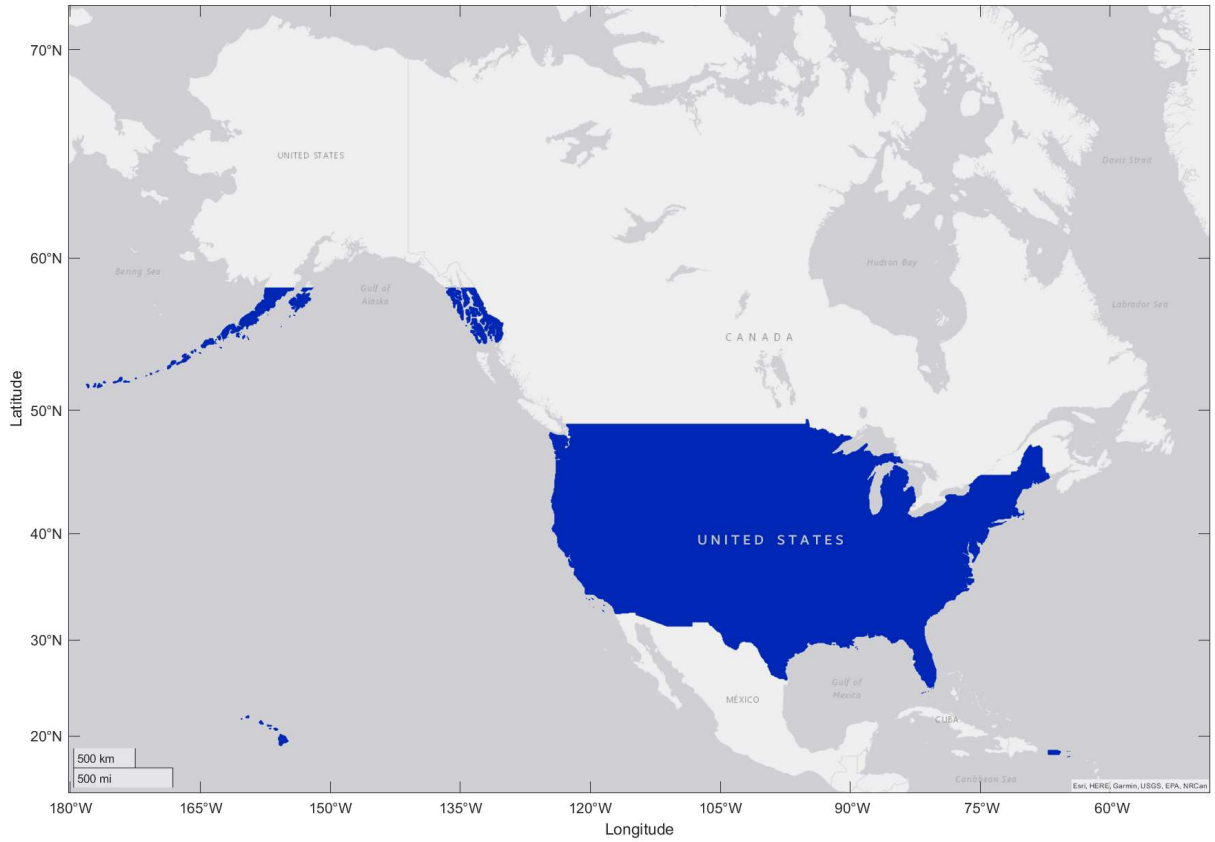

Figure A.6-1: A shaded map showing the coverage of the direct-to-cellular network. Note that the upper coverage limit is 58 degrees North latitude.

A.7 Cessation of Emissions

Each active satellite transmission chain (channel amplifiers and associated solid state power amplifier) can be individually turned on and off by ground telecommand, thereby causing cessation of emissions from the satellite, as required by Section 25.207 of the Commission's rules.

A.8 E911 Compliance

The direct-to-cellular system will meet requirements for MSS emergency 911 services under Section 9.18 of the Commission's rules.[13]

[13] *See* 47 C.F.R. § 9.18.

A.9 Frequency Tolerance

The carrier frequency of each space station transmitter shall be maintained within 0.002 percent of the reference frequency, as required by Section 25.202(e) of the Commission's rules.

A.10 Interference Analyses

The Commission has recognized that a proposed modification to an NGSO authorization should be granted where it "does not present any significant interference problems and is otherwise consistent with Commission policies."[14] As discussed in greater detail below, the advanced capabilities of SpaceX's direct-to-cellular system will enable effective and efficient spectrum sharing with other licensed users of the band. The following discussion relates specifically to proposed operations in the United States, but SpaceX can take similar steps to ensure compatible operations with licensees in other countries, as local regulations require.

Compliance With In-Band Field Strength Limits

The Commission's Part 25 rules and the ITU Radio Regulations do not directly establish a power-flux density ("PFD") limit for downlink (space-to-Earth) communications in the PCS G Block. Instead, under Section 24.236 for PCS operations, "[t]he predicted or measured median field strength at any location on the border of the PCS service area shall not exceed 47 dBμV/m unless the parties agree to a higher field strength."[15] In-band, SpaceX and T-Mobile have agreed to an appropriate field strength limit.

Recognizing that Section 24.236 applies at borders between (a) the United States and Mexico and (b) the United States and Canada, the field strength limits specified in Section 24.236

[14] *Space Exploration Holdings, LLC*, 36 FCC Rcd. 7995 (2021) (quoting *Teledesic* ¶ 5).

[15] 47 C.F.R. § 24.236.

can be converted into an equivalent PFD limit that will provide the same protections to in-band operations as the field strength limit itself. SpaceX will maintain PFD levels below the equivalent PFD value at national borders and space downlink beams appropriately from those borders to protect primary terrestrial mobile operations from interference. SpaceX will only exceed these limits at the national border in the event that it has been authorized to do so by the regulatory authority of the appropriate border country and after it has provided documentation of such authorization to the Commission.

With respect to in-band emissions for uplink transmissions (Earth-to-space), all mobile phones operating in the PCS G Block already comply with all relevant Part 24 rules, thus posing no new interference concerns.

Compliance With Out-of-Band Field Strength Limits

Both Section 24.238 and Section 25.202(f) of the Commission's rules contain out-of-band emissions limitations for broadband PCS and satellite equipment, respectively, with Section 24.238 creating a stricter limit.[16] SpaceX has carefully engineered its system to meet the Section 24.238 PCS limit, even though it is more stringent than required by Section 25.202(f). By adhering to the stricter limit for all transmissions while operating in the PCS G Block, any out-of-band emissions into the bands below 1990 MHz or above 1995 MHz will be protected according to the same strict PCS limits regardless of whether a user is communicating with the terrestrial or satellite network.

With respect to out-of-band emissions for uplink transmissions (Earth-to-space), all mobile phones operating in the PCS G Block already comply with all relevant Part 24 rules, thus posing no new interference concerns.

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16 *See* 47 C.F.R. §§ 24.238, 25.202(f).

Interference Protection for Geostationary Satellite Networks

No geostationary orbit ("GSO") satellite networks have been filed for coordination in the PCS G Block worldwide. Should GSO operators seek access to these frequencies in the future, the Commission should refrain from imposing equivalent power flux-density ("EPFD") limits on NGSO systems. Notwithstanding the fact that NGSO providers would have filing priority, current operations within multiple frequencies affirm that NGSO systems can capably co-exist with GSO services without unnecessary EPFD limits.[17]

Interference with Respect to Other Non-Geostationary Satellite Systems

The ITU has procedures for coordination among NGSO systems.[18] SpaceX has engineered its system with the technical flexibility that will facilitate the necessary coordination with other NGSO satellite systems and is committed to achieving mutually satisfactory agreements. There are no NGSO systems filed through the United States operating in the PCS G Block and none filed by any other administration that has been granted U.S. market access. Thus, no further coordination or protection is required as part of this application for service in the United States.

Interference with Respect to Terrestrial Networks

T-Mobile is the exclusive licensee of the PCS G Block in the United States. T-Mobile has stated in a separate spectrum manager lease notification that it has an agreement with SpaceX regarding operation of the direct-to-cellular system in a way that is compatible with T-Mobile's primary terrestrial mobile operations. Thus, no further coordination or protection is required.

A.11 Coordination With U.S. Government Networks

To the extent necessary, SpaceX will coordinate with the National Telecommunications

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[17] *See* ITU Radio Regs. 22.5C, 22.5D, and 22.5F.

[18] *See id.* Ch. 3, Art. 9.12.

and Information Administration ("NTIA") to protect any operations in this or adjacent bands from harmful interference and to ensure that they are compatible with federal uses. SpaceX notes that the U.S. Table of Frequency Allocations lists no federal allocations from 1850-2205 MHz.

A.12 ITU Filings for SpaceX

The German Administration has submitted system information on SpaceX's behalf for ITU publication under the names MARS-VLS and MARS-ULS. With respect to operations in the United States, the filings request operation in the PCS G Block on a non-interference, non-protection basis to support the direct-to-cellular system through an Advance Publication Information ("API") based on Radio Regulation 4.4.[19]

MARS-VLS and MARS-ULS ITU Filings
German Administration **Date of Receipt: 23 August 2022**
1910-1915 MHz API/RR4.4*: Mobile-Satellite (Earth-to-space)
1990-1995 MHz API/RR4.4*: Mobile-Satellite (space-to-Earth)
* *Filed on non-interference, non-protection basis*

Table A.12-1: Summary table of ITU filing information relevant to the PCS G Block.

For operations outside of the United States, the MARS-VLS and MARS-ULS ITU filings contemplate use of frequencies from 1429 MHz to 2690 MHz. SpaceX intends to provide similar direct-to-cellular operations in international markets, subject to cooperation with terrestrial mobile

[19] *See id*., Ch. 2, Art. 4.4 ("Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.")

partners authorized to provide service on specified frequencies, and consistent with spectrum reuse authorizations within each country. These cooperative arrangements will provide protections for services allocated under Safety-of-Life, Radio Astronomy, Space Research, Radionavigation Satellite, Aeronautical Radionavigation, and Space Operations. SpaceX's operations will be consistent with the parameters specified in its ITU filings and compliant with any conditions of the authorizing Administration.

A.13 Orbital Debris Mitigation

SpaceX hereby incorporates by reference the orbital debris mitigation discussion from the Gen2 system application and authorization, and the SpaceX direct-to-cellular system will comply with any conditions on the Gen2 system relating to orbital debris mitigation.[20]

[20] *See generally* Previous Applications; *see also* Letter from David Goldman to Marlene H. Dortch, IBFS File Nos. SAT-LOA-20200526-00055 and SAT-AMD-20210818-00105, at 1-5 (Aug. 19, 2022).

ENGINEERING CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application, and that it is complete and accurate to the best of my knowledge and belief.

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Date