Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
THE BOEING COMPANY	)	
	)	
Application for Authority	)	
to Launch and Operate a Ka-band	)	File No. SAT-LOA-2016____-_____
Non-Geostationary Satellite Orbit	)	
System in the Fixed-Satellite Service	)	
and in the Mobile-Satellite Service	)	

APPLICATION

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November 15, 2016

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APPLICATION

The Boeing Company ("Boeing"), by its attorneys and pursuant to Sections 308 and 309 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 308 and 309, hereby requests authority to launch and operate a non-geostationary satellite orbit ("NGSO") system ("NGSO System") using spectrum in the Ka-band. Boeing's NGSO System will operate in the Fixed-Satellite Service ("FSS") in the 17.8-19.3 GHz and the 19.7-20.2 GHz bands (space-to-Earth) and the 27.6-29.1 GHz and the 29.5-30.0 GHz bands (Earth-to-space); and in the Mobile-Satellite Service ("MSS") in the 19.7-20.2 GHz (space-to-Earth) and the 29.5-30 GHz (Earth-to-space) bands; with MSS feeder links in the 19.3-19.7 GHz (space-to-Earth) and the 29.1-29.5 GHz (Earth-to-space) bands.

I. INTRODUCTION

Boeing is a leader in the global aerospace and satellite communications industries, providing technical expertise, manufacturing, launch services and on-orbit network control for a wide variety of commercial and government satellite systems. Boeing is developing its NGSO System in order to expand its contribution to the U.S. technological leadership and economic growth by introducing new satellite-delivered broadband services, thereby enhancing competition and the availability of broadband access in the United States and globally.

The NGSO System would provide very high data rate connectivity to support a wide range of Internet and communication services for residential, institutional, governmental and professional users worldwide. The satellites, gateways, and user terminals would use advanced antennas, narrow beam forming, and satellite tracking capabilities to continuously re-use all of the Ka-band frequencies within the coverage footprint of each satellite, resulting in tremendous and highly efficient spectrum re-use and aggregate system capacity. Boeing would operate its NGSO System, but the broadband capacity of the system may be used by multiple broadband service providers around the world to fulfill the needs of consumers. The public interest benefits offered by the NGSO System are substantial.

A detailed description of Boeing's proposed NGSO System, along with the narrative information required by Part 25 of the Commission's rules, is provided in Part II of this Application. Part III of this Application highlights the public interest benefits that could be achieved through the launch and operation of the NGSO System. Part IV contains the waiver requests necessitated by this Application and the justifications for their grant. Part V of this Application provides an interference analysis demonstrating the spectrum sharing capabilities of the NGSO System with other users of the Ka-band. In light of the significant public interest need for globally available and competitive broadband communications services, Boeing urges the Commission to promptly grant this Application.

II. NARRATIVE INFORMATION REQUIRED BY PART 25

The following narrative information is required by Part 25 of the Commission's rules for NGSO FSS and MSS satellite system applications and is not addressed either by Form 312 or Schedule S.

§ 25.114(c)(4)(v) Minimum Gain-to-Temperature Ratio

Section 25.114(c)(4)(v) of the Commission's rules requires the identification of the minimum gain-to-temperature ratio within the proposed coverage area of each shapeable beam. Schedule S, however, does not appear to have input fields for this data. The values are provided below using the same beam identification numbers ("IDs") that were included in the "Receiving Beam" section of the Schedule S for this Application.

Table II-1. Minimum Gain-to-Temperature Ratio

Beam ID	Minimum G/T within coverage area of each shapeable beam, dB/K
K6L1	1.8
K6L2	16.6
K7L1	1.9
K7L2	16.7
K9L1	2.1
K9L2	17.0
K6R1	1.8
K6R2	16.6
K7R1	1.9
K7R2	16.7
K9R1	2.1
K9R2	17.0

§ 25.114(c)(4)(vi) Antenna Gain Contours

The NGSO System will employ fixed, steerable, and steerable/shapeable transmit and receive beams as documented in Schedule S. Each of the Ka-band satellites in each plane of the NGSO System will have identical antenna characteristics. Therefore, the information provided in Schedule S for a single satellite applies to every Ka-band satellite in the NGSO System. The contour files attached to the "Receiving Beam" and "Transmit Beam" sections of Schedule S are representative contours as seen from satellite "S18" over the southwestern United States as shown in Figure II-3.

For transmit and receive beams that are both steerable and shapeable, the beam sizes and shapes are reconfigurable in orbit and have beam forming capabilities that are effectively infinite. Schedule S includes a representative number of beams, including the smallest and largest beams that the NGSO System would generate. These examples also bound the highest and lowest G/T, EIRP and saturation flux density ("SFD") for the Ka-band beams. The beam IDs of the smallest to the largest beams in Schedule S are provided below.

Table II-2. Range of Steerable and Shapeable Beams

	Steerable and shapeable beam	
Beam size	Receive beam ID	Transmit beam ID
Largest (regional)	N/A	K0LR, K1LR, K2LR, K4LR, K0RR, K1RR, K2RR, K4RR
Medium (spot 1)	K6L1, K7L1, K9L1, K6R1, K7R1, K9R1	K0L1, K1L1, K2L1, K4L1, K0R1, K1R1, K2R1, K4R1
Smallest (spot 2)	K6L2, K7L2, K9L2, K6R2, K7R2, K9R2	K0L2, K1L2, K2L2, K4L2, K0R2, K1R2, K2R2, K4R2

§ 25.114(c)(8) & § 25.208 Maximum Power Flux Density Levels

Section 25.114(c)(8) of the Commission's rules requires applicants for FSS space station authorizations to provide the calculated maximum power flux density ("PFD") levels within each coverage area and energy dispersal bandwidths, if any, needed for compliance with Section 25.208. This information is provided in the "Transmitting Beam" section of Schedule S of this Application. Sections 25.208(c-e) specify PFD limits for the following spectrum bands covered by this Application: 18.3-18.8 GHz and 19.3-19.7 GHz (§ 25.208(c)), 18.6-18.8 GHz

(§ 25.208(d)), and the 18.8-19.3 GHz bands (§ 25.208(e)). The NGSO system will operate within these limits as shown in Figure II-1.

Section 25.208 does not specify PFD limits for the 17.8-18.3 GHz band because this band is not allocated in the United States for FSS. (Boeing is requesting a waiver to operate in this band in Part IV (Requested Waivers) of this Application below.) Article 21 of the ITU Radio Regulations does include PFD limits for NGSO FSS systems operating in the 17.8-18.3 GHz band, which are identical to the PFD limits maintained in Section 25.208(e). The NGSO System will meet these PFD limits for its NGSO operations in the 17.8-18.3 GHz band as shown in Figures II-1a and II-1b.

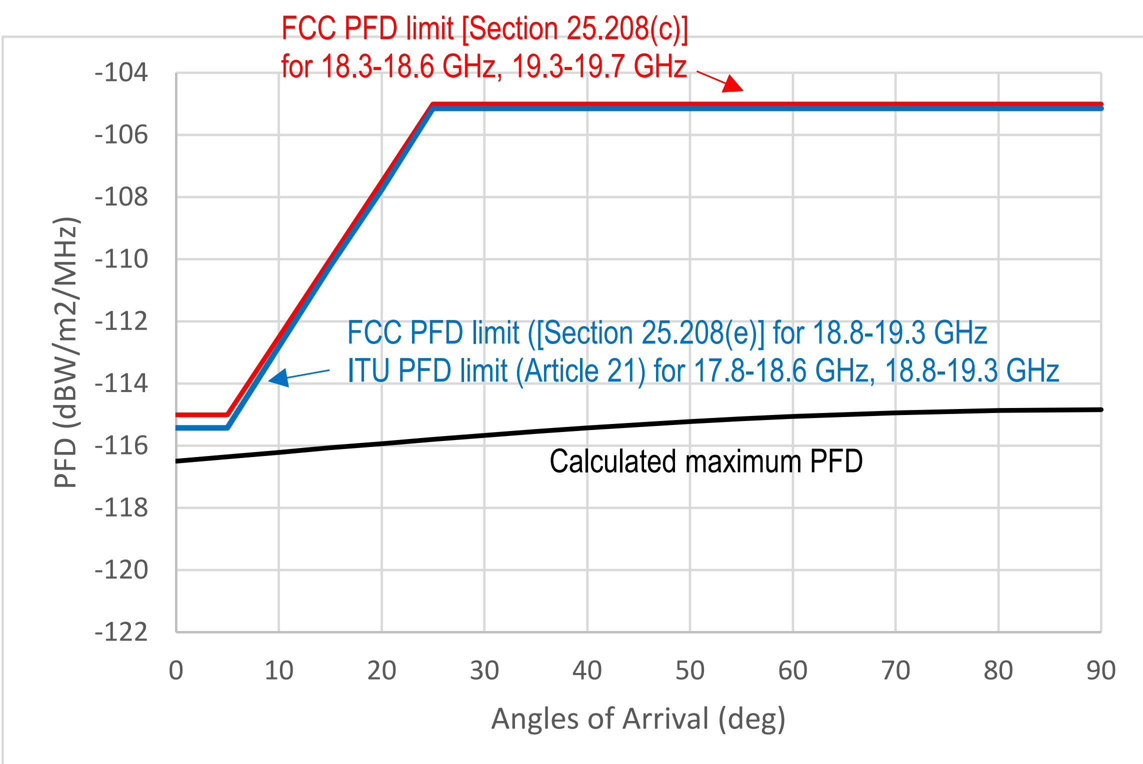

Figure II-1a. Calculated Maximum PFD (17.9-18.6 GHz and 18.8-19.7 GHz)

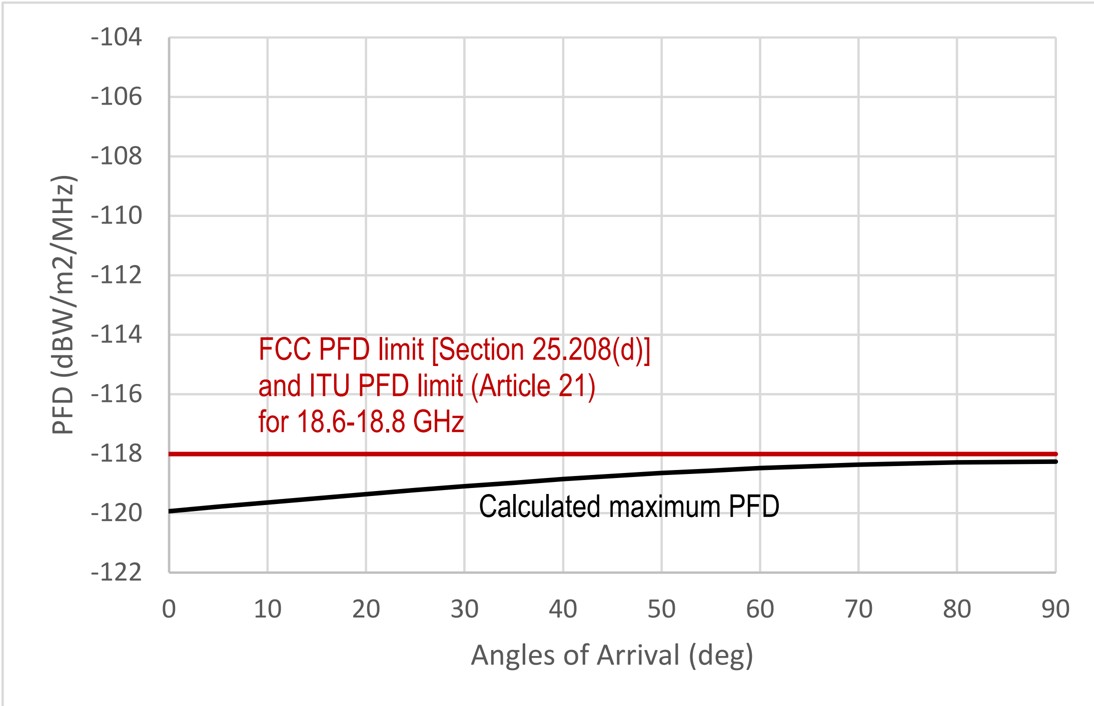

Figure II-1b. Calculated Maximum PFD (18.6-18.8 GHz)

§ 25.114(d)(1) System Facilities, Operations and Services and How Uplink Frequency Bands Connect to Downlink Frequency Bands

A. System Facilities, Operations, and Services

The NGSO System is designed to provide advanced communications services for residential, institutional, governmental, and professional users worldwide. Figure II-2 provides an overview of the NGSO System facilities and connectivity.

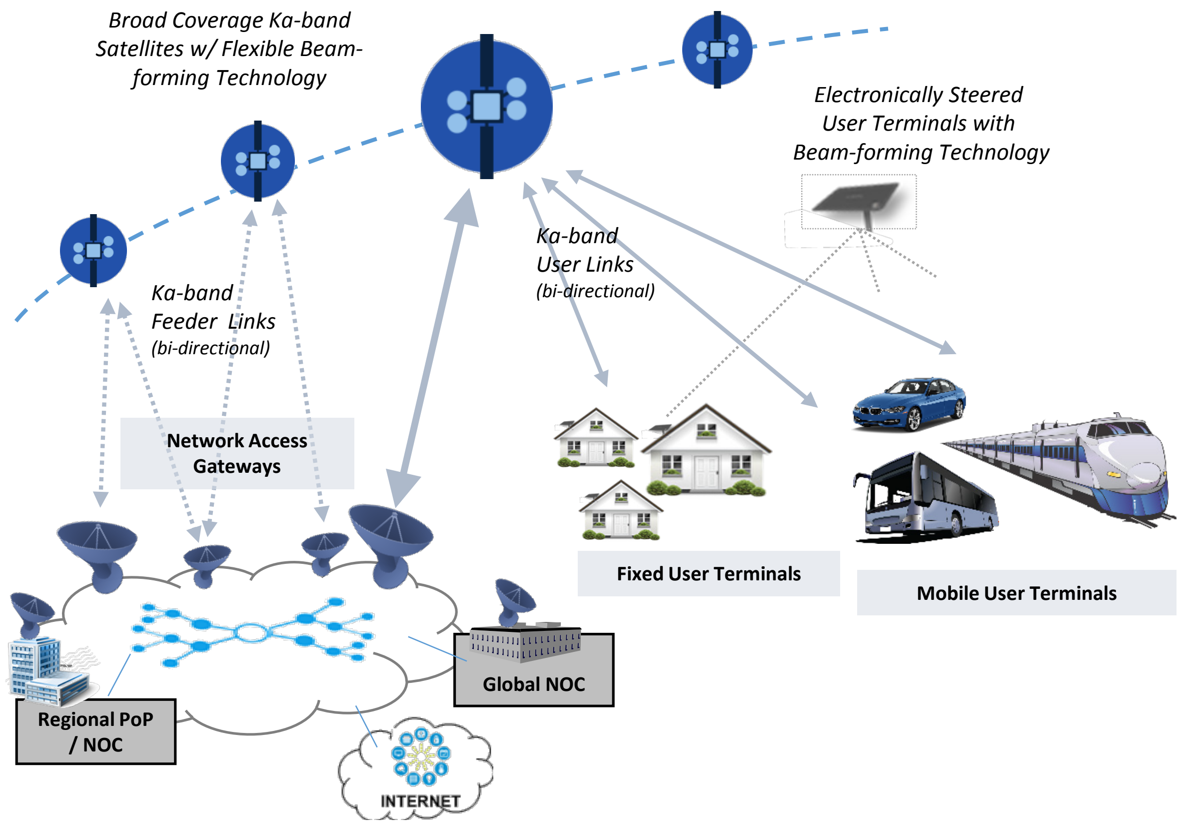

Figure II-2. NGSO System Overview and Facilities

The NGSO System would consist of a total constellation of 60 NGSO satellites to provide very high speed connectivity for end-user earth stations ("user terminals") via the system's gateways and associated terrestrial fiber network. The satellites, gateways, and user terminals would be managed from a Global Network Operations Center ("GNOC") and Regional NOCs to provide connectivity and management for multiple gateways within various regions worldwide.

Both user terminals and gateways would use bi-directional links operating within the Ka-band FSS spectrum, sharing and re-using the frequency band within the coverage footprint of each satellite. Sharing and efficient use of the spectrum would be enabled by advanced beam forming technologies within the satellite payload. User terminals operating with the NGSO System would use similar technologies with a small aperture size to provide highly directive, steered antenna beams that track the system's satellites. The system's gateways would use tracking antennas to generate high-gain beams to communicate with multiple NGSO satellites from a single gateway site. Overall control of the satellites and payloads would be accomplished from the GNOC via remote access to the in-band Ka-band TT&C links provided by the gateways.

1. NGSO System Constellation and Coverage

The complete deployment of Boeing's Ka-band NGSO System will consist of 60 highly inclined NGSO satellites operating in three constellations, an Americas constellation, an Africa/Europe constellation, and an Asia/Australia constellation. Figure II-3 illustrates the sub-satellite ground track of the complete deployment.

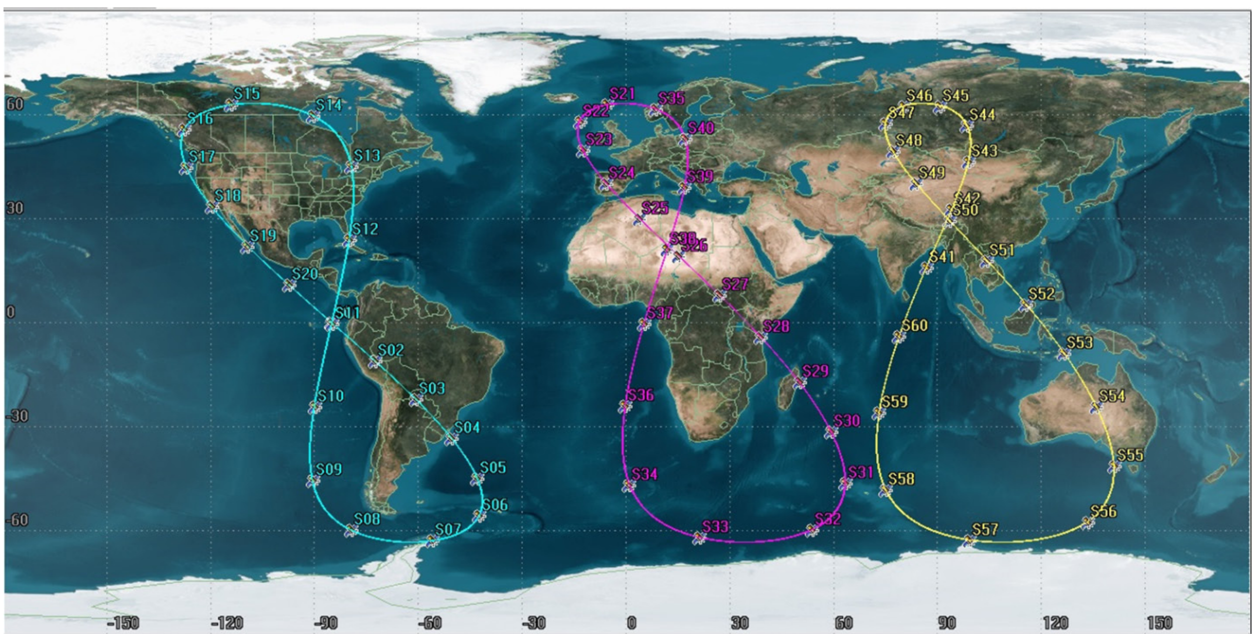

Figure II-3. Ka-Band NGSO System Complete Deployment

For more than two decades, Boeing (including the former Hughes Space and Communications Company) has developed and implemented proprietary and patented constellation designs incorporating highly inclined orbits. In addition, Boeing has extensive experience with the operation of satellites in highly inclined orbits. The use of this constellation design will reduce the overall quantity of satellites and enable efficient spectrum use, in part by avoiding interference to satellites in geostationary satellite orbit ("GSO"). Each of Boeing's satellites would operate in its own eccentric-orbit plane operating at a 63.4 degree inclination and at altitudes between approximately 27,355 kilometers and 44,221 kilometers. A detailed description of the satellite constellation is included in the "Non-Geostationary Satellite Orbital Information" section of Schedule S.

Boeing proposes to deploy its NGSO System in multiple phases. Phase One of Boeing's NGSO System would consist of ten satellites operating in the Americas constellation, which is sufficient to provide complete ground coverage to meet Boeing's anticipated initial capacity requirements and to satisfy Section 25.145(c)(2) of the Commission's geographic service requirements. Phase One is depicted in Figure II-4 below.

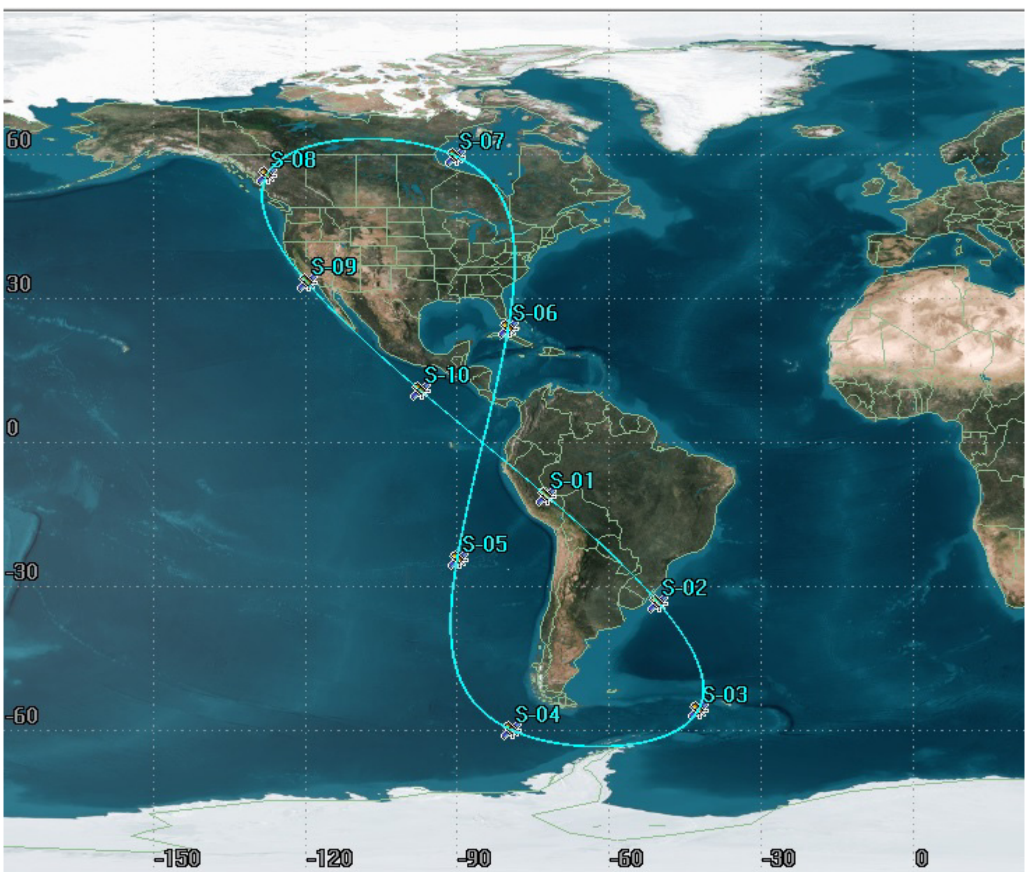

Figure II-4. Ka-Band NGSO System Phase One Deployment

The Phase One deployment would provide continuous satellite visibility at an earth station elevation angle of greater than 40 degrees for user terminals in the United States, Puerto Rico, and the U.S. Virgin Islands. High elevation angles offer a significant advantage for system operation by enabling reduced losses due to link impairments and offering multiple line of sight ("LOS") paths to avoid blockage. The system's gateway earth stations would operate with elevation angles as low as 25 degrees, both to reduce the number of gateways sites and to facilitate handover operations.

Phase Two of Boeing's NGSO System would consist of twenty additional satellites, ten of them deployed in the Africa/Europe constellation and ten of them in the Asia/Australia constellation. Boeing's Phase Two deployment would include sufficient satellites to provide continuous coverage to most major landmasses and satisfy the anticipated initial capacity requirements of system users in those regions of the world. Finally, Phase Three of Boeing's NGSO System deployment would consist of thirty additional NGSO satellites that would be added proportionally to the three constellations on an incremental basis to satisfy increasing capacity requirements.

The NGSO System would use its advanced beam forming payload to generate a multiplicity of beams of various sizes in designated areas of the Earth's surface. The NGSO System would be used primarily to provide content to large numbers of user terminals using a combination of broad area coverage beams and spot beams. Figure II-5 shows an example of a beam coverage pattern that could be employed to meet the domestic coverage requirements of Section 25.145(c)(2).

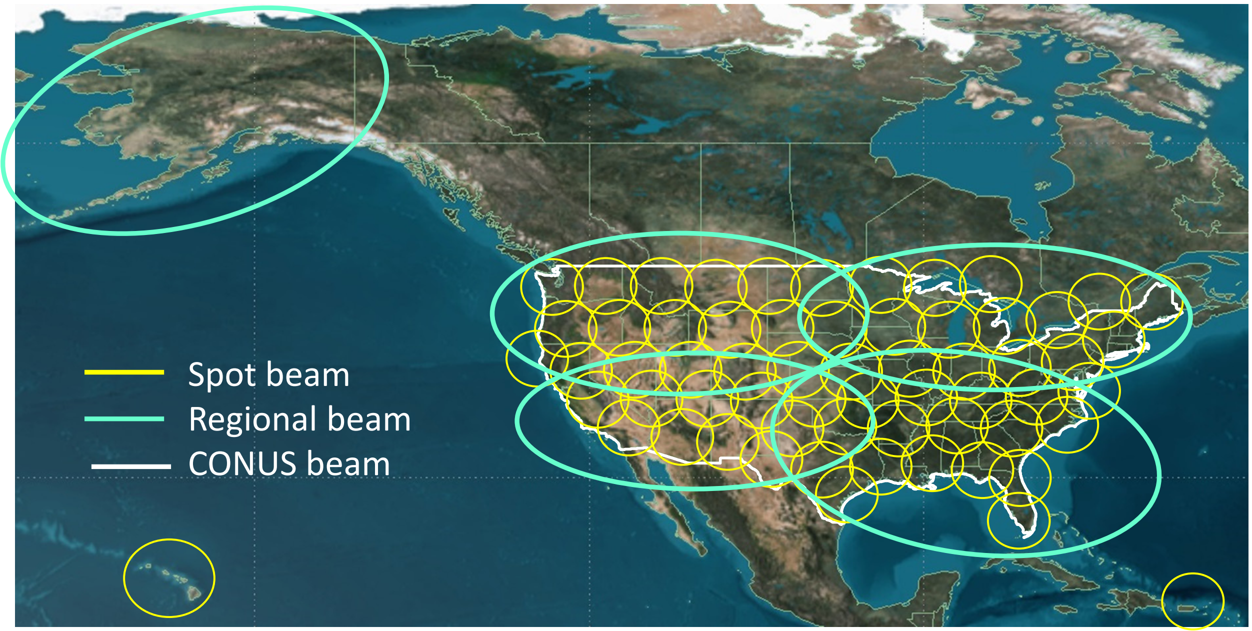

Figure II-5. Ka-Band Segment Satellite Coverage Footprints for United States

Narrow spot beams with low sidelobes would enable frequency re-use among the many beams within each satellite footprint. Efficient re-use of the Ka-band spectrum is described in Part B of this section and in the narrative covering Section 25.210(f). System gateways use the same Ka-band FSS spectrum as the user service, and would typically be located outside of highly-populated regions. Gateway location diversity would be provided, enabling system users in the vicinity of a gateway to be assigned to NGSO satellites that are served by other gateways. Such gateway diversity also enables spectrum sharing with other NGSO systems as described further in Section V of this Application.

Each NGSO satellite would be able to form beams as small as 250 kilometers within the overall satellite coverage footprint. The largest satellite beam would provide coverage of the contiguous continental United States ("CONUS"). Examples of the Ka-band beams are described in the "Receiving Beam" and "Transmitting Beam" sections of Schedule S and the antenna contours are further explained in the narrative covering Section 25.114(c)(4)(vi). User terminals would be mapped to one or more beam coverage areas and the payload beams would be directed towards these coverage areas as the NGSO satellites pass over. The system NOCs would ensure that user terminals are handed over at elevation angles greater than 40 degrees, providing seamless user communications service via a make-before-break handover approach. The NOCs would perform satellite-to-gateway handovers at elevation angles as low as 25 degrees to ensure continuous coverage to users in the designated coverage areas.

2. System Terminals and Services

The NGSO System would provide advanced communications services to a range of earth stations. The user terminals for the NGSO System would consist of a family of advanced array terminals including fixed and transportable ground-based terminals, as well as terminals onboard mobile platforms. These terminals would transmit and receive wideband signals on any system channel, with higher throughputs supported by terminals designed for multi-channel/multi-polarization operation.

The system earth stations (both gateways and user terminals) would use advanced digital modulation and coding, along with adaptive modulation coding and power control, to achieve high spectral efficiencies and availability while efficiently managing the use of earth station and satellite transmission power. Section B below discusses the assignment of uplink and downlink frequencies to earth stations. The NGSO System would dynamically assign carriers and polarization, and hence capacity, to the earth stations within each satellite footprint cell. The dynamic bandwidth assignment would align the satellite capacity with the satellite motion and could accommodate the time-varying nature of the user traffic demand across the coverage footprint.

The NGSO System gateways would operate both within the same FSS spectrum as the user terminals and also in the spectrum identified for MSS feeder links. The system's gateways would use both frequency polarizations (LHCP and RHCP). Gateway sites may contain more than one antenna thereby enabling simultaneous access to multiple Ka-band satellites from a single site.

B. System Frequency Usage and Frequency Plan

The uplink and downlink frequency plans for the NGSO System are shown in Table II-3 and the "Operating Frequency Bands" section of Schedule S. The communication channels, beacon channels, and telemetry and command channels associated with these frequency bands are described in the "Receiving Channels" and "Transmitting Channels" sections of Schedule S.

Table II-3. Ka-band Segment Plan

Link	Service	Band
Gateway to satellite	FSS	27.6-29.1 GHz 29.5-30.0 GHz
	MSS feeder link	29.1-29.5 GHz
Satellite to gateway	FSS	18.6-19.3 GHz 19.7-20.2 GHz
	MSS feeder link	19.3-19.7 GHz
User to satellite	FSS	28.4-29.1 GHz
	FSS / MSS	29.5-30.0 GHz
Satellite to user	FSS	17.8-19.3 GHz
	FSS / MSS	19.7-20.2 GHz

As shown in Table II-3, data communication associated with mobile user terminals would be restricted to the frequency bands labeled "FSS/MSS." The system NOCs would enforce these constraints.

1. Uplink Frequency Plan – Communication Channels

As shown in Figure II-6 (red- and green-shaded channels) and in the "Receiving Channels" section of Schedule S, uplink data communication channels would consist of nine channels per polarization, each occupying between 200 MHz and 390 MHz in the 27.6-30.0 GHz range. Five of these channels (per polarization) would be used both for gateway-to-satellite forward uplinks and for user-to-satellite return uplinks and four of the channels would be used only for gateway-to-satellite forward uplinks. Each of these channels may be partially or fully occupied by one or more carriers.

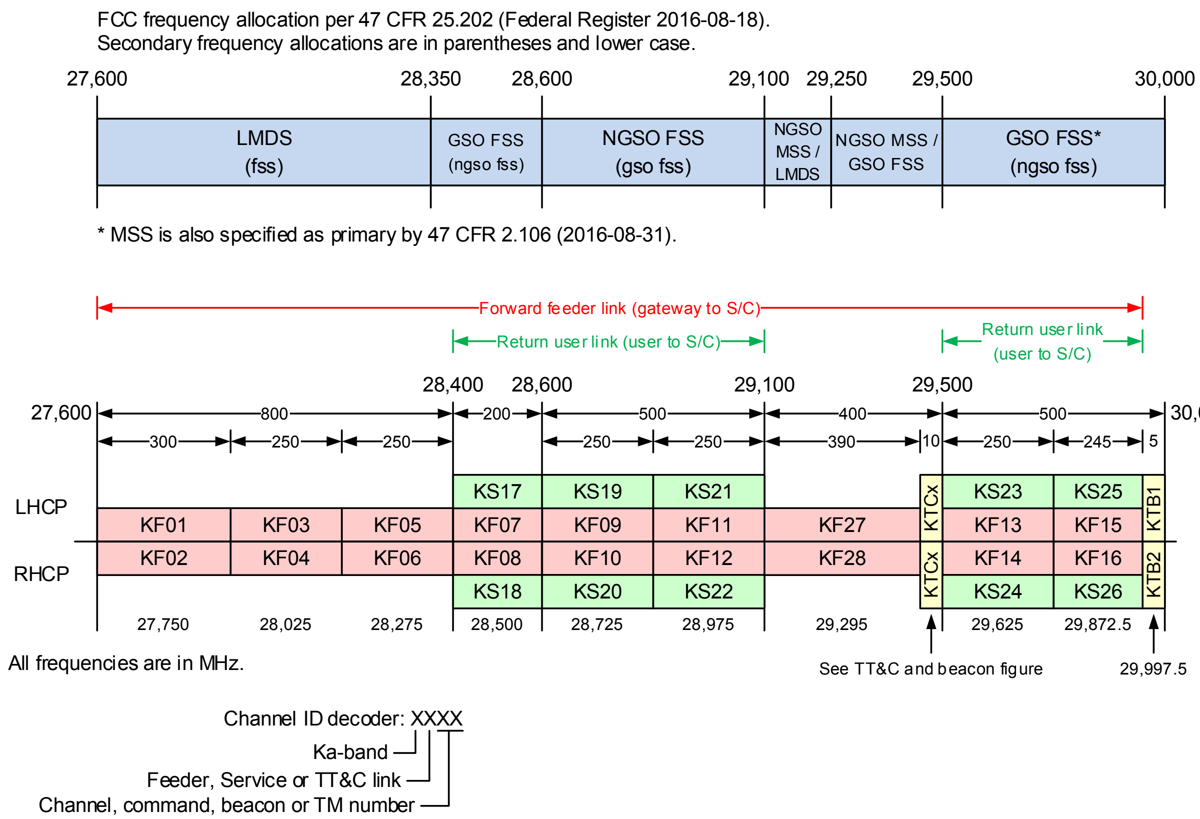

Figure II-6. Ka-Band Uplink Channel Frequency Plan

2. Uplink Command Channels

As shown in Figure II-7 below, satellite command channels (identified as KTCx) are allocated within 10 MHz of the upper edge of the 29.25-29.50 GHz band. Within that 10 MHz, two 1.2 MHz satellite command channels (per polarization) would be allocated to support high speed uplink command carriers as shown in the "Receiving Channels" section of Schedule S. One 16 kHz satellite command channel (per polarization) would be allocated to support low speed uplink command carriers to be used in conjunction with hemispherical coverage beams (KCLL/KCRL) as shown in the "Receiving Beams" section of Schedule S. Each high speed command carrier would allow robust commanding from a single gateway site to a multiplicity of NGSO satellites within the field of view of the gateway. Figure II-7 below identifies the center frequencies of each of the channels.

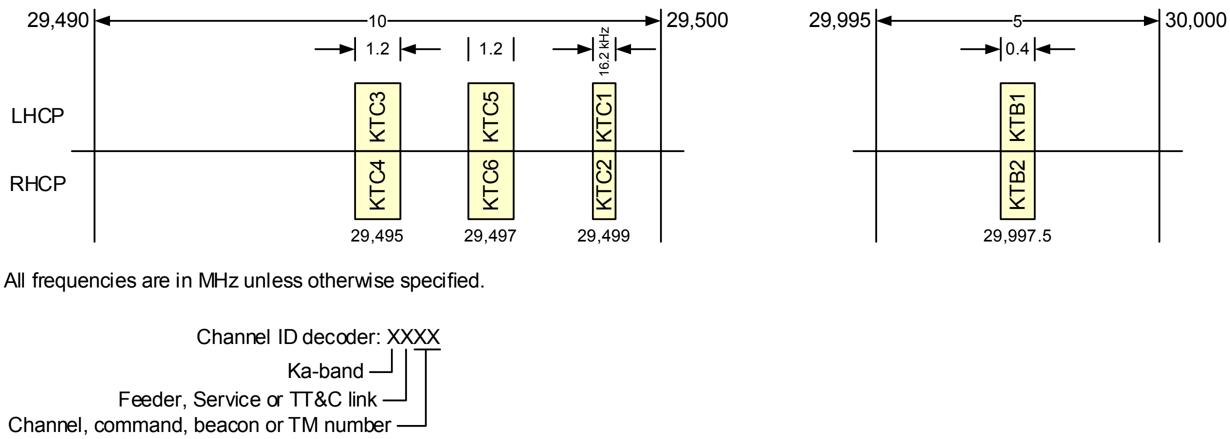

Figure II-7. Uplink TT&C Channel Frequency Plan

3. Uplink Beacon Channels

As shown on the right side of Figure II-7 above, uplink beacon channels (identified as KTB1, KTB2) are allocated within 5 MHz of the upper edge of the 29.5-30.0 GHz band. One 400 kHz uplink beacon channel (per polarization) would be allocated to enable rapid gateway acquisition by the system satellites, enabling robust NGSO System operation and handovers.

4. Downlink Frequency Plan – Communication Channels

As shown in Figure II-8 (red- and green-shaded channels) and in the "Transmitting Channels" section of Schedule S, downlink data communication channels would consist of nine channels per polarization, each occupying between 200 MHz and 390 MHz in the 17.8-20.2 GHz range. Five of these channels (per polarization) would be used both for satellite-to-user forward downlinks and for satellite-to-gateway return downlinks, three of the channels would be used only for satellite-to-user forward downlinks and one channel would be used only for satellite-to-gateway return downlinks. Each of these channels may be partially or fully occupied by one or more carriers.

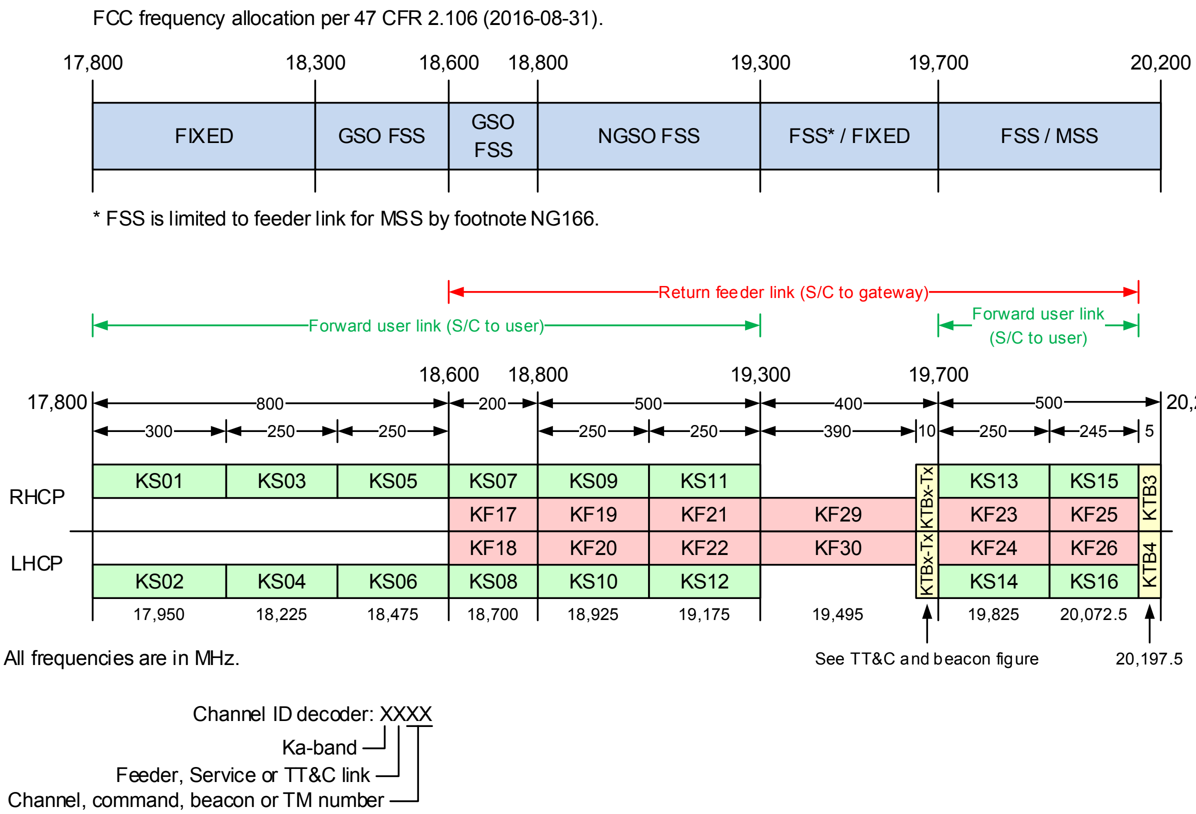

Figure II-8. Ka-Band Downlink Channel Frequency Plan

5. Downlink Telemetry Channel

As shown in Figure II-9 below, satellite telemetry channels (identified as KTTx) are allocated within 10 MHz of the upper edge of the 19.3-19.7 GHz band. Within that 10 MHz, one 1.2 MHz satellite telemetry channel (per polarization) would be allocated to support high speed downlink telemetry carriers as shown in the “Transmitting Channels” section of Schedule S. One 12 kHz satellite telemetry channel (per polarization) would be allocated to support low speed downlink telemetry carriers to be used in conjunction with hemispherical coverage beams (KTLL/KTRL) as shown in the “Transmitting Beams” section of Schedule S. Each high speed telemetry carrier would provide a robust telemetry stream from each NGSO satellite within the field of view of a single gateway. Figure II-9 below identifies the center frequencies of each of the channels.

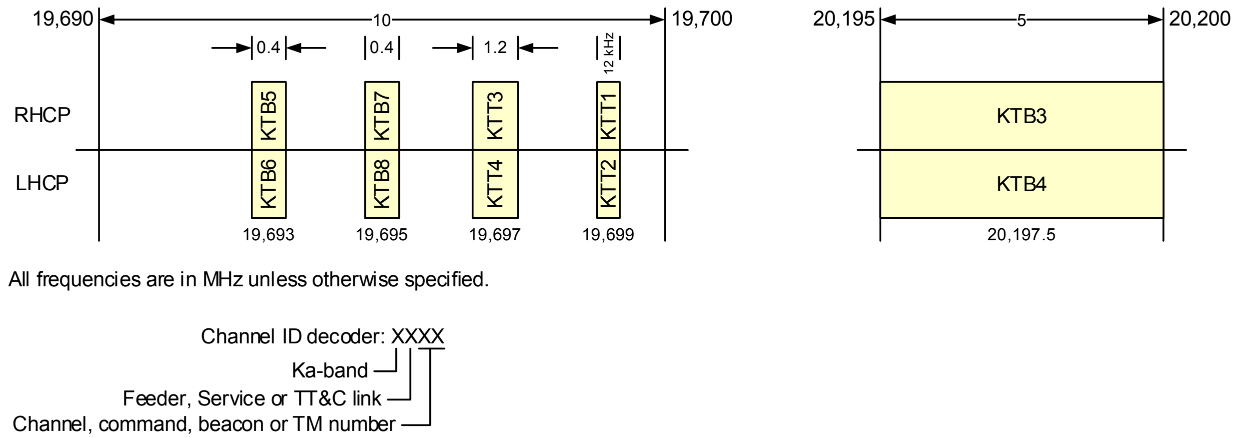

Figure II-9. Downlink TT&C Channel Frequency Plan

6. Downlink Beacon Channels

The satellites would use two different types of downlink beacon transmission. As shown in Figure II-9 above, downlink beacon channels (identified as KTBx) are allocated within 10 MHz of the upper edge of the 19.3-19.7 GHz band. Other downlink beacon channels (identified as KTB3, KTB4) are allocated within 5 MHz of the upper edge of the 19.7-20.2 GHz band. Within the 19.7-20.2 GHz band, one 5 MHz downlink beacon channel (per polarization) would be allocated as shown in the "Transmitting Channels" section of Schedule S. An approximately 5 MHz beacon signal would be transmitted in this channel using broad area coverage beams (KBLB/KBRB) as shown in the "Transmitting Beams" section of Schedule S. Within the 19.3-19.7 GHz band, two 400 kHz downlink beacon channels (per polarization) would be allocated. Together, these beacon signals would enable rapid satellite acquisition by the system earth stations, enabling robust NGSO system operation and handovers. Figure II-9 above identifies the center frequencies of each of the channels.

§ 25.114(d)(6) Public Interest Considerations

Public interest considerations supporting the grant of this Application are set forth in Part III of this Application.

§ 25.114(d)(14) Mitigation of Orbital Debris (including § 25.283)

The NGSO System would employ the following design and operational strategies to mitigate orbital debris and conduct a comprehensive end-of-life disposal.

A. Satellite Hardware Design

The NGSO System satellites would deploy and operate on-orbit without the generation or release of debris over the mission life. As such, the satellites would not use exterior materials or designs that may generate debris due to environmental factors (*e.g.*, radiation degradation, thermal fatigue, *etc.*). The design would also prevent the satellites from becoming a source of debris due to collisions with micrometeoroids.

To ensure that the satellites would perform post-mission disposal and prevent loss of control at any point of the mission, the satellites would be designed to be resilient to the space environment, including radiation degradation and micrometeoroid impacts over the mission life. These proven design measures, used in heritage GSO missions, have resulted in proven greater than 85 percent bus reliability on-orbit, include redundancy for vulnerable and critical satellite elements. Critical elements – power, attitude control, thermal control, and propulsion systems – would be protected with bumper shields and micrometeoroid/debris blankets to minimize the probability of catastrophic failure and resulting loss of control that could preclude successful post-mission disposal. Verification of satellite shielding effectiveness has been performed using the NASA micrometeoroid/orbit debris risk analysis software BUMPER and an environment defined by the NASA Orbit Debris Environment Model (ORDEM 3.0).

B. Mitigating Accidental Explosions

To minimize risk of accidental explosions during mission operations, and to ensure that any debris generation will not result from the conversion of energy sources on board the spacecraft into energy that fragments the spacecraft, onboard storage of energy in the satellites would be limited to:

- Lithium ion batteries,
- Reaction wheel assemblies,
- Pressurized propellant tanks, and
- Constant conductance heat pipes.

The batteries, reaction wheel assemblies, and pressurized fuel tank would operate safely within regulated and specified conditions and without risk of environmental-induced failures (*e.g.*, debris damage, radiation degradation, damage from electrostatic discharge events, *etc.*). Traditionally, constant conductance heat pipes have been used for thermal control and are standard space-qualified designs, which contain low pressure ammonia working fluids, are not conducive to explosions when damaged, and have had no prior explosive incidents on-orbit.

Following completion of mission operations and successful transfer of the satellites into a disposal orbit, passivation of the on-board sources of stored energy would be performed to limit the risk of accidental explosions. This process would include the full discharge and depletion of the batteries and de-spinning of the reaction wheel assemblies. Depletion burns at the end-of-life would be required to ensure that all residual propellant has been eliminated and the fuel tank would be completely depressurized with subsequent venting.

C. Safe Flight Profiles and Operational Configuration

There is no risk of conjunction between Boeing's NGSO satellites and any GSO satellites due to the orbit design of the NGSO System. Boeing, with data provided by the Space Surveillance Network ("SSN"), would monitor all tracked objects in the U.S. Space Catalog.

The tracked-object catalog includes the most recent orbital estimate and best estimate of object radius. Orbits would be propagated over a seven-day period. Objects determined to have a "likely close approach" would result in a request to gather more orbit determination data derived from the SSN in the following days. As orbit estimations are refined, the probability of collision would be updated. If the probability of collision is greater than 10^{-4} for the given tolerated miss distance (determined by the space object radius) at one day before the time of close approach, a collision avoidance maneuver would be performed.

D. Post-Mission Disposal

At end-of-life, the Ka-band NGSO satellites would be inserted from their nominal orbit into a safe graveyard orbit. As noted in the previous section, the operating orbit is elliptical, with an apogee at 44,221 kilometers and a perigee at 27,355 kilometers. As such, the optimal disposal orbit would retain the same apogee and a raised perigee safely above the GSO arc. The altitude of the graveyard orbit apogee is determined by the following formula:

35,786 km + 200 km + 35 km + (1000 C_R A/m)

where the 200 kilometer term accounts for a graveyard buffer zone relative to the GSO belt, 35 kilometer for the maximum descent due to lunar, solar, and geopotential perturbations, C_R is the solar radiation pressure coefficient of a satellite, and A/m is the area to mass ratio, in square meters per kilogram, of a satellite.[1] For the Ka-band NGSO satellites, the perturbation due to solar radiation pressure is 94 kilometers and the disposal orbit would have a perigee of 36,115 kilometer altitude. Sufficient propellant will be allocated and reserved to perform the disposal maneuvers.

[1] *See* Mitigation of Orbital Debris, IB Docket No. 02-54, *Second Report and Order*, ¶¶ 65, 68 (June 21, 2004) (adopting in the Commission's rules the above-referenced formula developed by the Inter-Agency Space Debris Coordination Committee ("AIDC")).

§ 25.145(c) Geographic Coverage Requirements

Sections 25.145(c) of the Commission's rules requires that the proposed system be capable of provide FSS to (1) all locations as far north as 70° North latitude and as far south as 55° South latitude for at least 75 percent of every 24-hour period; and (2) on a continuous basis throughout the fifty states, Puerto Rico and the U.S. Virgin Islands.

The Phase One deployment of the NGSO System will comply with Section 25.145(c)(2) of the geographic service rules relating to domestic coverage. The NGSO System, however, will not be able to comply with Section 25.145(c)(1) (international coverage) following Phase Three deployment because, even though all major landmasses will be covered, a lack of coverage will exist (shown in dark blue in Figure II-10 below) in portions of the Pacific and Atlantic Ocean regions. Boeing is requesting a waiver of this rule, which is addressed in Part IV (Requested Waivers) of this Application.[2]

[2] Both FCC Form 312 and Schedule S include a question about compliance with the Commission's geographic coverage rules. With respect to Schedule S, Boeing indicated that the applicable geographic service requirements are not met. With respect to Form 312, question 43a, however, none of the three optional answers accurately reflects Boeing's situation. Answer A is not applicable because Boeing's Ka-band NGSO System is subject to the Commission's geographic service rules. Answer B is not applicable because the NGSO System will not fully comply with the Commission's geographic service rules. Answer C is also not applicable because it states the criteria for waiver of the geographic service rules that is applicable to satellites in the direct broadcast satellite service, rather than FSS or MSS. Boeing therefore selected Answer B, but acknowledges herein and in Schedule S that Boeing's NGSO System will not fully comply with the relevant geographic service rules.

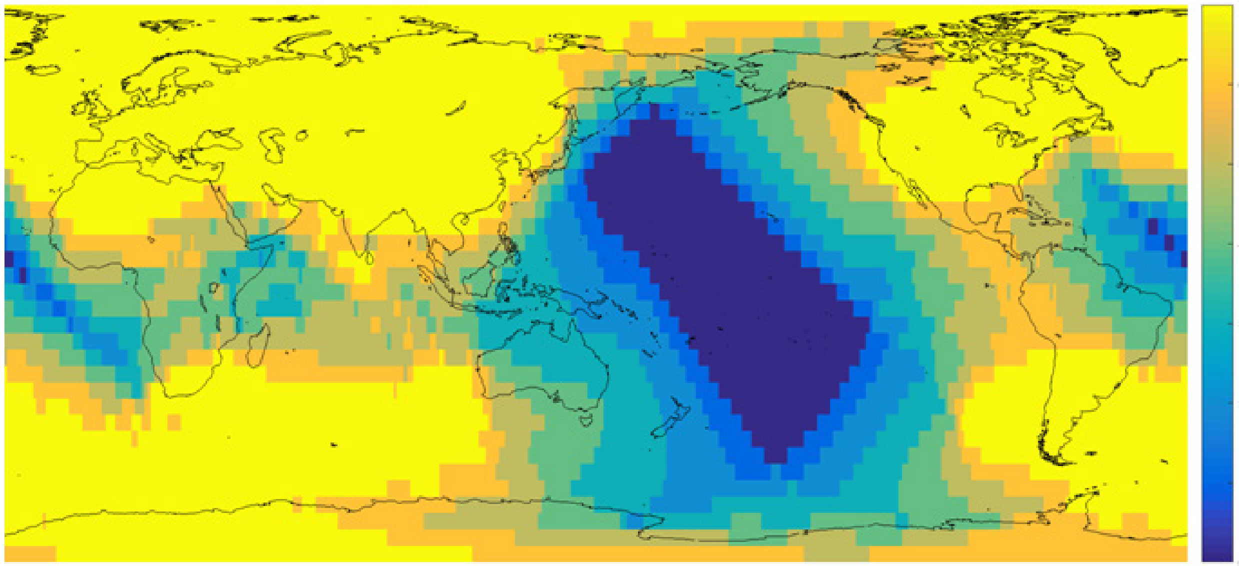

Figure II-10. Ka-band NGSO System Geographic Coverage[3]

§ 25.145(e) Prohibition of Certain Agreements

Boeing hereby certifies that it will not, nor will any persons or companies controlling or controlled by the applicant, acquire or enjoy any right, for the purpose of handling traffic to or from the United States, its territories or possessions, to construct or operate space segment or earth stations, or to interchange traffic, which is denied to any other United States company by reason of any concession, contract, understanding, or working arrangement to which the Licensee or any persons or companies controlling or controlled by the Licensee are parties.

§ 25.156(d)(4) Separate Treatment of Feeder Links and Service Links

Boeing is requesting a waiver of this rule section, which are addressed in Part IV (Requested Waivers) of this Application.

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[3] As indicated in the key on the right of the figure, across most landmasses (shown in yellow) about 7 satellites will always be visible at an elevation angle of above 40°, while some landmasses will have 5 to 6 satellites visible (shown in orange), a few will have 4 satellites always visible (shown in green) and a few other areas will have at least 3 satellite visible (shown in light blue).

§ 25.157(e) Bandwidth Assignments Resulting From Processing Rounds

Boeing is requesting a waiver of certain aspects of this rule section, which are addressed in Part IV (Requested Waivers) of this Application. As Boeing explains in Part V of this Application, the NGSO System can share the Ka-band with other GSO and NGSO satellite systems.

§ 25.164(b) Construction Milestones

Section 25.164(b) of the Commission's rules requires licensees of NGSO systems to "launch the space stations, place them in the assigned orbits, and operate them in accordance with the station authorization no later than six years after the grant of the license, unless a different schedule is established by Title 47, Chapter I, or the Commission."[4] Given Boeing's proposal for a phased deployment of its NGSO System, Boeing herein requests that the Commission establish a different schedule that ensures the launch and operation of the initial phase of the NGSO System within the time frame contemplated by the Commission's rules, but also affords Boeing the flexibility to enhance the NGSO System's capabilities over time.

As discussed previously in this Application, Boeing proposes to launch its Ka-band NGSO System in three phases. The Phase One deployment of the NGSO System would include a sufficient number of satellites to satisfy the Commission's domestic geographic coverage requirements of providing service on a continuous basis throughout the fifty states, Puerto Rico and the U.S. Virgin Islands and would provide enough capacity to meet the anticipated needs of the initial customers. The Phase Two deployment would provide additional coverage to most major populated landmasses in the rest of the world. The Phase Three deployment would provide additional capacity to meet growing demand requirements.

[4] 47 C.F.R. § 25.164(b).

Given this proposed schedule, Boeing proposes that the Commission designate two milestones for the launch and operation of Boeing's NGSO System. The first milestone would require Boeing to launch and operate its Phase One deployment by the end of the sixth year after the grant of the license in compliance with Section 25.164(b) of the Commission's rules. The second milestone would require Boeing to launch and operate its Phase Two deployment by the end of the tenth year after the grant of the license for Boeing's NGSO System.

Good cause exists to authorize Boeing to use this phased approach. The Commission has long maintained milestone requirements "to deter warehousing by satellite operators before a proposed space station has been launched and begun operations." [5] The launch and operation of the Phase One deployment of ten satellites within six years and the Phase Two deployment of twenty satellites within ten years would not constitute warehousing of orbital or spectrum resources. As described herein, the Boeing NGSO System can share spectrum effectively with GSO and NGSO systems so adopting the proposed milestone for Phase Two and allowing capacity augmentation during Phase Three would have no adverse effects on access to the band by other satellite systems. In addition, the NGSO System's Phase One deployment would satisfy the Commission's domestic geographic coverage requirements, the Phase Two deployment

[5] Comprehensive Review of Licensing and Operating Rules for Satellite Services, IB Docket No. 12-267, *Second Report and Order*, FCC 15-167, ¶ 53 (2015) (*citing* Inquiry into the Development of Regulatory Policy in Regard to Direct Broadcast Satellites for the Period Following the 1983 Regional Administrative Radio Conference, Gen. Docket No. 80-603, *Report and Order*, 90 FCC 2nd 676, 719, ¶ 114 (1982); MCI Communications Corporation, Application for Extensions of Time to Construct and Launch Space Stations in the Domestic Fixed-Satellite Service, *Memorandum Opinion and Order*, 2 FCC Rcd 233, 233, ¶ 5 (Com. Car. Bur. 1987); Norris Satellite Communications, Inc., Application for Review of Order Denying Extension of Time to Construct and Launch Ka-Band Satellite System, *Memorandum Opinion and Order*, 12 FCC Rcd 22299 (1997); Morning Star Satellite Company, L.L.C., Application for Authority to Construct, Launch, and Operate a Ka-band Satellite System in the Fixed-Satellite Service at Orbital Locations 62° W.L., 30° E.L., 107.5° E.L., and 147° W.L., *Memorandum Opinion and Order*, 16 FCC Rcd 11550 (2001)).

would satisfy nearly all of the Commission's international geographic coverage requirements, and the satellites in all phases of deployment would use the entire 2.4 GHz of paired Ka-band spectrum to provide a comprehensive service.

A phased milestone approach, as well as the proposed treatment of Boeing's Phase Three deployment, would be consistent with the Commission's recent decision to permit Planet Labs to increase its NGSO constellation size from approximately 67 satellites to 200 satellites without imposing milestones or bond requirements on the additional deployment,[6] and to permit Spire Global to increase the size of its NGSO constellation by 20 satellites without imposing milestones or bond requirements on the additional deployment.[7] Such an approach would also be consistent with the Commission's anti-warehousing policies while being cognizant of potential implementation constraints and the need for operational flexibility associated with the launch and operation of large NGSO constellations.

§ 25.165 Surety Bond

Section 25.165 of the Commission's rules requires NGSO System licensees to post a Surety Bond, which entails an escalating bond reaching up to $5 million at the end of the sixth year following the grant of an NGSO system license. Section 25.165(c) indicates that an NGSO system licensee will be considered to be in default of its bond "if it fails to meet any milestone deadline set forth in §25.164 and, at the time of milestone deadline, the licensee has not provided

[6] *See* Grant of Application of Planet Labs Inc. for Modification of Authority to Launch and Operate an NGSO Satellite System (call sign S2912), IBFS No. SAT-MOD-20150802-00053, ¶ 13 (June 15, 2016).

[7] *See* Grant of Application of Spire Global, Inc. for Authority to Launch and Operate an NGSO Satellite System (call sign S2946), IBFS No. SAT-LOA-20151123-00078, ¶ 7 (June 16, 2016).

a sufficient basis for extending the milestone."[8] As noted in the previous section of this Application, Boeing has requested that the Commission establish two milestones for the construction and launch of its NGSO System.

Boeing believes that the Commission need only require Boeing to comply with the first of these two milestones in order to avoid default on its surety bond in a manner consistent with the requirements of Section 25.165 of the Commission's rules, but that failure to meet the second milestone should result in revocation of authority to operate the expanded Phase Two portions of the NGSO System. As discussed previously, because authorizing Boeing to construct and operate the Phase Two portion of its system would not preclude use of the spectrum and orbital resource by other satellite systems, there is no policy reason to impose additional surety bond requirements on Boeing beyond the initial Phase One implementation requirements. To the extent the Commission determines its milestone and bond rules require imposition of a performance bond beyond the initial six-year milestone associated with Boeing's Phase One implementation, however, Boeing believes that the Commission may simply extend the bond period to enforce the Phase Two milestone without further escalation or requiring a second, wholly independent surety bond.

§ 25.202(a)(1) Spectrum Bands Available for FSS

As noted above, Boeing is requesting authority to operate its NGSO system in the United States in the FSS frequency bands: 17.8-19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.6-29.1 GHz and 29.5-30.0 GHz (Earth-to-space). The U.S. Table of Frequency Allocations contains an allocation for Federal FSS in the 17.8-18.3 GHz portion of this range, but not for

[8] 47 C.F.R. § 25.165(c).

non-Federal FSS.[9] Consistent with this, section 25.202(a)(1) of the Commission's rules does not include the 17.8-18.3 GHz band as available for FSS. In addition, pursuant to footnote NG164, the use of the 18.3-18.8 GHz band for FSS is limited to GSO systems. Boeing requests a waiver of these rules in Part IV of this Application.

§ 25.202(g) Telemetry, Tracking and Command FSS

In conformance with Section 25.202(g)(2) of the Commission's rules, Boeing has selected the frequencies, polarizations, and coding of telemetry, tracking, and command ("TT&C") transmissions in a manner that minimizes interference into other satellite networks. Further, Boeing's selection of TT&C frequencies, some but not all of which are on the band edges, will result in no greater interference to, and require no greater protection from harmful interference from, the communications traffic of other satellite networks.

§ 25.204(b)-(e) Earth Station Transmissions Limits

Boeing has designed its NGSO System to comply with the relevant earth station EIRP transmission limits specified in Section 25.204(b)-(e). To meet the desired link performance while minimizing interference between networks, earth station transmissions under conditions of uplink fading will use power control methods to not exceed 1 dB above the actual uplink excess attenuation over clear sky conditions, as required by Section 25.204(e).

§ 25.207 Cessation of Emissions

The GNOC for the NGSO System will be able to command and effectuate the cessation of emissions from any or all of the NGSO spacecraft if the need arises.

[9] 47 C.F.R. § 2.106.

§ 25.208(c-e) Maximum Power Flux Density Levels

Please see discussion above in reference to Section 25.114(c)(8).

§ 25.210(f) Frequency Reuse

As illustrated by the frequency plan in the narrative for Section 25.114(d)(1), the NGSO System would use 2.4 GHz of paired Ka-band spectrum for uplink and downlink, including the use of both polarizations (LHCP and RHCP). The satellites would use state-of-the-art phased-array antennas to generate adjustable beams within the coverage footprint of the satellites. The system would employ extensive frequency re-use to provide a very high rate broadband data service to user terminals and to communicate with gateways within each coverage footprint. The frequency re-use plan is described in the narrative for Section 25.114(d)(1).

The Ka-band paired spectrum allocation of 2.4 GHz per polarization may be flexibly used by the system in 200-390 MHz increments, as described in the “Receiving Channels” and “Transmitting Channels” sections of Schedule S, and may be sub-divided into the narrower channel bandwidths. Except in those bands that are limited to MSS feeder links, the entire Ka-band paired spectrum allocation would be shared and re-used many times by each satellite to serve both user terminals and gateways operating within the satellite’s coverage footprint.

Typical 3- and 4-cell re-use patterns could be used by the system to achieve very high spectral efficiencies. The specific assignment of timeslot, frequency, bandwidth, and polarization usage to the cells (beams) in each satellite coverage footprint may utilize any of these patterns or other re-use schedule, which would vary based on the relative location of the NGSO satellite versus the earth stations and other factors. The frequency and polarization re-use pattern would also vary due to the general time-varying nature of the traffic demand from the earth stations. Overall, the Ka-band segment would provide a highly efficient re-use of the spectrum, using the 2.4 GHz paired uplink and downlink Ka-band spectrum many times over the United States and across the globe, while fully complying with the beam characteristics and emissions limitations as described in this Application.

§ 25.250 Sharing Between NGSO MSS Feeder Link Earth Stations

Boeing has designed its NGSO System to comply with the feeder link earth station siting and coordination requirements of Section 25.250 of the Commission's rules. Boeing will also cooperate fully with other NGSO MSS operators in complying with the feeder link earth station siting requirements.

§ 25.257 NGSO MSS Operations Regarding LMDS

Boeing has designed its Ka-band NGSO System to comply with the feeder link earth station siting and coordination requirements of Section 25.257 of the Commission's rules. Boeing will also cooperate fully with other NGSO MSS operators and make reasonable efforts to identify mutually acceptable locations for feeder link earth station complexes.

§ 25.258 NGSO MSS Feeder Link Stations and GSO FSS

Boeing has designed the NGSO MSS feeder link uplink operations for its NGSO System so they can share the 29.25-29.5 GHz band with GSO FSS and NGSO MSS systems that have been authorized for operation in that band. Pursuant to Section 25.258(c) of the Commission's rules, a demonstration of these sharing capabilities is provided in Part V of this Application. Boeing will also cooperate fully with operators of other NGSO MSS feeder link and GSO FSS earth stations to coordinate the operations of their respective systems.

§ 25.261 Procedures for Avoidance of In-Line Interference

Section 25.261 prescribes coordination procedures for non-Federal NGSO FSS satellite networks operating in the 18.8-19.3 GHz and 28.6-29.1 GHz bands.[10] Boeing will develop appropriate coordination agreements or design its system to follow the default procedure,[11] as necessary. Boeing will also coordinate with any other licensees of Ka-band NGSO satellite systems already operating or resulting from this processing round.

§ 25.278 Additional NGSO Coordination Obligations

Boeing will comply with the requirements of Section 25.278 regarding the coordination of feeder links for its NGSO System with the feeder links of GSO networks operating in the same spectrum.

III. PUBLIC INTEREST BENEFITS

The Internet is a fundamental tool in how we live, learn, work, and play. In proceeding after proceeding, the Commission has reaffirmed that broadband Internet access is "the most significant communications technology of today"[12] and that "Americans…turn to advanced telecommunications capability for every facet of daily life."[13] Participation in the educational system, the workforce, and civic life requires not just nominal "access" to Internet, but access to

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[10] 47 C.F.R. § 25.261.

[11] 47 C.F.R. § 25.261(c).

[12] Protecting the Privacy of Customers of Broadband and Other Telecommunications Services, WC Docket No. 16-106, *Report and Order*, FCC 16-148, ¶ 1 (Oct. 27, 2016).

[13] Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act, GN Docket No. 15-191, *2016 Broadband Progress Report*, FCC 16-6, ¶ 2 (Jan. 29, 2016) ("*2016 Broadband Progress Report*").

affordable, high-quality broadband that fulfills (and exceeds) the Commission's goal of at least 25 Mbps downstream and 3 Mbps upstream.[14]

Despite this unequivocal acknowledgement of the importance of broadband access, however, nationwide deployment remains an ongoing project. Substantial progress has been made, but, despite hundreds of millions of dollars and years of regulatory effort, the Commission's "policies to encourage and accelerate broadband deployment over the last seven years just haven't worked."[15] The most recent Broadband Progress Report finds, for the fifth report in a row, that U.S. broadband deployment continues to fall significantly short of what is needed, particularly in rural and remote areas.[16] This is not entirely surprisingly. Terrestrial broadband technologies such as fiber, 4G, and forthcoming 5G service, are all inherently tied to a business case that emphasizes densely populated areas. For this reason, improvement in broadband capabilities is available first in large urban areas, expanding only later and incompletely to less dense suburban, rural, and remote areas.

This natural, almost inevitable concentration of resources in major population areas creates the ongoing disparity that has come to be known as the "broadband gap." The 2010 *National Broadband Plan* acknowledged that broadband deployment is "the great infrastructure challenge of the early 21st century" and pledged that broadband "ought to be found in every

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[14] Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, GN Docket No. 14-126, *Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment*, 30 FCC Rcd 1375, ¶ 26 (2015) ("*2015 Broadband Progress Report*").

[15] *2016 Broadband Progress Report*, Statement of Commissioner Ajit Pai.

[16] *Id.,* ¶ 4.

village, in every home and on every farm in every part of the United States."[17] Six years on, although the Commission has striven mightily and taken great strides, an intractable broadband gap persists between those with access to affordable broadband Internet access and those without.[18] As the Commission starkly concluded in its 2015 Broadband Progress Report, "it is simply not acceptable for rural and Tribal areas to be left behind from the advanced services envisioned by Congress."[19]

Through this Application, Boeing proposes a new and powerful tool to decisively address the broadband gap and fulfill the Commission's Congressional mandate. Recent advances in satellite technology have enabled unprecedented speed and capacity from satellite broadband service, enabling satellites to assume a much larger role in the broadband ecosystem. Boeing's proposed NGSO System will provide cost-effective data transport for broadband data access and video streaming, along with uplink capacity supporting two-way broadband service. By providing users in rural and urban areas alike with the same access to connectivity, Boeing's proposed Ka-band system will help unlock the opportunities afforded by true broadband connectivity.

NGSO FSS systems, such as the Ka-band constellation Boeing proposes herein, by their very nature provide service equally to all locations in the major landmasses and thus can overcome the terrestrial network deployment challenges at the heart of why the broadband gap exists and still persists. Because this service will be available to all Americans and will provide

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[17] Federal Communications Commission, Omnibus Broadband Initiative, *Connecting America: The National Broadband Plan* (2010) ("*National Broadband Plan*"), at xi (*available at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-296935A1.pdf).

[18] *2016 Broadband Progress Report*, ¶ 12. The broadband crisis is particularly acute on Tribal Lands where 41 percent of those living on Tribal Lands – more than 1.5 million people – lack access, including 68 percent of those living on Tribal Lands in rural areas. *Id.,* ¶ 88.

[19] *2015 Broadband Progress Report*, ¶ 140.

speeds well in excess of the Commission's 25/3 Mbps benchmark, regardless of location, it is ideally suited to fulfill the Commission's statutory mandate to ensure that those living in rural, insular, and high cost areas have access to broadband service that is "reasonably comparable to those services provided in urban areas."[20] The Commission has acknowledged that no one technology will provide nationwide broadband coverage by itself.[21] Boeing's proposed NGSO System complements existing and future terrestrial technologies by bringing high-speed broadband to places where terrestrial services cannot or will not go.

Far from serving solely as a "carrier of last resort" in sparsely populated areas, however, Boeing's ubiquitous, high-quality broadband offering will also provide a much-needed competitor to terrestrial wired and wireless services in cities and suburbs, driving innovation and preventing the stagnation that inevitably occurs when customer choice is limited by the high cost of entry.[22] As the Department of Commerce Broadband Opportunity Council explained, "[l]owering barriers to deployment and fostering market competition can drive down price, increase speeds, and improve service and adoption rates across all markets."[23] The proposed Ka-band NGSO System would therefore not only provide a leg up to Americans that still do not have access to advanced telecommunications services, it would just as importantly set a new benchmark for broadband

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[20] 47 U.S.C. § 254(b)(3).

[21] Connect America Fund, WC Docket No. 10-90, *Report and Order and Further Notice of Proposed Rulemaking*, FCC 11-161, 26 FCC Rcd 17663, ¶ 30 (2011) (allocating "at least $100 million per year to ensure that Americans living in the most remote areas in the nation, where the cost of deploying traditional terrestrial broadband networks is extremely high, can obtain affordable access through alternative technology platforms, including satellite and unlicensed wireless services").

[22] *See*, e.g. Google Fiber's Ripple Effect, MIT Technology Review (Apr. 26, 2013) (available at https://www.technologyreview.com/s/514176/google-fibers-ripple-effect/).

[23] Broadband Opportunity Council Report and Recommendations at 6 (Aug. 20, 2015) (available at https://www.whitehouse.gov/sites/default/files/broadband_opportunity_council_report_final.pdf).

service nationwide, challenging other broadband providers to continue to innovate and provide the high-quality services at affordable prices.

Boeing's proposal makes a business case for ubiquitous, high-quality broadband service that does not segregate Americans' access to advanced communications technologies based on where they live. It does not force terrestrial technologies to go places they cannot reach or cannot justify and it does not await Commission regulation or federal funding to close the business case. Grant of this Application could provide true nationwide and global broadband connectivity that will help bridge the stubborn divide in access to broadband communications services.

IV. REQUESTED WAIVERS

Pursuant to Section 25.112(b)(1) of the Commission's rules, Boeing requests waivers of all or portions of the following rules:

- Section 2.106 and 25.202(a)(1) available FSS spectrum bands,
- Section 25.145(c)(1) default international geographic coverage,
- Section 25.156(d)(4) treating feeder links as separate applications, and
- Section 25.157(e) bandwidth assignments resulting from processing rounds.

The Commission's standards for the grant of waivers and the specific justifications for each of the requested waivers are discussed below.

A. The Waiver Standard

The Commission's rules expressly permit the FCC to grant waivers of its rules on a showing of "good cause."[24] The U.S. Supreme Court has indicated that the FCC not only has the

[24] 47 C.F.R. § 1.3 (1999).

legal right, but also an obligation to consider and grant waivers of its rules.[25] The Court indicated that the Commission's responsibility to consider waivers stems from its statutory obligation to serve the "public interest, convenience, or necessity."[26] In applying this directive, the courts have created a "hard look" requirement, which prohibits the Commission from giving "perfunctory treatment" to waiver requests to ensure

> that a general rule serving the public interest for a broad range of situations will not be rigidly applied where its application would not be in the public interest as, for example, where an applicant "proposes a new service that will not undermine the policy" served by the rule.[27]

The judicial reference to applications for *new services* underscores the applicability of the Commission's waiver authority to this Application for the NGSO System. In each circumstance discussed below, good cause is presented for the grant of each waiver requested and such grant would serve the public interest while not undermining any existing policy consideration that originally formed the basis for the rule in question.

B. Waiver of §§ 2.106 and 25.202(a)(1)

Sections 2.106 and 25.202(a)(1) of the Commission's rules identify the spectrum allocations that are available for use by FSS systems in the United States.[28] In support of its

[25] National Broadcasting Co. v. U.S., 319 U.S. 190 (1943); *see also* United States v. Storer Broadcasting Co., 351 U.S. 192, 205 (1956) (concluding that the Commission must grant a hearing to consider a justified request for waiver of its multiple ownership rules).

[26] *National Broadcasting Co.*, 319 U.S. at 225.

[27] Bellsouth Corp. v. FCC, 162 F.3d 1215, 1224 (D.C. Cir. 1999) (*quoting* WAIT Radio v. FCC, 418 F.2d 1153, 1157 (D.C. Cir. 1969)) (concluding that the Commission adequately considered, before denying, a request for waiver of the FCC's commercial mobile radio spectrum cap limits).

[28] 47 C.F.R. §§ 2.106, 25.202(a)(1).

proposed Ka-band NGSO System, Boeing requests waiver of certain allocations and footnotes relating to the Ka-band spectrum:

17.8-18.3 GHz: There is no non-Federal domestic satellite allocation for FSS in this band. The 17.8-18.3 GHz band does include an FSS allocation in the international Table of Frequency Allocations. Further, Article 21 of the ITU Radio Regulations includes PFD limits for NGSO FSS systems operating in the 17.8-18.3 GHz band. The Commission has previously authorized O3b Limited ("O3b") to operate its NGSO network and associated earth stations in this band on a non-conforming basis.[29] Boeing seeks a similar waiver.

18.3-18.8 GHz: This band is allocated for FSS, but pursuant to footnote NG164, FSS operations in this spectrum are limited to GSO systems.[30] Boeing requests a waiver of this rule to permit NGSO operations in this band. The Commission has previously granted waiver of NG164 in the 18.3-18.6 GHz band to O3b when it demonstrated that its proposed non-conforming use would not cause harmful interference to present or future users of the bands.[31] In the sharing discussion at Part V below, Boeing provides a comparable discussion for the 18.3-18.8 GHz band showing that Boeing's proposed NGSO operations will not cause harmful interference to any service authorized under the U.S. Table of Frequency Allocations and will accept any interference from services authorized by the Commission. Because the Boeing operations will provide the requisite level of protection for GSO FSS systems, it is appropriate to permit Boeing to operate in this band on an unprotected, non-interference basis.

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[29] *See* Application of O3b Limited, File No. SAT-LOI-20141029-00118 (granted Jan. 22, 2015) ("*June 2015 O3b Grant*") (authorized for operations in the 17.8-18.6 GHz range).

[30] 47 C.F.R. § 2.106.

[31] Letter from Jose P. Albuquerque, Chief, Satellite Division, International Bureau, to Suzanne Malloy, Vice President, Regulatory Affairs, O3b Limited, DA 14-1369, IBFS File No. SES-MSC-20140318-00150, at 2 (Sept. 22, 2014).

C. Waiver of § 25.145(c)(1)

Sections 25.145(c)(1) of the Commission's rules requires that the proposed system be capable of provide FSS (1) to all locations as far north as 70° North latitude and as far south as 55° South latitude for at least 75 percent of every 24-hour period. The Phase One deployment of Boeing's Ka-band NGSO System will comply with the Commission's domestic geographic service requirements (Section 25.145(c)(2)). The Phase Three deployment of Boeing's NGSO System, however, will not fully comply with the international geographic service requirements. Good cause exists, however, to grant a waiver of this requirement.

First, as indicated in the following graphic, the Phase Two deployment of Boeing's Ka-band NGSO System will provide compliant coverage of most major landmasses as far north as 70° North latitude and as far south as 55° South latitude for at least 75 percent of every 24-hour period. However, Boeing's Ka-band NGSO System, even following Phase Three, will not provide coverage to central portions of the Pacific and Atlantic Oceans (shown in dark blue in Figure IV-1 below). Therefore, the vast majority of the global population will be within the coverage area of Boeing's NGSO System, ensuring that Boeing's use of orbital and spectral resources will serve the public interest.

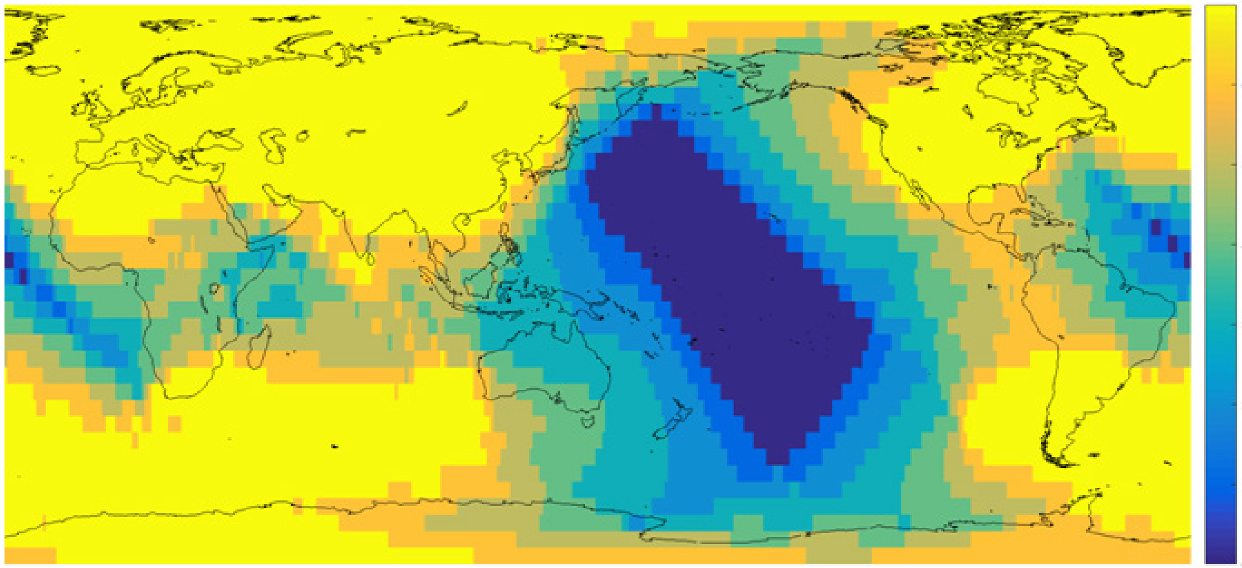

Figure IV-1. Ka-band NGSO System Geographic Coverage

Second, as explained in Part V of this Application, Boeing's Ka-band NGSO System will be able to share the Ka-band with existing and future NGSO and GSO FSS systems, along with other authorized users of the Ka-band. Therefore, Boeing's use of these orbital and spectral resources will not preclude their use by other service providers.

The Commission granted a similar waiver to O3b permitting its Ka-band NGSO FSS system to access the U.S. market.[32] The Commission's authorization for O3b stated that a waiver of the geographic service rules was granted because the O3b system "operates in an equatorial orbit as opposed to inclined orbit and as a result, due to look angle constraints, there is a limitation on the northernmost and southernmost latitudes that can be served by its system."[33]

[32] Authorization of O3b Limited, IBFS File Nos. SAT-LOI-20141029-00118 and D-SAT-AMD-20150115-00004 (Call Sign S2935) (first issued Jan. 22, 2015).

[33] *Id.*, ¶ 14. As O3b explained in its application, its system "is designed to focus bandwidth efficiently to areas where it is needed by the customer, rather than waste satellite power purporting to serve areas already adequately served or where there is no demand." O3b Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the O3b MEO Satellite System, IBFS File Nos. SAT-LOI-20141029-00118 and D-SAT-AMD-20150115-00004, at 16 (Oct. 29, 2014).

Thus, the Commission balanced the NGSO satellite operator's constellation design decision with the policy desire to maximize geographic coverage.

The Commission maintains geographic service rules to ensure that scarce orbital and spectrum resources are used to provide service that is available to all communities. In this case, the Boeing NGSO System is specifically designed to maximize service over most major landmasses (and thus population areas), but does not extensively cover certain areas in the Atlantic and Pacific Ocean regions. The NGSO System's unique and highly efficient design will still serve the vast majority of the global population and does not preclude other systems from providing service in regions where less coverage may exist. Therefore, good cause exists to grant such a waiver.

D. Waiver of § 25.156(d)(4)

Section 25.156(d)(4) of the Commission's rules indicates that an application for feeder link authority will be treated by the Commission as a separate application from its associated service band.[34] This rule is premised on the legacy practice of operating feeder links and service links using separate frequency bands to avoid intra-system interference. The NGSO System, however, would use TDMA and precise beam-forming to use much of the same spectrum (specifically, the 18.6-19.3 GHz, 19.7-20.19 GHz, 28.4-29.1 GHz and 29.5-29.99 GHz bands) for both service links and feeder links.

Boeing's approach is much more spectrally efficient because it permits each satellite to use all of the spectrum authorized for that system to provide very high data rate services to end users in geographic regions of high demand, while concurrently using all (or nearly all) of its authorized spectrum for feeder links operating in separate beams to

[34] 47 C.F.R. § 25.156(d)(4).

communicate with gateway earth stations located in geographic regions where user demand is very low. This additional spectrum re-use enhances the aggregate capacity and throughput of the NGSO System, making it more competitive with other available broadband offerings.

Because Boeing's proposed approach to spectrum use is far more effective and efficient than legacy approaches, good cause exists for the Commission to waive the requirements of Section 25.156(d)(4) and to refrain from applying it to this Application.

E. Wavier of § 25.157(e)

Sections 25.157(e)(1) and (e)(2) of the Commission's rules, as recently revised by the Commission's Second Order on Reconsideration,[35] indicates that, in cases where multiple NGSO FSS systems are granted licenses in the same processing round and insufficient spectrum is available to meet the needs of each licensee, the Commission will divide the available spectrum among them.

Boeing requests a waiver of this concept because a licensing process that divides the Ka-band spectrum between multiple NGSO FSS system licensees would prevent any of those satellite systems from making available to a large base of subscribers the high data rate communications services that are necessary to achieve the Commission's stated goals for broadband and to provide services that are as attractive to consumers as terrestrial networks. Instead, modern NGSO FSS systems can employ spectrum sharing techniques to enable co-frequency spectrum sharing with other NGSO FSS systems and thereby avoid the need for highly

[35] *See* Amendment of the Commission's Space Station Licensing Rules and Policies, IB Docket No. 02-34, *Second Order on Reconsideration*, FCC 16-108 (Aug. 16, 2016).

inefficient and counterproductive spectrum segmentation. The spectrum sharing capabilities of NGSO FSS systems have long been recognized by the Commission.

For example, in 2002 the Commission adopted a NGSO FSS spectrum sharing approach based on "avoidance of in-line interference events," which was premised on an acknowledgement that co-frequency spectrum sharing between NGSO FSS systems is desirable and achievable.[36] The Commission's International Bureau recently affirmed the importance of its "in-line avoidance" approach, indicating that the sharing requirement would be applied to NGSO FSS systems operating in additional spectrum bands.[37] Importantly, the "in-line avoidance" approach advocated by the Commission is in direct conflict with the band-segmentation approach embodied in Section 25.157(e), further justifying a waiver of the latter.

An additional reason to grant a waiver of Section 25.157(e) is because it inadvertently encourages speculation and arbitrage in NGSO FSS satellite system licenses. Pursuant to the Commission's "in-line avoidance" approach to spectrum sharing, each applicant for an NGSO FSS system license in a particular spectrum band places no impediment on the plans of other NGSO FSS system applicants in the same spectrum band because each applicant knows that it will be expected to share spectrum on a co-frequency basis with other systems that are actually launched. In contrast, pursuant to the band-segmentation approach of Section 25.157(e), each additional applicant for an NGSO FSS system in a particular spectrum band substantially reduces the amount of spectrum that would be available to other NGSO FSS system applicants, potentially (and likely) precluding their construction and launch. Therefore, the Commission

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[36] *See generally* Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ku-Band, *Report and Order and Further Notice of Proposed Rulemaking*, FCC 02-123, ¶¶ 27-55 (2002) ("*Ku-Band NGSO Sharing Order*").

[37] *See* International Bureau Provides Guidance Concerning Avoidance of In-Line Interference Events Among Ku-Band NGSO FSS Systems, DA 15-1197 (Oct. 20, 2015).

should waive the band segmentation requirements of Section 25.157(e) to discourage speculation and arbitrage in Ka-band NGSO system licenses.

V. DEMONSTRATION OF SPECTRUM SHARING CAPABILITIES

The NGSO System is designed to operate in the Ka-band without causing harmful interference to other users of the Ka-band. The NGSO system provides a large number of beneficial features that enable successful spectrum sharing, including an advanced beam forming payload, narrow spot beam coverage with low sidelobes, flexible frequency and channel assignment to spot beams, multiple diverse gateway earth stations with the ability to use different gateway locations from the NGSO satellites, and moderate to large earth stations, which provide narrow beams and low sidelobes that reduce interference into and from other GSO, NGSO, or terrestrial systems. This section describes the interference-mitigation techniques that would be employed by the NGSO System in specific frequency bands and demonstrates the NGSO System capability to operate on a shared basis with other users of the spectrum.

A. Space-to-Earth Communications

1. Existing and Proposed Use of the 17.8-18.3 GHz Bands

This band has a Federal FSS allocation and the only allocated non-Federal use of the band is for the Fixed Service ("FS"). The Commission has nonetheless previously authorized O3b to operate its NGSO network and associated earth stations in this band on a non-conforming basis,[38] and a market access application filed by WorldVu requests the same authority.[39] Boeing seeks a similar waiver in Part IV.B of this Application.

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[38] *See June 2015 O3b Grant*.

[39] *See* WorldVu Satellites Limited, Petition for Declaratory Ruling of OneWeb Ltd., IBFS File No. SAT-LOI-20160428-00041 (April 28, 2016) ("*OneWeb Petition*").

Non-federal terrestrial use of this band is modest, consisting primarily of Common Carrier Fixed Point to Point Links (1440 licenses), as well as Microwave Industrial/Business Pool (538 licenses) and Microwave Public Safety Pool (412 licenses).

Non-Federal GSO satellite systems consist primarily of satellites operating in the Broadcast Satellite Service ("BSS") licensed to Pegasus, DirecTV, Dish Network and Echostar, and Intelsat.

Federal use of the band consists of the National Science Foundation radio astronomy research of various spectral lines and continuum measurements and several military agencies, which use this band as a downlink for some satellite networks.[40]

a) Sharing with Fixed Service Systems

The NGSO System would provide significant features that enable sharing of the 17.8-18.3 GHz spectrum with terrestrial bi-directional services. The NGSO System introduces minimal interference into terrestrial FS operations, which is limited by the system design and operational constraints as enumerated below.

First, the satellite downlink transmissions to all Ka-band NGSO earth stations will comply with the existing FCC PFD limits as demonstrated in Part II of this Application in the section addressing Sections 25.114(c)(8) and 25.208 of the Commission's rules. These PFD limits are intended to protect the FS from interference from satellite downlinks.

Second, FS links typically operate in a horizontal or low elevation angle operation relative to the horizon, using narrow beam antennas. The NGSO System is designed to provide

[40] Federal Spectrum Use Summary, 30 MHz–3000 GHz, National Telecommunications and Information Administration, Office of Spectrum Management (Jun. 21, 2010) (available at https://www.ntia.doc.gov/files/ntia/Spectrum_Use_Summary_Master-06212010.pdf) ("*Federal Spectrum Use Summary 2010*").

service to user terminals at elevation angles in excess of 40 degrees. Given the highly directional nature of the FS antennas in this frequency band, sufficient sidelobe isolation, typically in excess of 28 to 30 dB, would be available to ensure that FS links receiving Ka-band NGSO downlinks at the authorized PFD limits would experience very limited interference impacts relative to their operational noise floor.

In the unlikely event that potential interference into the NGSO System earth stations is caused from FS activity in an area operating in the 17.8-18.3 GHz band, Boeing will undertake appropriate measures to prevent it from impacting earth station operations. A limited number of cases may exist where terrestrial HD FS service towers introduce substantially non-horizontal links, or where satellite earth stations are located in close proximity to the terrestrial FS towers. In these cases, the isolation values assumed in these analyses may be reduced for short periods even when earth stations are directing their receive beams at or above the minimum 40 degree elevation angle. The NGSO System could mitigate interference in these cases. Interference mitigation measures may include adjusting the minimum operational elevation angle, selectively increasing satellite power (within PFD limits), assigning earth stations to alternative frequency channels, applying earth station shielding, or any combination thereof. In order to successfully apply these measures, Boeing would coordinate with all FS operators to ensure proper operations, including as needed, obtaining databases of their respective transmitters and receivers.

b) Sharing with GSO Satellite Systems

In the 17.8-18.3 GHz downlink band, the ITU has developed downlink equivalent power flux density ("$EPFD_{down}$") limits to protect GSO FSS networks from unacceptable interference from NGSO FSS systems operating in the same frequencies. These limits are included in Article 22 of the ITU Radio Regulations and, if the applicable $EPFD_{down}$ limits are met, NGSO FSS satellite systems are considered to have met their obligations to protect GSO FSS networks from unacceptable interference.

Boeing's NGSO System will comply with the ITU $EPFD_{down}$ limits applicable to the 17.8-18.3 GHz band, based on a GSO arc avoidance angle (α) of 6 degrees. Boeing NGSO System satellites would be operationally prevented from directing transmissions toward any earth locations having less than 6 degrees of angular separation from the NGSO satellite to the nearest point on the GSO arc, thereby reducing interference to GSO earth stations in these locations. This constraint would be implemented by inhibiting transmissions from all NGSO System satellites within a "GSO protection zone" that is centered on the equator relative to the sub-satellite orbital path. Prior to entry of an NGSO System satellite into the GSO protection zone, the system NOCs would hand over the affected NGSO System user terminals to alternate satellites within their field of view, ensuring uninterrupted service to all users.

Implementation of the GSO protection zone described above also has the effect of mitigating interference into NGSO System earth stations, both gateways and user terminals, caused by GSO satellites. Prior to entry of an NGSO satellite into the protection zone, all user terminals being served by that satellite would be handed over to alternate satellites that have a greater separation angle from the GSO arc. The gateway that is receiving downlink signals from the NGSO satellite entering the protection zone would be re-tasked, making it available to serve other satellites as they enter its field of view, again at greater separation angles from the GSO arc.

c) Sharing with NGSO Systems

Sharing with other NGSO systems using Feeder Links only (OneWeb): Sharing of Ka-band spectrum between the Boeing NGSO System and the OneWeb system can be accomplished using a variety of spectrum sharing techniques, including space-to-ground beam isolation, NGSO-to-NGSO constellation modeling to assess short-term and long-term I/N statistics, gateway site diversity switching, and frequency plan coordination if necessary. Application of these spectrum sharing techniques will require coordination discussions between Boeing and OneWeb.

Interference into OneWeb gateways caused by Boeing's NGSO System gateway beams will be minimized by a combination of: a) narrow NGSO System gateway downlink beams with low sidelobe levels; and b) coordination between Boeing and OneWeb to select NGSO System gateway sites with sufficient physical separation from OneWeb gateway sites, resulting in space-to-beam isolation that reduces potential interference to acceptable levels. Likewise, interference into Boeing NGSO System gateways caused by OneWeb gateway downlink beams will be mitigated using techniques similar to those described above. Boeing NGSO System gateway sites will be selected with sufficient physical separation from OneWeb gateway sites, taking into account the OneWeb gateway downlink beam width and sidelobe levels.

Interference into OneWeb gateways caused by NGSO System service link beams will be minimized, in general, by the low probability and short duration of conjunction events that align OneWeb satellites and NGSO System satellites within the gateway beams. NGSO-to-NGSO constellation modeling will be performed to evaluate mainlobe-to-mainlobe and mainlobe-to-sidelobe I/N statistics to determine if sufficient beam isolation can be achieved for a high percentage of time. For conjunction events that lead to significant interference, the OneWeb system is capable of making use of its inherent gateway diversity to provide switching between gateways to mitigate interference during the rare conjunction events.[41] Boeing intends to coordinate directly with OneWeb and other similar NGSO operators that may operate high-gain

[41] *OneWeb Petition*, § A.8.1.2, at 33-34 and § A.8.2 at 36.

gateway stations to establish mutually agreeable conditions and define sharing of orbital and operational information that can allow interference-free coexistence of NGSO systems.

Similarly, measures to address interference into Boeing NGSO System user terminals caused by OneWeb gateway beams (for user terminals located in proximity to OneWeb gateway sites) will require similar analysis and discussions. NGSO-to-NGSO constellation modeling will be performed to assess the I/N levels from the OneWeb gateway beam to the Boeing NGSO System user terminals as a function of separation distance of the user terminals from the OneWeb gateway location. For conjunction events that will affect Boeing NGSO user terminal operations, the diversity of the OneWeb gateway system can again be exploited to minimize any Boeing NGSO user terminal outages during these rare conjunction events.

Sharing with other NGSO systems using both Feeder Links and User Links (O3b): Implementation of the GSO protection zone described in Section V.A.1.b above, combined with other techniques, serve to minimize interference into O3b gateways and user terminals caused by Boeing's NGSO System gateway and user service downlink beams. In general, a Boeing NGSO satellite will only transmit to earth locations that are in the same hemisphere as the satellite's current position in its inclined orbital path. In this case, as a satellite exits the GSO protection zone and begins transmitting, the minimum separation angle between the Boeing NGSO satellite and any O3b satellite at any covered earth location will always be greater than the 6 degree minimum GSO separation angle. This is due to the much lower altitude of O3b satellites compared to GSO satellites and Boeing's NGSO satellites.

For Boeing user terminals in locations close to the equator, however, it may be necessary for Boeing's NGSO satellites to provide service to these user terminals using "cross-hemisphere" service downlink beams. In this case, the Boeing NGSO System NOCs would apply additional constraints to ensure that the satellites transmit to these earth locations only when they are in orbital latitudes that provide an acceptable minimum separation angle to O3b satellites, taking into account the specific characteristics of O3b user terminals in these locations that would be susceptible to interference from the Boeing NGSO System service downlink beams.

The techniques described above to minimize interference into O3b earth stations due to Boeing NGSO System downlink beams also serve to minimize interference into Boeing NGSO System earth stations due to O3b gateway and user service downlink beams. The combination of orbital geometry differences between the two systems, the GSO protection zone, and additional constraints on cross-hemisphere service link beams eliminate the possibility of co-alignment events that would produce unacceptable interference to the Boeing NGSO System.

d) Sharing with Federal Space Stations

Footnote US334 states that in the 17.8-20.2 GHz range, Federal GSO and NGSO space stations and associated earth stations in the FSS may be authorized on a primary basis if the space station is located outside the arc of 70-120° West longitude. Non-Federal space systems must coordinate with such federal stations. Federal earth stations operating on a primary basis are authorized only in Denver, Colorado; Washington, D.C.; San Miguel, California; and Guam.[42] Boeing confirms that it will coordinate as necessary to avoid interference to any existing or future Federal GSO and NGSO operations.

[42] 47 C.F.R. § 2.106 n.US334(b).

e) Sharing with Meteorological Satellites

Footnote US519 also provides for the meteorological-satellite service (space-to-Earth) on a primary basis in the 18.0-18.3 GHz segment of the band.[43] Boeing has not identified any specific meteorological satellites operating in this band, however, to the extent necessary Boeing will avoid interference with this service through coordination.

2. Existing and Proposed Use of the 18.3-18.6 MHz Band

This band is allocated solely to FSS, with allocations for both Federal and Non-Federal systems. Pursuant to footnote NG164, non-Federal use of this band is limited to GSO systems. Boeing requests a waiver of this rule, see Part IV.B.

Terrestrial usage consists of common carrier fixed point-to-point microwave links (81 licenses), local television transmission (13 licenses), microwave industrial/business pool radios (51 licenses), and microwave public safety pool radio systems (26 licenses).[44]

Satellite operations in the 18.3-18.6 GHz band appear to consist primarily of GSO FSS operators providing direct-to-home and satellite Internet service, including DirecTV, Dish, Echostar/Hughes, and Intelsat.

NTIA reports that military agencies use this band as a downlink for some satellite networks, with earth stations in Denver, Colorado; Washington, D.C.; San Miguel, California; and Guam.[45] The National Science Foundation uses this band for the radio astronomy research of various spectral lines and continuum measurements.[46]

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[43] 47 C.F.R. § 2.106 n.US519.

[44] ULS Database (last visited Sept. 2, 2016).

[45] *Id.*; 47 C.F.R. § 2.106 n.US334(b).

[46] *Federal Spectrum Use Summary 2010* at 66.

a) Sharing with Fixed Service Systems

See spectrum sharing discussion above in Section V.A.1.a.

b) Sharing with GSO Satellite Networks

See spectrum sharing discussion above in Section V.A.1.b.

c) Sharing with NGSO Systems

See spectrum sharing discussion above in Section V.A.1.c. The discussion in Section V.A.1.c. above is focused primarily on sharing with previously proposed or constructed NGSO systems such as O3b and OneWeb, but would also be applicable to other NGSO systems with similar constellation designs.

d) Sharing with Federal Space Stations

See spectrum sharing discussion above in Section V.A.1.c.

3. Existing and Proposed Use in the 18.6-18.8 MHz Band

This band is shared on a co-primary basis between Federal and non-Federal earth exploration satellite service ("EESS"), FSS, and Space Research services. Pursuant to footnote NG164, this band is limited to GSO systems.[47] Boeing requests a waiver of this rule in Part IV.B of this Application. Footnote US254 limits "fixed and mobile services" in the band to a maximum EIRP of more than 35 dBW and power delivered to the antenna at no more than -3 dBW.[48] Terrestrial use consists primarily of common carrier fixed point-to-point microwave

[47] 47 C.F.R. § 2.106 n.US164(b).

[48] 47 C.F.R. § 2.106 n.US254.

relays (109 licenses) and microwave public safety pool radio networks (68 licenses).[49] A number of GSO FSS systems have been authorized to operate, or are currently operating in the 18.6-18.8 GHz band.[50]

Government use of the spectrum consists of NSF radio astronomy research and the use of this band by military agencies as a downlink for some satellite networks.[51] In addition, NASA uses the band for passive Earth sensing.

a) Sharing with Terrestrial Fixed Systems

See spectrum sharing discussion above in Section V.A.1.a.

b) Sharing with GSO Satellite Networks

See spectrum sharing discussion above in Section V.A.1.b.

c) Sharing with NGSO Systems

See spectrum sharing discussion above in Section V.A.1.c. The discussion in Section V.A.1.c. above is focused primarily on sharing with previously proposed or constructed NGSO systems such as O3b and OneWeb, but would also be applicable to other NGSO systems with similar constellation designs.

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[49] ULS Database (last visited Sep. 2, 2016). The band is also used by microwave industrial/business pool networks (36 licenses) and local television transmission links (5 licenses). *Id*.

[50] *See, e.g.,* SES Americom, Inc, IBFS File No. SAT-LOA-20160512-00047 (granted Jun. 24, 2016); Americom, Inc., For Modification of its Authorization to Launch and Operate a Ka-band Satellite System in the Fixed-Satellite Service at 85º W.L., IBFS File No. SAT-MOD-20040227-00022 (Sept. 2, 2004); *see also* Intelsat License LLC, Application for Authority to Launch and Operate Intelsat 37e, a Replacement Satellite With New Frequencies, at 18.0º W.L. (342.0º E.L.), IBFS File No. SAT-LOA-20160915-00089 (filed Sept. 15, 2016). Other examples are available in the FCC's IBFS system.

[51] *Federal Spectrum Use Summary 2010* at 67.

d) Sharing with Federal Space Stations

See spectrum sharing discussion above in Section V.A.1.c.

e) Sharing with Radio Astronomy and Space Research

Boeing has a long history of coordinating its various operations with the scientific community and certifies that it will take all practical steps to protect radio astronomy and that the necessary agreements will be in place prior to commencing operations. Boeing will coordinate with NASA regarding any additional protection measures required to protect its Earth sensing operations.

4. Existing and Proposed Use in the 18.8-20.2 GHz Band

The 18.8-19.3 GHz, 19.3-19.7 GHz, and 19.7-20.2 GHz frequency ranges requested by Boeing represent several spectrum bands with similar allocations and usage. The entire 18.8-20.2 GHz band is allocated for FSS space-to-Earth operations by both Federal and non-Federal users.[52] In addition to FSS, there are allocations for non-federal FS (19.3-19.7 GHz) and non-Federal MSS (19.7-20.2 GHz). Footnote NG165 limits use by non-federal FSS operations in the 18.8-19.3 GHz band to NGSO systems.[53] Footnote NG166 limits non-Federal FSS operations in the 19.3-19.7 GHz band to feeder links for MSS.[54] Footnote 5.528 instructs that MSS systems in the band 19.7-20.1 GHz in Region 2 and in the band 20.1-20.2 GHz shall take all practicable steps to ensure the continued availability of these bands for Administrations operating fixed and mobile systems in accordance with the provisions of No. 5.524.

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[52] 47 C.F.R. § 2.106.

[53] 47 C.F.R. § 2.106 n.NG165.

[54] 47 C.F.R. § 2.106 n.NG166.

Non-Federal satellite operations include GSO systems operated by ViaSat, Intelsat, SES Americom, Echostar/Hughes, and DirecTV.[55] Because NGSO systems have primary status in these bands, these systems operate on a non-conforming, secondary basis. NGSO systems are operated by Iridium and O3b. Iridium operates its constellation in the range 19.4-19.6 GHz and has associated earth stations in Fairbanks, Alaska; Tempe, Arizona; and Hawaii.[56] O3b operates an NGSO system and gateway earth stations in Bristow, Virginia;[57] Haleiwa, Hawaii;[58] and Vernon, Texas,[59] as well as earth stations on vessels[60] in this band.

Non-Federal terrestrial usage consists primarily of common carrier fixed point-to-point microwave links, with 8,300 individual licenses nationwide.[61] There are also approximately 2,700 Microwave Industrial/Business Pool licenses,[62] approximately 2,000 Microwave Public

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[55] *See, e.g.*, SAT-LOA-20110722-00132 (ViaSat, Inc.), SAT-LOA-20150327-00016 (Intelsat), SAT-LOA-19950929-00133 (SES Americom/Echostar), SAT-LOA-20120424-00075 (Hughes), SAT-LOA-20040803-00154 (Echostar), (SAT-LOA-20140825-00094) (DirecTV).

[56] *See* Application for Modification to Launch and Operate Replacement Satellites, Iridium Constellation LLC, SAT-MOD-20131227-00148, Call Sign S2110 (granted Jan. 9, 2015); *see also* Application of Iridium, SES-LIC-20051010-01392, Call Sign E050282 (granted Feb. 15, 2006), Application of Iridium, SES-LIC-20060804-01311, Call Sign E060300 (granted Apr. 4, 2007).

[57] Amendment of O3b Limited, SES-AMD-20131122-01187 (granted July 1, 2015).

[58] Application of O3b Limited, SES-LIC-20100723-00952 (granted Sept. 10, 2014).

[59] Application of O3b Limited, SES-LIC-20130124-00089 (granted June 26, 2013).

[60] Application of O3b Limited, SES-LIC-20130528-00455 (granted May 13, 2014).

[61] ULS Database shows 8281 licenses with the Service Code “CF” as of July 14, 2016.

[62] ULS Database shows 2654 licenses with the Service Code “MG” as of July 14, 2016.

Safety Pool licenses,[63] and approximately 100 TV Intercity Relay/TV Studio Transmitter Link licenses.[64]

NTIA reported in 2010 that at that time the military agencies used the bands between 18.8-20.2 GHz for downlink from some satellite networks.[65] Additionally, NSF conducts radio astronomy research in this band.

a) Sharing with Federal Space Systems

Federal usage in this band is allocated solely for FSS space-to-Earth operations throughout this range.[66] Footnote G117 specifies that Federal FSS operations in this range are limited to military systems.[67] Footnote US334 further limits Federal operations in this range to certain geographic areas.[68] Specifically, GSO space stations are authorized on a primary basis only outside the arc defined by 70-120° West longitude (corresponding to the majority of the continental United States). In addition, Federal earth stations are authorized on a primary basis only in Denver, Colorado; Washington, D.C.; San Miguel, California; and Guam. In these areas, non-Federal users must coordinate with NTIA before commencing terrestrial operations.

b) Sharing with NGSO Systems

Sharing with other NGSO systems using Feeder Links only (Iridium): Interference into Iridium gateways operating in the 19.4-19.6 GHz band caused by NGSO System gateway

[63] ULS Database shows 1966 licenses with the Service Code "MW" as of July 14, 2016.

[64] ULS Database shows 103 licenses with the Service Code "TI" or "TS" as of July 14, 2016.

[65] *Federal Spectrum Use Summary 2010* at 67.

[66] 47 C.F.R. § 2.106.

[67] 47 C.F.R. § 2.106 n.G117.

[68] 47 C.F.R. § 2.106 n.US334.

downlink beams will be minimized by a combination of: a) narrow NGSO System gateway downlink beams with low sidelobe levels; and b) careful selection of NGSO System gateway sites to provide sufficient spatial isolation from Iridium gateway sites to reduce interference to acceptable levels. Likewise, interference into NGSO System gateways caused by Iridium gateway downlink beams will be mitigated using techniques similar to those described above. NGSO System gateway site selection will be partially based on consideration of the interference produced by the sidelobes of Iridium downlink gateway beams.

Spectrum sharing with the OneWeb and O3b systems is addressed in Section V.A.1.c.

c) Sharing with Terrestrial Fixed Systems

See spectrum sharing discussion above in Section V.A.1.a.

d) Sharing with Radio Astronomy

See spectrum sharing discussion above in Section V.A.1.c.

B. Earth-to-Space Communication

1. Existing and Proposed Use in the 27.6-29.1 GHz, 29.1-29.5 GHz, and 29.5-30.0 GHz Range

The 27.6-30.0 GHz range covers three requested frequency bands, the 27.6-29.1 GHz, 29.1-29.5 GHz, and 29.5-30.0 GHz bands, which have similar allocations and similar spectrum characteristics. FSS (Earth-to-space) is listed in the domestic Table of Frequency Allocations as primary throughout the range. The Commission, however, portioned this spectrum to designate priority for difference services in different portions of the spectrum.

Under the band plan, GSO and NGSO FSS systems may operate in any portion of the spectrum, except that GSO FSS may not operate in the 29.10-29.25 GHz band and NGSO FSS may not operate in the 29.10-29.50 GHz band.[69] Use of the 29.1-29.25 GHz band is limited to NGSO MSS feeder links, which operate on a co-primary basis with the Local Multipoint Distribution Service ("LMDS").[70] Use of the 29.25-29.50 GHz band segment is limited to NGSO MSS feeder links and GSO FSS systems.[71]

In the 28.6-29.1 GHz band, GSO FSS systems are designated on a secondary basis to NGSO FSS systems.[72] In the 28.35-28.60 GHz and 29.5-30.0 GHz bands, NGSO FSS systems are designated on a secondary basis to GSO FSS systems.[73] Both GSO and NGSO FSS systems are designated as secondary users with respect to identified terrestrial uses in the 27.50-28.35 GHz band, previous including only LMDS licenses, but very recently including the Upper Microwave Flexible Use Service ("UMFUS") licensees.[74]

In terms of current NGSO satellite operations and applications in this band, the three systems previously identified, Iridium, O3b, and OneWeb, are operating or have applied for authority to operate in these uplink bands. Iridium currently operates and OneWeb plans to operate gateway feeder links only in this band; whereas O3b operates both user and gateway feeder links in the band from its equatorial NGSO medium-Earth orbit.

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[69] *See* Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5-29.5 GHz Frequency Band, to Reallocate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services, *First Report and Order and Fourth Notice of Proposed Rulemaking*, 11 FCC Rcd 19005 (1996).

[70] *See* 47 C.F.R. § 25.202(a)(1), n.4.

[71] *See* 47 C.F.R. § 25.202(a)(1), n.5.

[72] *See* 47 C.F.R. § 25.202(a)(1), n.3.

[73] *See* 47 C.F.R. § 25.202(a)(1), n.2.

[74] *See Spectrum Frontiers Report and Order*; *see also* 47 C.F.R. § 25.202(a)(1), n.7 (indicating that "FSS is secondary to LMDS in this band").

Non-Federal satellite use of the spectrum consists primarily of GSO BSS satellites operated by DirecTV, Dish, and Echostar/Hughes.[75] Intelsat, SES Americom, and ViaSat are also licensed for FSS operations and Iridium operates MSS feeder links.[76]

Current terrestrial use of this band is primarily by voice and data carriers providing LMDS.[77] In the recent Spectrum Frontiers proceeding, however, the Commission adopted rules for UMFUS mobile operations in the 27.5-28.35 GHz portion of this range.[78] As described below, the NGSO will be able to share spectrum effectively with UMFUS operations.

There is no allocation for Federal operations in this band and NTIA reports only limited use of the band by NSF for radio astronomy.[79]

a) Sharing with Upper Microwave Flexible Use Services

The UMFUS systems adopted in the 27.5-28.35 GHz band are primarily "fifth generation" ("5G") cellular mobile systems designed to augment the existing terrestrial cellular 3G and 4G deployments by providing higher data rates to users in dense urban and developed areas. These UMFUS systems would operate bi-directionally, using the 27.5-28.35 GHz band for both forward and return transmissions between mobile devices and fixed base stations. In addition, some short-range fixed device links, such as links between base stations, are also contemplated.

In the Spectrum Frontiers Order, the Commission concluded that FSS earth stations in the 28 GHz band can share the band with minimal impact on terrestrial operations, including

[75] *See, e.g.*, Echostar (SAT-LOA-20030827-00186), Hughes (SAT-LOA-20120424-00075).

[76] Iridium (SAT-LOA-19970926-00147), Intelsat (SAT-LOA-20150327-00016)

[77] ULS identifies 208 LMDS licensees, as well as 19 fixed point to point microwave licenses as of August 10, 2016.

[78] *Spectrum Frontiers Order.*

[79] *Federal Spectrum Use Summary 2010* at 71.

UMFUS.[80] The new rules adopted in the Spectrum Frontiers Order allow for up to three locations in each county where FSS earth stations may be deployed on a protected basis.[81] Exclusions zones must be defined around these protected earth stations based on a PFD level specified in the Order.[82] Prior to filing an application for an earth station in a location where there is an existing 28 GHz UMFUS licensee, earth station applicants must coordinate their operation with the existing UMFUS licensees using the coordination procedures in Section 101.103(d) of the Commission's rules.[83] Otherwise, FSS earth stations may be located anywhere, provided they are operated strictly on a secondary, non-interference basis.[84]

As noted above, Boeing intends to locate the system gateways outside of highly populated regions. Gateway earth stations are each capable of communicating with multiple Ka-band NGSO satellites, thereby minimizing the number of sites that may need to be coordinated with UMFUS licensees. Boeing will comply with all applicable regulations regarding earth stations UMFUS operations in effect when applying for operational earth station licenses.

b) Sharing with GSO Systems

The ITU has developed uplink equivalent power flux density ("$EPFD_{up}$") limits to protect GSO FSS networks from unacceptable interference from NGSO FSS systems operating in the 27.6-28.6 GHz and 29.5-30.0 GHz bands. These limits are included in Article 22.5D of the ITU Radio Regulations and, if the applicable $EPFD_{up}$ limits are met, NGSO FSS satellite systems are

[80] *Spectrum Frontiers Order*, ¶ 45.

[81] *Id.*, ¶ 54.

[82] *Id.*

[83] *Id.*

[84] *Id.*, ¶ 58 and n.129 (noting that "Earth stations authorized on a secondary basis will be subject to immediate shutdown if harmful interference to an UMFUS station occurs").

considered to have met their obligations to protect GSO FSS networks from unacceptable interference. Boeing's NGSO System will comply with the applicable ITU $EPFD_{up}$ limits, using methods similar to those described in Section V.A.1.b. to prevent its earth stations, both gateways and user terminals, from generating unacceptable interference into GSO satellites. The NGSO System earth stations would be operationally prevented from transmitting to an NGSO System satellite that has a separation angle to the nearest point on the GSO arc of less than 6 degrees. Prior to entry of an NGSO System satellite into the "GSO protection zone" described in Section V.A.1.b, the system NOCs would hand over the affected NGSO System user terminals to alternate satellites within their field of view, ensuring uninterrupted service to all users.

The techniques described in Section V.A.1.b also serve to minimize interference into NGSO System satellites caused by GSO earth station uplink beams. The satellite uplink receive beams would never be pointed at earth locations that have a separation angle of less than 6 degrees from the GSO arc.

c) Sharing with NGSO Systems

Sharing with other NGSO systems using Feeder Links only (OneWeb): Sharing of Ka-band uplink spectrum between the Boeing NGSO System and the OneWeb system can be accomplished using spectrum sharing technique similar to those discussed in section V.A.1.c above. These techniques include ground-to-space beam isolation, NGSO-to-NGSO constellation modeling to assess short-term and long-term I/N statistics, gateway site diversity switching, and frequency plan coordination if necessary. Application of these spectrum sharing techniques will require coordination between Boeing and OneWeb. Interference into Boeing NGSO satellite gateway receive beams caused by OneWeb gateway uplink beams will be mitigated by a combination of: a) narrow NGSO satellite gateway receive beams with low sidelobe levels; and b) coordination between Boeing and OneWeb to select NGSO System gateway sites with sufficient physical separation from OneWeb gateway sites, resulting in isolation that reduces potential interference to acceptable levels.

Interference into OneWeb satellite gateway uplink beams caused by Boeing's NGSO gateway earth station or user terminal uplinks will be minimized, in general, by the narrow beams of these earth stations and the resulting low probability and short duration of conjunction events which align OneWeb satellites and NGSO satellite within the OneWeb satellite gateway uplink beams. NGSO-to-NGSO constellation modeling will be performed to evaluate mainlobe-to-mainlobe and mainlobe-to-sidelobe I/N statistics to determine if sufficient beam isolation can be achieved for a high percentage of time. As noted in section V.A.1.c above, the OneWeb system is capable of making use of the inherent gateway diversity to provide switching between gateways to mitigate interference during the rare conjunction events. Boeing intends to coordinate directly with OneWeb or other similar NGSO operators that may operate high-gain gateway stations to establish mutually agreeable conditions and define sharing of orbital and operational information that can allow interference-free coexistence of NGSO systems.

Interference into Boeing NGSO satellite user receive beams caused by OneWeb gateway uplinks (for user terminals located in proximity to OneWeb gateway sites) will require similar analysis and discussions. For conjunction events that will affect Boeing NGSO terminal operations, the diversity of the OneWeb gateway system can again be exploited to minimize any Boeing NGSO user terminal outages during these rare conjunction events.

Sharing with other NGSO systems using Feeder Links only (Iridium): Interference into Iridium system satellites with gateway uplinks operating in the 29.1-29.3 GHz range caused by Boeing NGSO System gateway uplink beams will be minimized by a combination of: a) narrow NGSO System gateway uplink beams with low sidelobe levels; and b) careful selection of NGSO

System gateway sites to provide sufficient spatial isolation from Iridium gateway sites to reduce interference to acceptable levels. Likewise, interference into Boeing NGSO satellites caused by Iridium gateway uplink beams will be mitigated using techniques similar to those described above. Boeing's gateway site selection will be partially based on consideration of the interference produced by the sidelobes of Iridium gateway uplink beams. Should the isolation provided by the physical separation of gateway sites and sidelobe isolation of Iridium uplink beams prove insufficient during direct in-line conjunction events between Iridium satellites and the Boeing NGSO satellites, the Boeing NGSO system can use alternate gateways to further reduce interference during these rare events. Boeing intends to coordinate directly with Iridium to establish mutually agreeable conditions and define sharing of orbital and operational information to enable gateway switching prior to direct in-line interference if required.

Sharing with other NGSO systems using both Feeder Links and User Links (O3b): The techniques described in Section V.A.1.c to enable downlink spectrum sharing between the Boeing NGSO System and the O3b system also serve to minimize interference into O3b satellite uplink beams caused by Boeing NGSO System earth stations. The narrow, low-sidelobe beams produced by the Boeing earth stations will always maintain a minimum separation angle from the orbital path of all O3b satellites. As in the downlink case, these techniques similarly serve to minimize interference into Boeing NGSO satellites caused by O3b earth station uplink beams.

d) Sharing with Radio Astronomy

See spectrum sharing discussion above in Section V.A.3.d.