Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
THE BOEING COMPANY	)	
	)	
Application for Authority	)	
to Launch and Operate a	)	File No.
Non-Geostationary Low	)	
Earth Orbit Satellite System	)	
in the Fixed Satellite Service	)	

APPLICATION

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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") fixed satellite service ("FSS") system operating in low Earth orbit ("LEO") in the 37.5-42.5 GHz (space-to-Earth), and the 47.2-50.2 and 50.4-52.4 GHz (Earth-to-space) bands (collectively, the "V-band"), herein referred to as the "NGSO System."

I. INTRODUCTION

Boeing is a leader in to 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. With this Application, Boeing seeks Commission authority 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 with extremely low latency to support a wide range of Internet and communication services for residential, commercial, institutional, governmental and professional users worldwide. The proposed system would communicate with both user terminals and gateway earth stations using the same V-band FSS spectrum. The satellites, gateways, and user terminals would use advanced phased-array antennas, narrow beam-forming, and satellite tracking capabilities to continuously re-use all of the V-band FSS frequencies within the coverage footprint of each satellite, resulting in tremendous and highly efficient spectrum re-use and aggregate system capacity.

The public interest benefits offered by the NGSO System are substantial. As a leader in aerospace and satellite technology, Boeing is in a position to introduce new technologies and efficiencies into the broadband communications market. Boeing has unmatched qualifications to launch and operate the NGSO System in the V-band.

Boeing is the world's largest manufacturer of commercial satellites and has been a leader in the satellite industry since the launch of Syncom, the first geosynchronous communications satellite, more than 50 years ago. In 1995, Boeing introduced the 702 spacecraft family and today more than three dozen have flown, with more than a dozen more currently in production. In 2014, the Boeing 502 satellite was introduced, providing an option for customers that desire a smaller satellite. Boeing also recently completed the construction and delivery of twelve next-generation Block IIF satellites for the Global Positioning System ("GPS"), which complement the capabilities of the initial forty GPS NGSO satellites that Boeing also constructed.

Boeing is a prime contractor to NASA for its new Space Launch System. Boeing is also currently under contract with NASA to support the Commercial Crew Transportation System using Boeing's CST-100 crew capsule, which can accommodate up to seven passengers, or a mix of crew and cargo to low-earth orbit destinations such as the International Space Station.

Boeing is also a world leader in providing launch services. For more than fifty years, Boeing's Expendable Launch Systems ("ELS") program played a major role in U.S. and international space programs. In 2005, Boeing formed United Launch Alliance ("ULA") with Lockheed Martin, and ULA now provides launch services using the Delta II, Delta IV and Atlas V expendable launch systems.

Boeing is also working to develop innovative new methods to accommodate the global demand for satellite launch services, including advanced concepts to reduce the cost and improve responsiveness of space access. A Boeing team is developing the next advances in small satellite launch vehicles for the Defense Advanced Research Projects Agency ("DARPA"), such as the XS-1 Experimental Spaceplane. Boeing was also a partner in the Sea Launch program, an innovative marine-based launch service providing customized launch capabilities to deliver up to five thousand kilograms of spacecraft mass into geostationary transfer orbit.

Boeing is NASA's prime contractor for the International Space Station, which is drawing on the scientific and technological expertise of sixteen cooperating nations, including the United States, Canada, Japan, Brazil, Russia and eleven member nations of the European Space Agency. Boeing's assignment included building 43,000 cubic feet of pressurized living and working space – the equivalent of the interior volume of two 747s.

Additionally, as NASA's leading contractor, Boeing built the Shuttle Orbiters and their main engines, prepared the Shuttle's payloads and performed integration for the overall Shuttle system.

Boeing is a highly capable and motivated contributor to the commercial satellite services industry. Boeing now seeks Commission authority to use its vast expertise in the aerospace and satellite industry to introduce new capabilities for broadband satellite communications services. The proposed NGSO System could enable greatly needed broadband communications capabilities to a wide range of residential, commercial, institutional and governmental customers. These services could be provided using a highly flexible and cost-effective satellite-based infrastructure, which could dynamically adjust to customer demand and compete effectively with terrestrial wireless and wireline services to provide global services.

A detailed description of the 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 V-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 satellite system applications and is not addressed either by Form 312 or Schedule S.

§ 25.111 ITU Publication Information

Boeing has already submitted to the Commission, and the Commission has provided to the International Telecommunication Union ("ITU"), the Advance Publication Information for the NGSO System operating in the V-band.[1] In relation to this submission, Boeing executed a declaration that it unconditionally accepts all consequent ITU cost-recovery responsibility for the filing.

§ 25.114(c)(4)(ii) EIRP Density for Transmitting Beams

The maximum EIRP density for each space station transmit beam is required by Section 25.114(c)(4)(ii), but Schedule S does not have input fields for this data. The values are provided below using the same beam IDs from Table S7 of Schedule S.

[1] The ITU filing for the NGSO System was published by the ITU on June 21, 2016 in IFIC 2822.

Beam ID	Maximum EIRP density (dBW/MHz)
BDL00	25.8
BDL15	26.1
BDL30	27.3
BDL36	28.2
BDR00	25.8
BDR15	26.1
BDR30	27.3
BDR36	28.2
BTLM	19.5
BBCNL	6.3
BBCNR	6.3
SDL20	26.4
SDR20	26.4
ADL30	31.1
ADR30	31.1

§ 25.114(c)(4)(v) Receive Beam Characteristics

The maximum saturation flux density ("SFD") and minimum G/T for each space station receive beam is required by Section 25.114(c)(4)(v), but Schedule S does not have input fields for this data. The values are provided below using the same beam IDs from Table S7 of Schedule S.

Beam ID	G/T at Min. Gain Pt. (dB/K)	Max. Saturation Flux Density (dBW/m^2)
BUL00	18.1	-72.1
BUL15	17.9	-71.9
BUL30	17.7	-71.7
BUL36	15	-69
BUR00	18.1	-72.1
BUR15	17.9	-71.9
BUR30	17.7	-71.7
BUR36	15	-69
BCMD	-31.5	-69.4
SUL20	8	-62
SUR20	8	-62
AUL30	17.7	-71.7
AUR30	17.7	-71.7

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

The NGSO System would include transmit and receive beam sizes and shapes that are reconfigurable in orbit. Figure II-1 shows five example beam contours scanned at 0, 15, 20, 30, and 36.5 degrees in azimuth (all relative to the sub-satellite point, *i.e.*, nadir). The beam contours correspond to the beams described in Table S8 of Schedule S. In each case in the figures below, the beam contours represent a roll off of -2 dB, -4 dB, -6 dB, -8 dB, -10 dB, -15 dB, and -20 dB.

Figures II-2 through II-6 illustrates the typical beam contours in an example coverage area at 40 GHz for satellite transmit beams. The contours shown are for the beams that are scanned at 0, 15, 20, 30, and 36.5 degree angles. The beam contours for LHCP and RHCP at the same scan angle are identical. Figure II-7 illustrates an example of a transmit beam over Alaska.

Similarly, the receive beam contours are shown in Figures II-8 through II-12 for scan angles at 0, 15, 20, 30, and 36.5 degrees. The beam contours for LHCP and RHCP at the same scan angle are identical. Figure II-13 shows an example of a received beam over Alaska.

The example beams shown at 0, 15, 30, and 36.5 degrees are typical spot beams for the smallest diameters (approximately 8 to 11 kilometers). These beams are used for typical broadband services. The beam pattern shown at a 20 degree scan angle is an example of a larger beam (of approximately 21 kilometers). These beams are for services such as low-rate multicast user data, acquisition and logon, and system resource management traffic.

Figure II-14 shows the beam contours of the transmit telemetry beam at 42.4 GHz and the receive command beam at 47.3 GHz.

Figure II-15 shows the beam contours of the transmit beacon beam at 42.4 GHz.

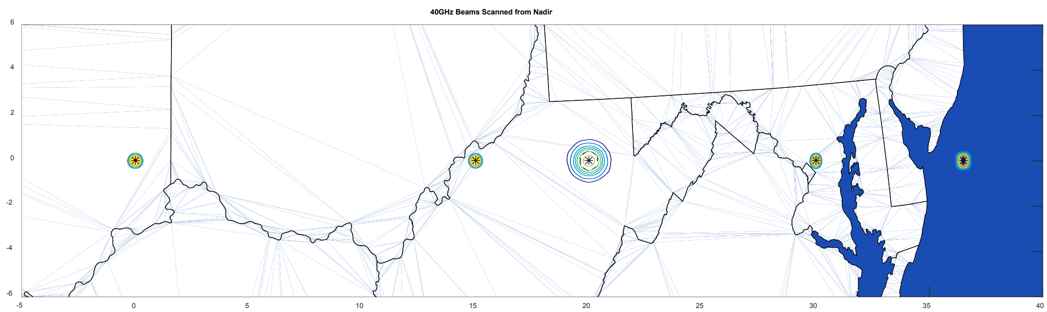


Figure II-1. Five Example Beams Scanned at 0°, 15°, 20°, 30°, and 36.5°

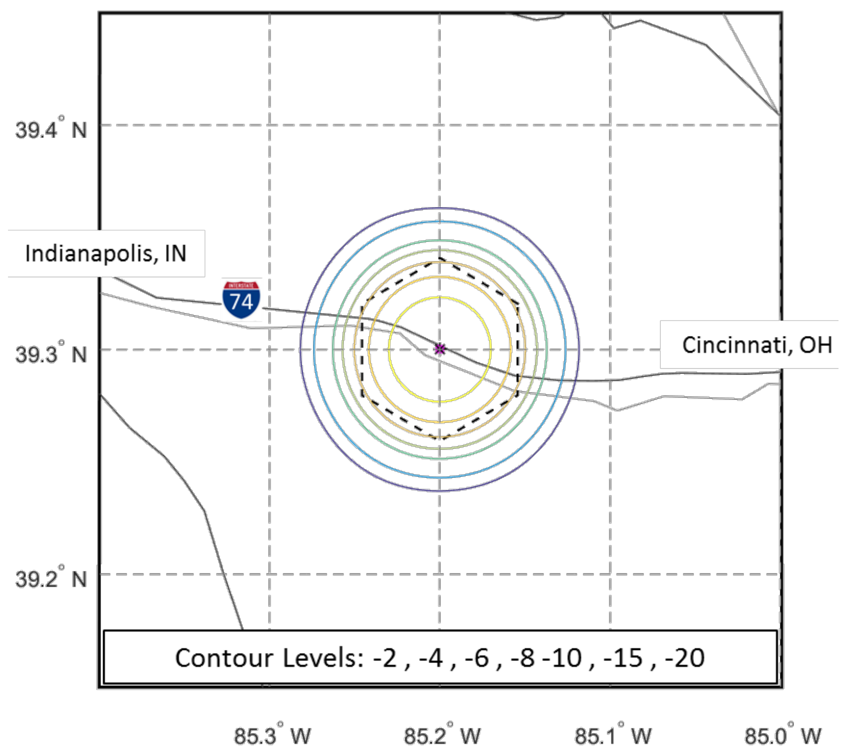


Figure II-2. Transmit Beam Contours of the 0° Scanned Beam at 40 GHz (Beams BDL00 and BDR00)

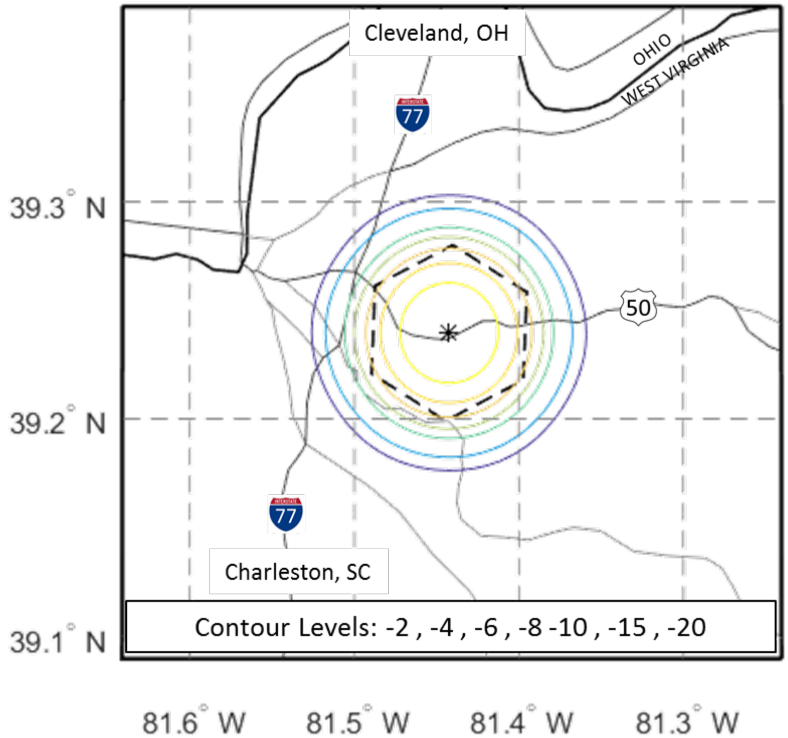


Figure II-3. Transmit Beam Contours of the 15° Scanned Beam at 40 GHz (Beams BDL15 and BDR15)

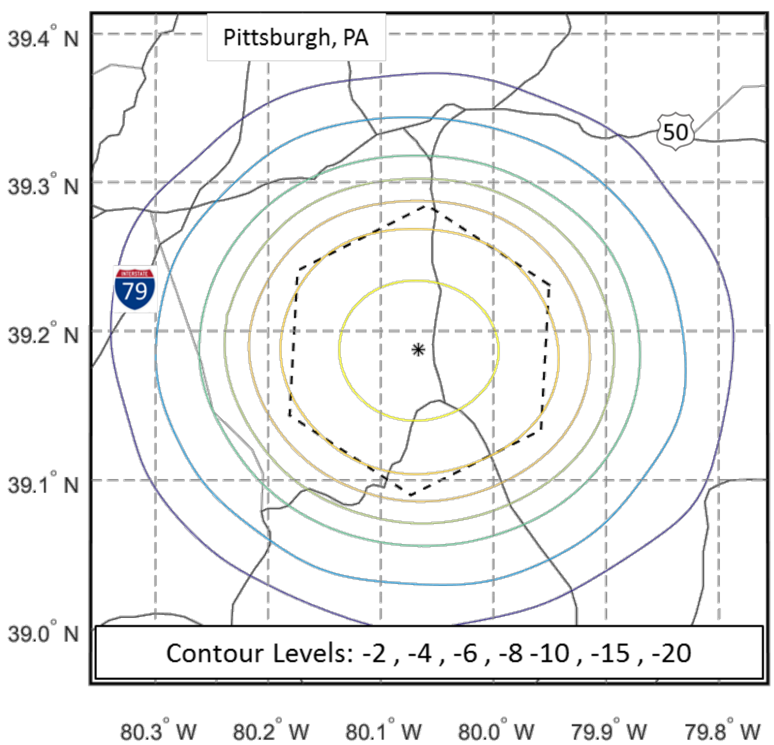


Figure II-4. Transmit Beam Contours of the 20° Scanned Beam at 40 GHz (Beams SDL20 and SDR20)

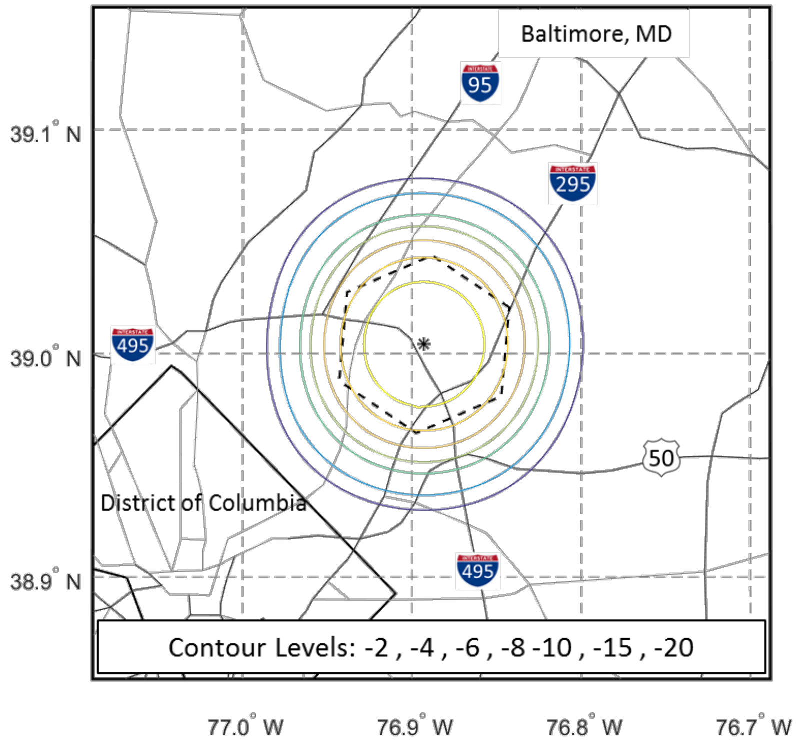


Figure II-5. Transmit Beam Contours of the 30° Scanned Beam at 40 GHz (Beams BDL30 and BDR30)

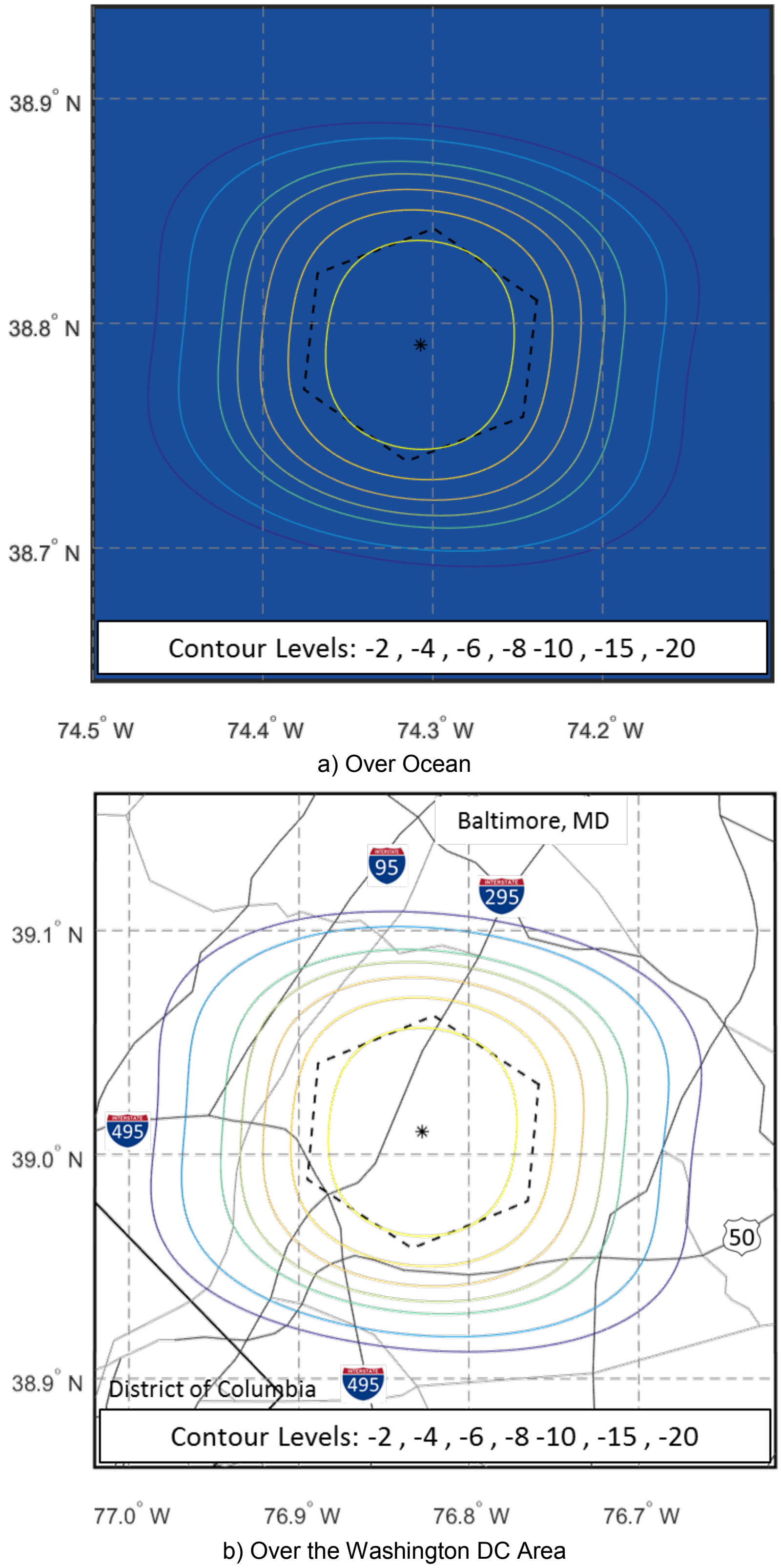


Figure II-6. Transmit Beam Contours of the 36.5° Scanned Beam at 40 GHz (Beams BDL36 and BDR36)

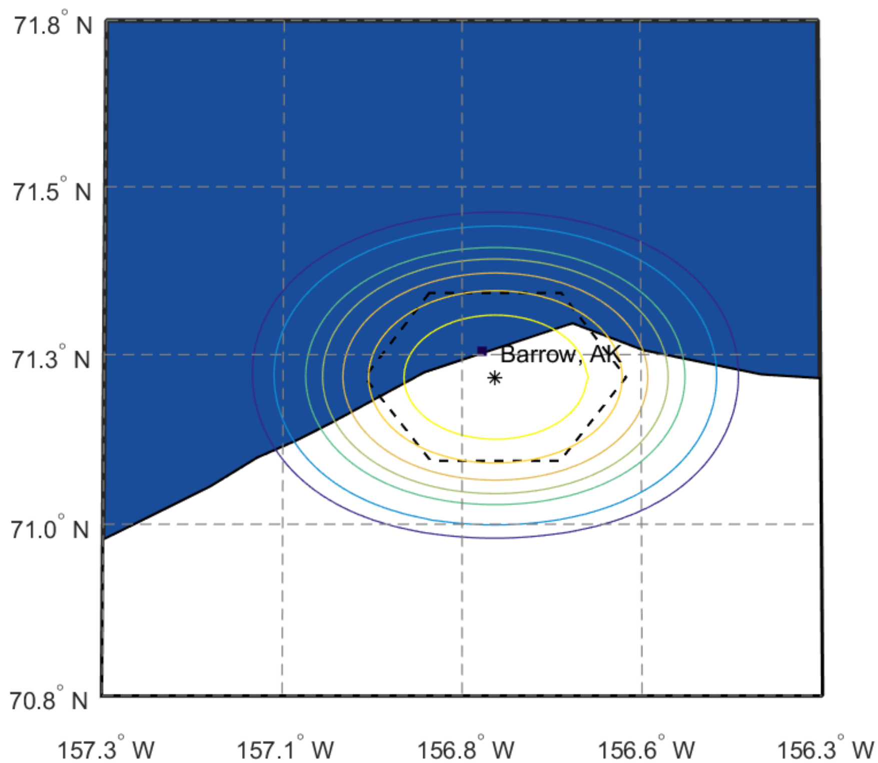


Figure II-7. Transmit Alaska Beam at 40 GHz
(Beams ADL30 and ADR30)

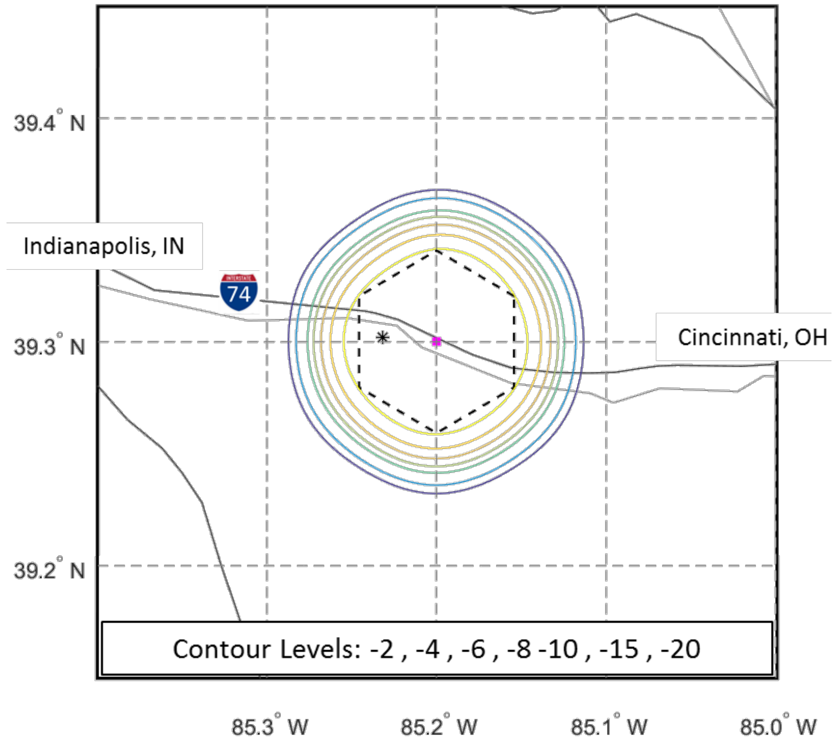


Figure II-8. Receive Beam Contours of the 0° Scanned Beam at 50 GHz (Beams BUL00 and BUR00)

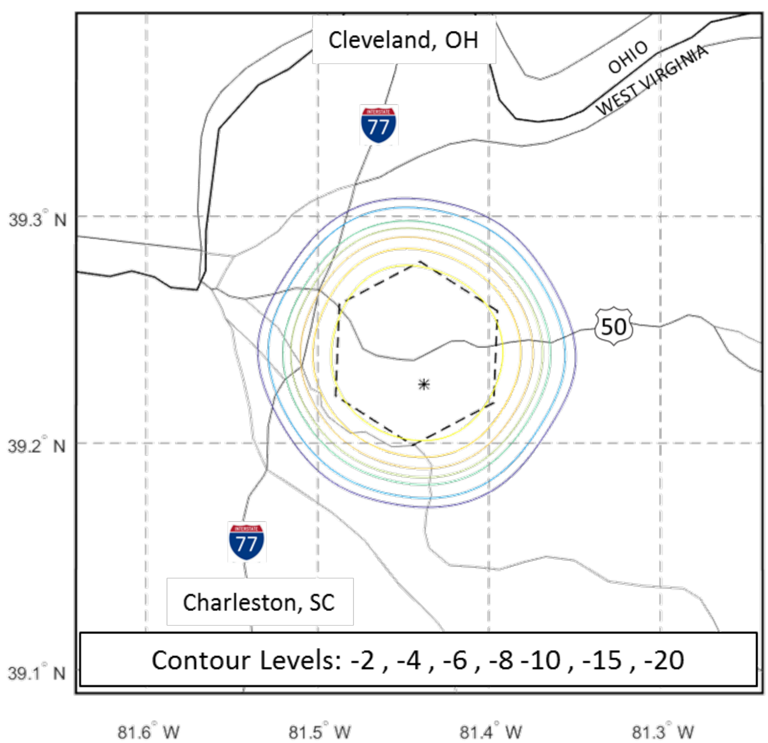


Figure II-9. Receive Beam Contours of the 15° Scanned Beam at 50 GHz (Beams BUL15 and BUR15)

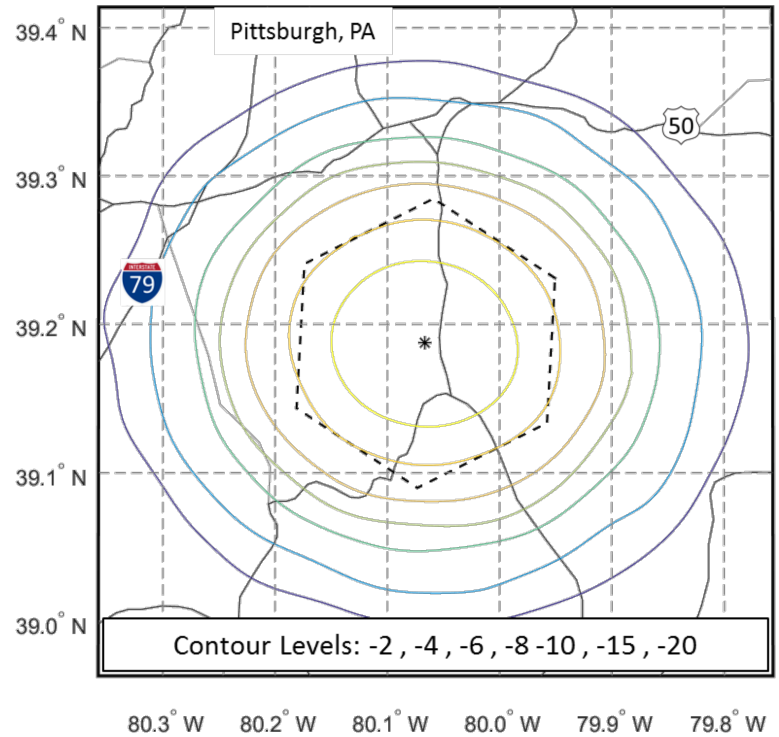


Figure II-10. Receive Beam Contours of the 20° Scanned Beam at 50 GHz (Beams SUL20 and SUR20)

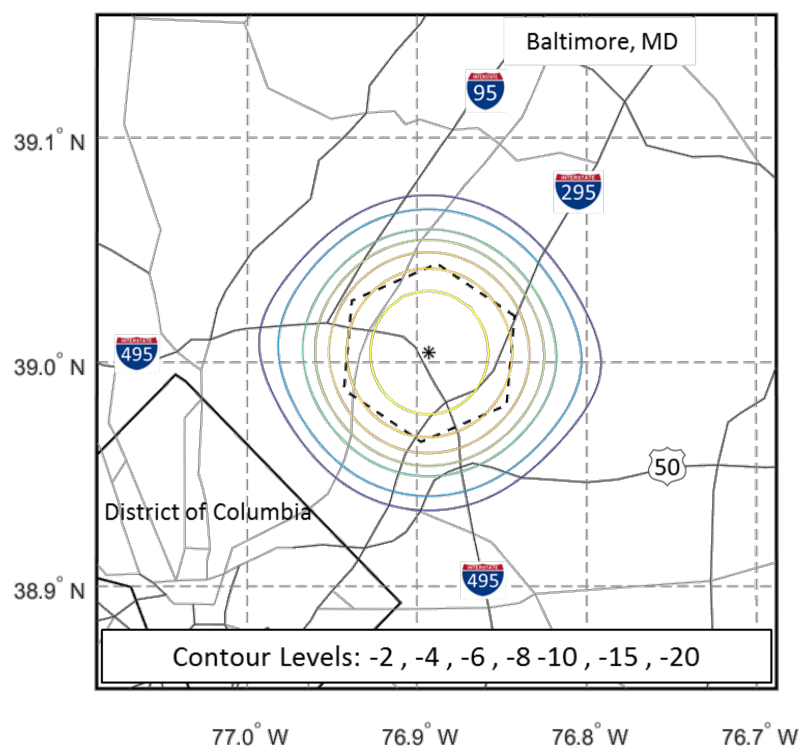
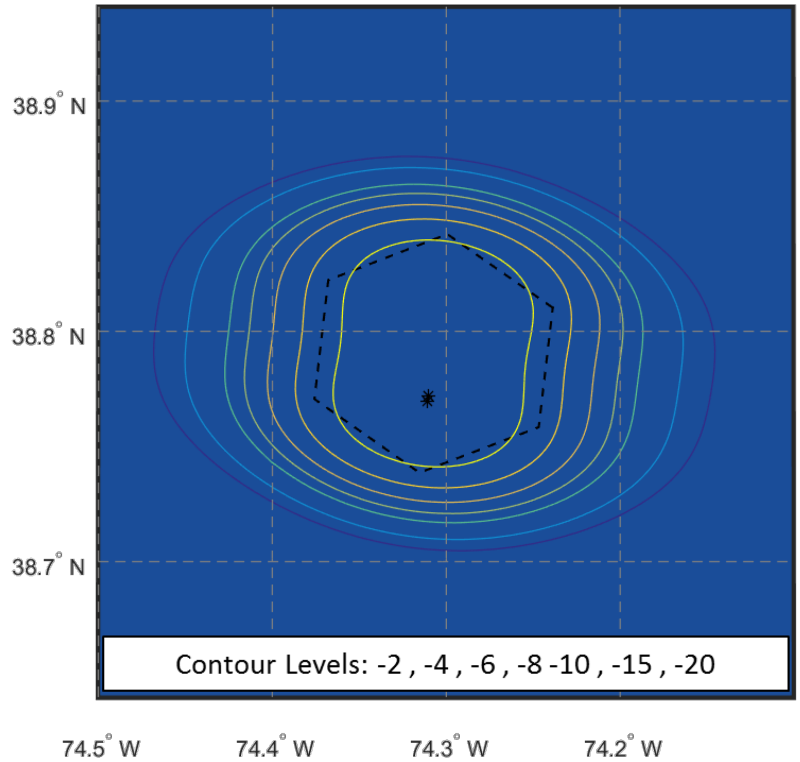
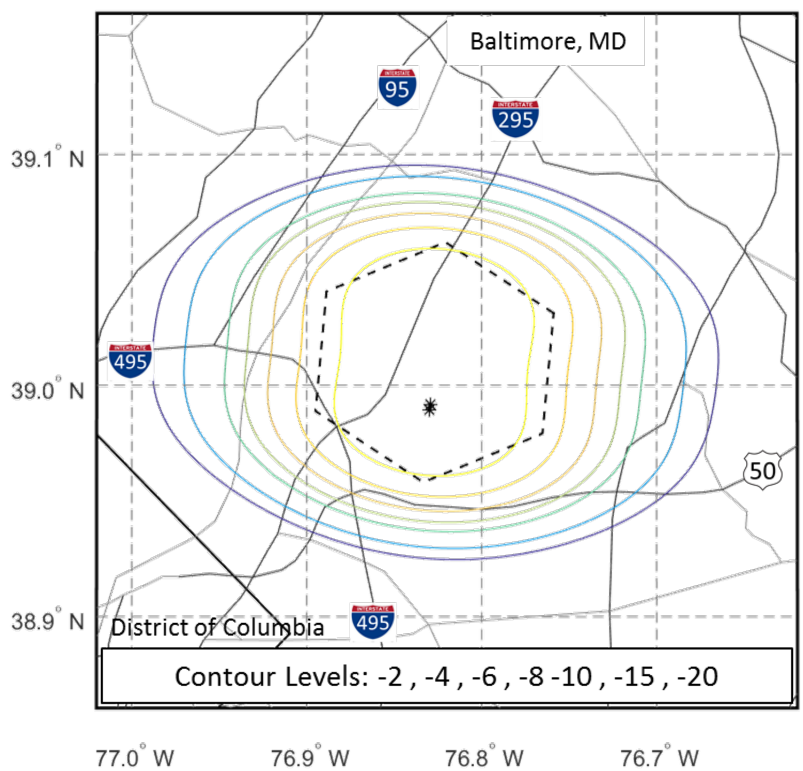


Figure II-11. Receive Beam Contour at 30° Scan Beam at 50 GHz (Beams BUL30 and BUR30)



a) Over Ocean



b) Over the Washington DC Area

Figure II-12. Receive Beam Contours of the 36.5° Scanned Beam at 50 GHz (Beams BUL36 and BUR36)

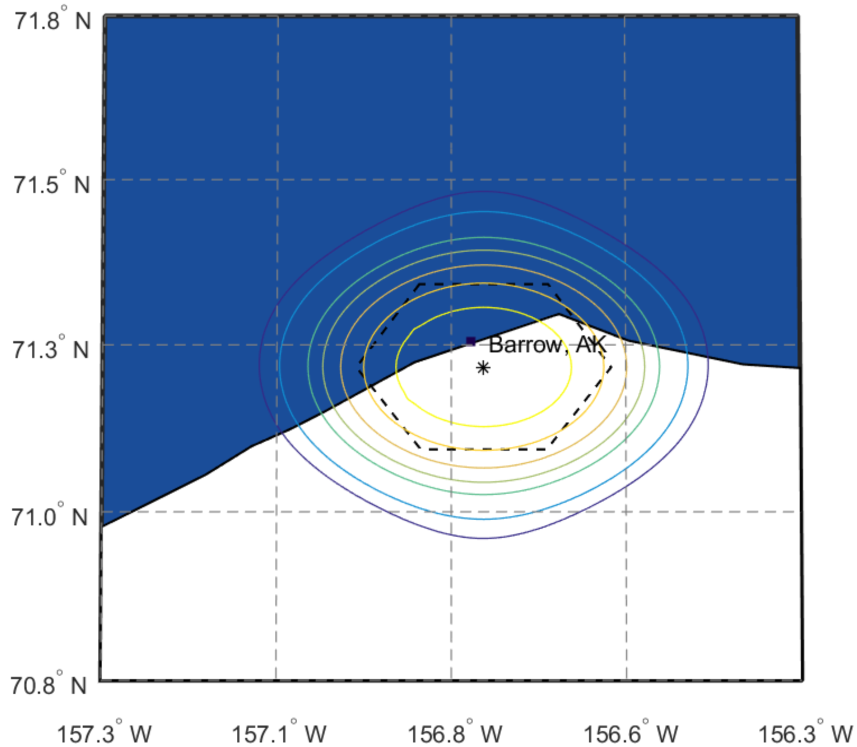
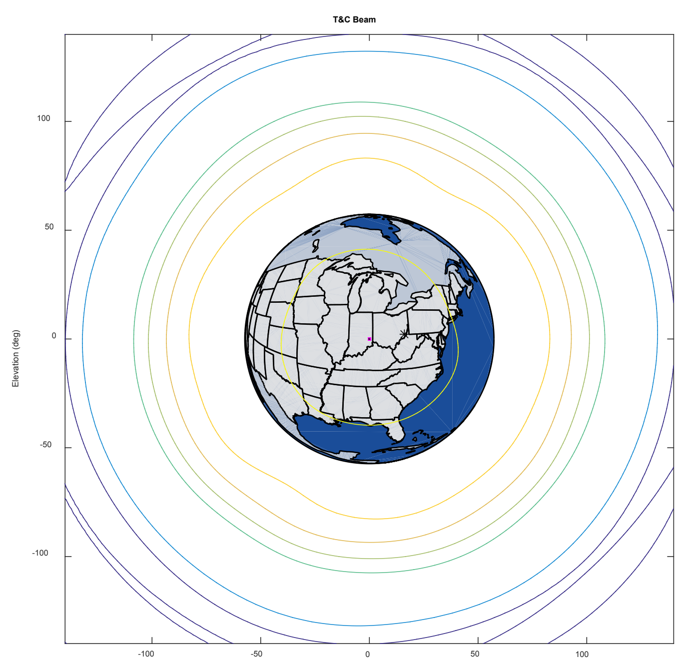


Figure II-13. Receive Beam Contours of Alaska Beam at 50 GHz (Beams AUL30 & AUR30)



Contour Levels: -2, -4, -6, -8, -10, -15, and -20

Figure II 14. Transmit Telemetry Beam (Beam BTLM) and Receive Command Beam (Beam BCMD) Contours

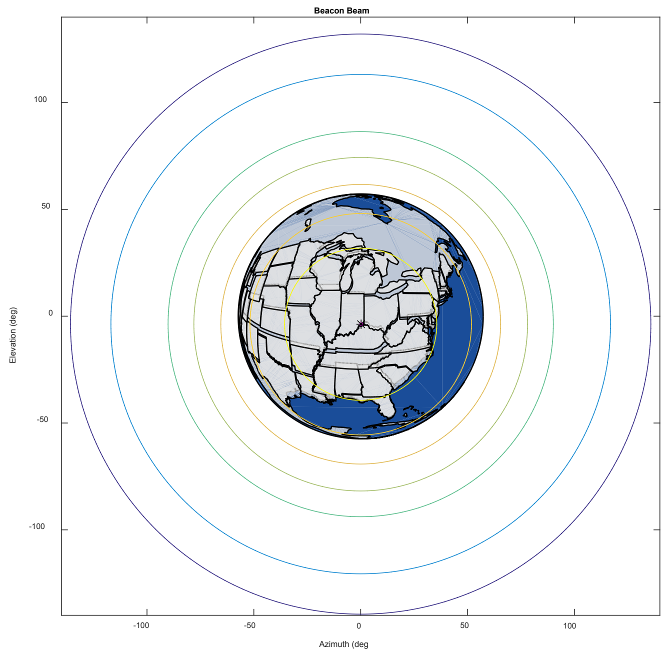


Figure II-15. Transmit Beacon Beam Contours at 42.4 GHz (Beams BBCNL and BBCNR)

§ 25.114(c)(8) 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 Schedule S, Table S8 of this Application. As indicated in Table S8, the NGSO System would comply with the PFD limits specified in Sections 25.208(s) and 25.208(t) of the Commission's rules for NGSO FSS satellite systems operating in the 40.0-40.5 and the 40.5-42.0 GHz bands, respectively.

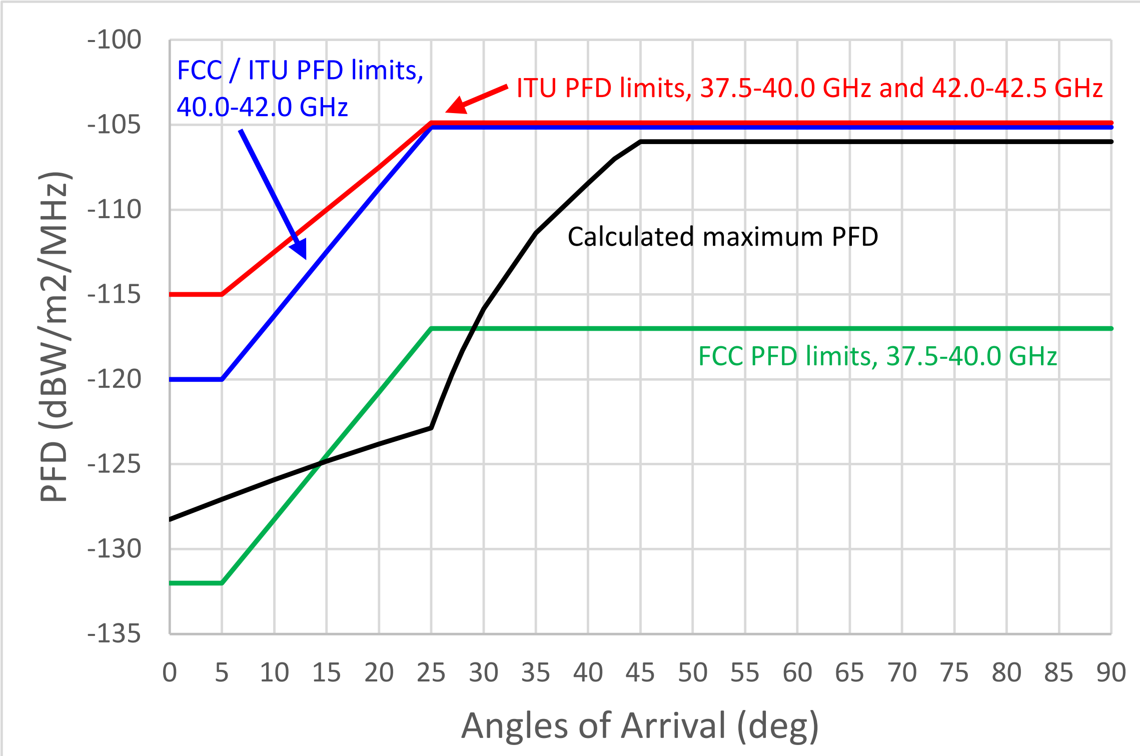
The NGSO System, however, is not designed to operate within the far more strict PFD limits specified in Section 25.208(r) of the Commission's rules for NGSO FSS systems operating in the 37.5-40.0 GHz band. Instead, Boeing seeks authority to operate the NGSO System in the 37.5-40.0 GHz band using the PFD limits adopted by the ITU for this spectrum, which are reflected in Article 21 (Table 21-4) of the Radio Regulations and are identical to the PFD limits adopted by both the ITU and the FCC for the adjacent 40.0-42.0 GHz band.[2] Boeing seeks authority to operate at the existing ITU PFD limits in the 37.5-40.0 GHz band because Boeing's spectrum sharing analysis for the 37.5-40.0 GHz band, provided below in Part V of this Application, indicates that operations at these higher PFD levels would not result in harmful interference to incumbent fixed or proposed terrestrial mobile services (*i.e.*, Upper Microwave Flexible Use ("UMFU") systems) in this spectrum. Further, Commission approval to operate at the higher ITU PFD limits is required to withstand anticipated interference from UMFU systems into satellite end user receivers operating with the NGSO System in the 37.5-40.0 GHz band. In support of this request, Boeing has included in Part IV of this Application a request for waiver of Sections 25.114(c)(8) and 25.208(r) of the Commission's rules.

The calculated maximum PFD for the NGSO System is based on the maximum downlink EIRP density. As shown in Table S7 of Schedule S, the maximum downlink EIRP density is 28.2 dBW/MHz for all coverage areas except Alaska and 31.1 dBW/MHz for Alaska. Taking into account the spreading loss from the satellite to the Earth's surface, the calculated maximum PFD levels as a function of arrival angle are

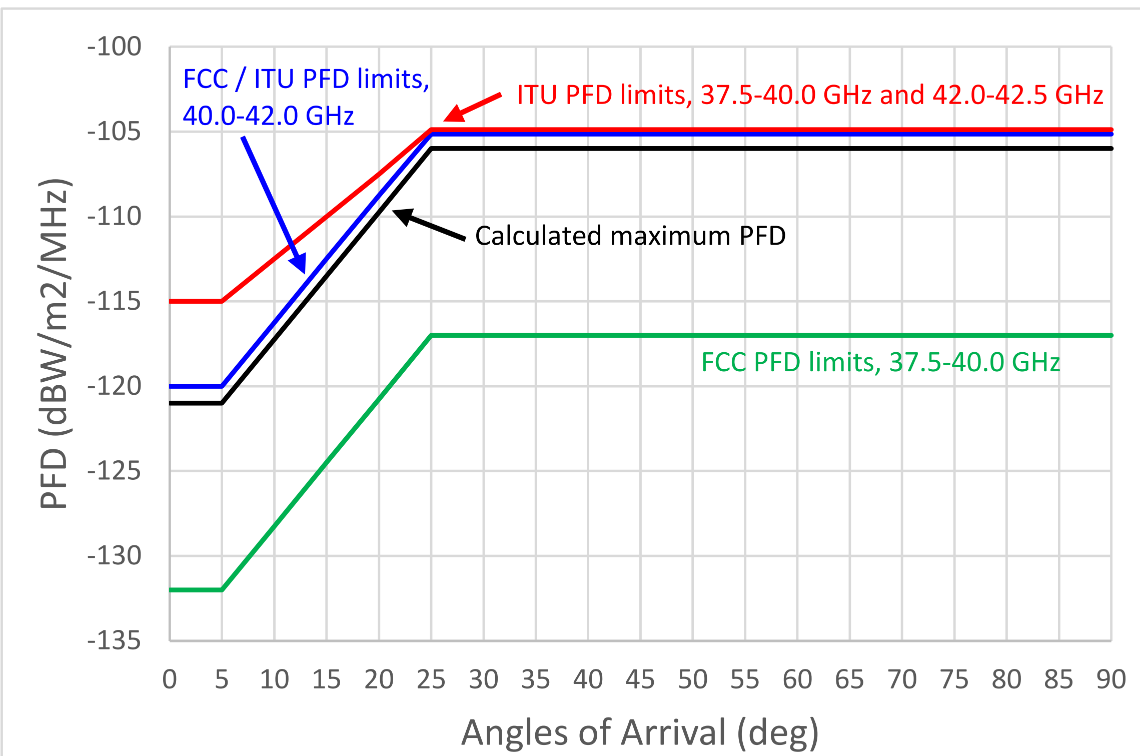
[2] Boeing acknowledges that footnote 21.16.4 of Article 21 (Table 21-4) indicates that the PFD limits specified apply to NGSO systems with 99 or fewer satellites and that further study may be needed with respect to the application of the limits to systems with 100 or more satellites. Footnote 21.16.4 was adopted by WRC-2000 and has not been modified since. To the extent that further study is deemed necessary regarding the application of the ITU limits to larger NGSO systems, Boeing will actively participate in such studies.

shown in Figure II-16 and are within the ITU limits for the 37.5-40.0 GHz and the 42.0-42.5 GHz bands and also within the FCC and ITU limits for the 40.0-42.0 GHz band.

For the 37.5 to 40.0 GHz band, Figure II-16 also shows that the calculated maximum PFD levels exceed the current FCC limits. As mentioned earlier, Boeing requests a waiver to Section 25.208(r) to allow the use of the higher ITU limits rather than the FCC limits. Section 25.208(r) also specifies higher limits that compensate for the effects of rain fade. These limits are the same as the higher ITU limits. The NGSO System would comply with these rain fade PFD limits.



a) For all coverage areas except Alaska



b) For Alaska

Figure II-16. Calculated Maximum PFD

Section 25.208 does not include any PFD limits for FSS operations in the 42.0-42.5 GHz band. Thus, this Application contemplates the operation of the NGSO System in the 42.0-42.5 GHz band using the PFD limits that are maintained by the ITU for this spectrum.

§ 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 a wide range of broadband Internet and communications services for residential, commercial, institutional, governmental and professional users worldwide. Figure II-17 provides an overview of the NGSO System facilities and connectivity.

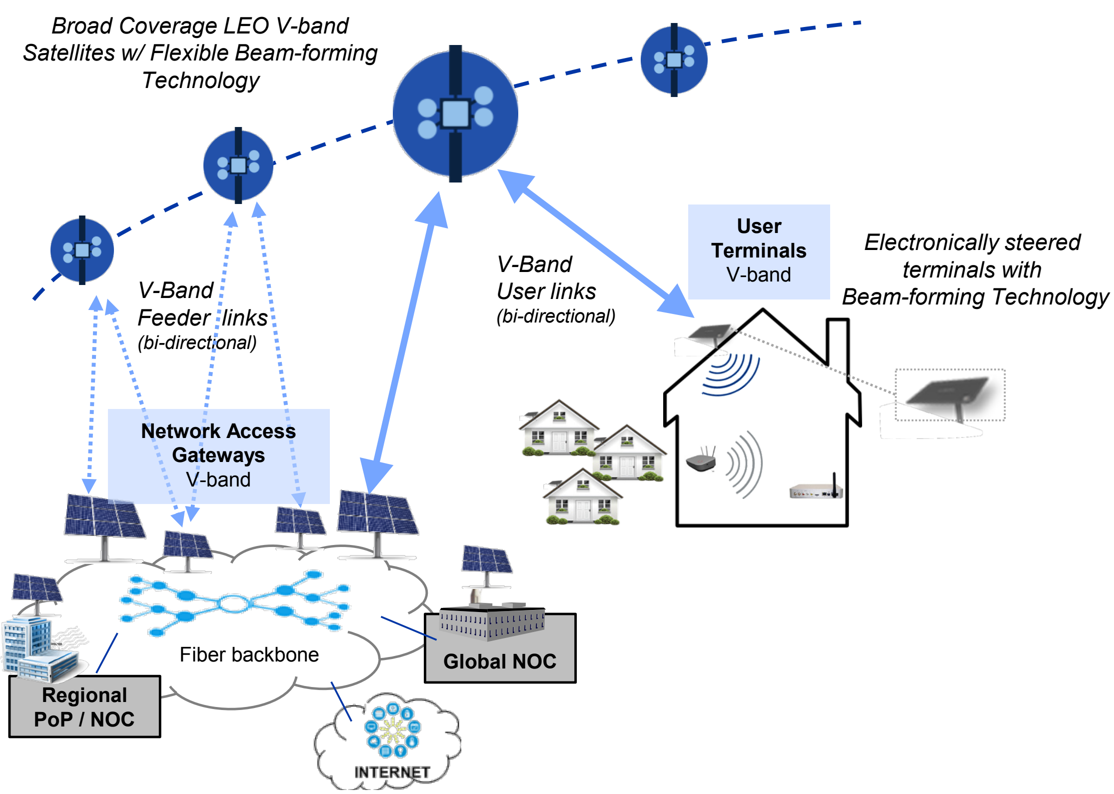


Figure II-17. NGSO System Overview and Facilities

The NGSO System would consist of a total constellation of 2,956 NGSO FSS satellites[3] to provide very high speed, low-latency Internet connectivity for user terminals via the system's network access gateways ("gateways") and associated terrestrial fiber network. The satellites, gateways, and user terminals would be managed from a Global Network Operations Center ("GNOC") using a series of 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 all internationally allocated V-band FSS spectrum, sharing and re-using the entire uplink and downlink frequency band within the coverage footprint of each satellite. Sharing and efficient use of the V-band spectrum would be enabled by the use of advanced beam-forming and digital processing 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 LEO satellites. The system's gateways similarly would apply advanced array technologies to generate high-gain steered 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 V-band T&C links provided by the gateways.

[3] As discussed in subsequent sections of this Application, Boeing seeks authority to launch the NGSO System in progressive stages that would include an Initial Deployment configuration of 1,396 satellites within six years of license grant and, as needed to meet anticipated demand, a Final Deployment configuration of 2,956 satellites.

1. NGSO System Constellation and Coverage

In its Initial Deployment, the Boeing NGSO System would consist of a constellation of 1,396 LEO satellites operating at a 1,200 kilometers altitude. The initial constellation would consist of 35 circular-orbit planes operating at a 45 degree inclination, augmented with 6 additional circular-orbit plans operating at a 55 degree inclination. A detailed description of the satellite constellation is included in Schedule S, Tables S4 and S5, and geographic coverage is discussed in the narrative covering Section 25.143(b)(2).

The initial configuration would provide satellite visibility at an earth station elevation angle of greater than 45 degrees for all users below 60 degree latitude, and would provide improved satellite visibility and coverage within the highly populated latitude regions. High elevation angles offer a significant advantage for system operation by enabling reduced losses due to link impairments and multiple line-of-sight ("LOS") paths to avoid blockage. These features also provide the system's gateways and user terminals with isolation from other users operating in the V-band spectrum (*see* Part V for a detailed discussion of spectrum sharing features of the NGSO System).

The Final Deployment of the NGSO System would increase the number of satellites to 2,956, adding 12 more 55 degree inclination planes operating at an altitude of 1,200 kilometers and adding 21 orbit planes inclined at a near-polar orbit of 88-degree operating at a lower altitude of 1,000 kilometers. This Final Deployment could provide additional system capacity and improve coverage for all users worldwide.

The NGSO System payload would use advanced beam-forming and digital processing to generate thousands of narrow spot beams to provide a cellular coverage on the Earth's surface. Figure II-18 shows the illustrative coverage footprints of multiple satellites over the continental United States ("CONUS") with the illustrative cells generated by a single satellite depicted in the highlighted footprint.

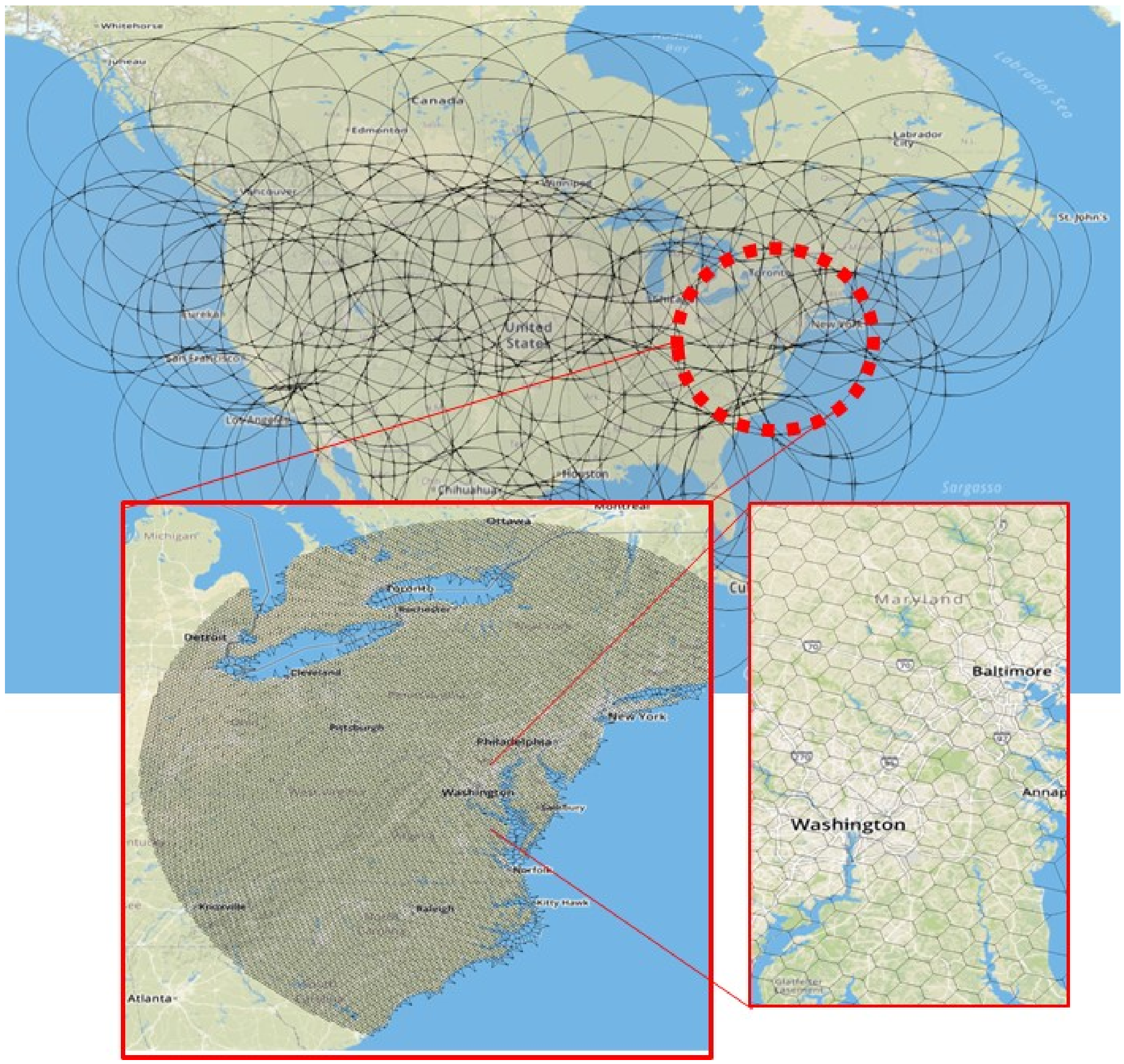


Figure II-18. NGSO System Satellite Coverage Footprints and Cells (Illustrated)

Narrow spot beams with low sidelobes would enable frequency re-use among the thousands of cells within each satellite footprint and unique time-division transmission techniques would enable frequency re-use between user terminals and gateways where both earth station types are present within the same cell. Efficient re-use of the V-band spectrum is described in the narrative covering Sections 25.114(d)(1)B and 25.210(f). System gateways would typically be located outside of highly-populated regions in areas of relatively low user demand. Each NGSO System satellite would be able to form beams corresponding to Earth-surface cell diameters ranging from 8 to 11 kilometers within the overall satellite coverage footprint. Examples of the NGSO System beams are shown in the narrative covering Section 25.114(c)(4)(vi) and are included in Schedule S, Table S8. User terminals would be mapped into cells, and the payload coverage beams would be directed towards these cells as the NGSO System satellites pass over. The system NOCs would ensure that user terminals and gateways are handed over from cell to cell (and satellite to satellite) at elevation angles greater than 45 degrees, providing seamless user communications service via a make-before-break handover approach.

2. Global Broadband Terminals and Services

The NGSO System would provide a wide range of advanced communications and Internet-based services to a state-of-the-art suite of V-band earth stations. The NGSO System user terminals would consist of advanced array antennas capable of generating and receiving wideband signals on any system channel, with higher throughputs supported by terminals designed for multi-channel/multi-polarization operation.

The NGSO System gateways would operate within the same V-band spectrum as the user terminals. The system's gateways would use both frequency polarizations (LHCP and RHCP). In addition, physical gateway sites may contain more than one antenna thereby enabling simultaneous access to the multiplicity of NGSO System satellites visible from a gateway site.

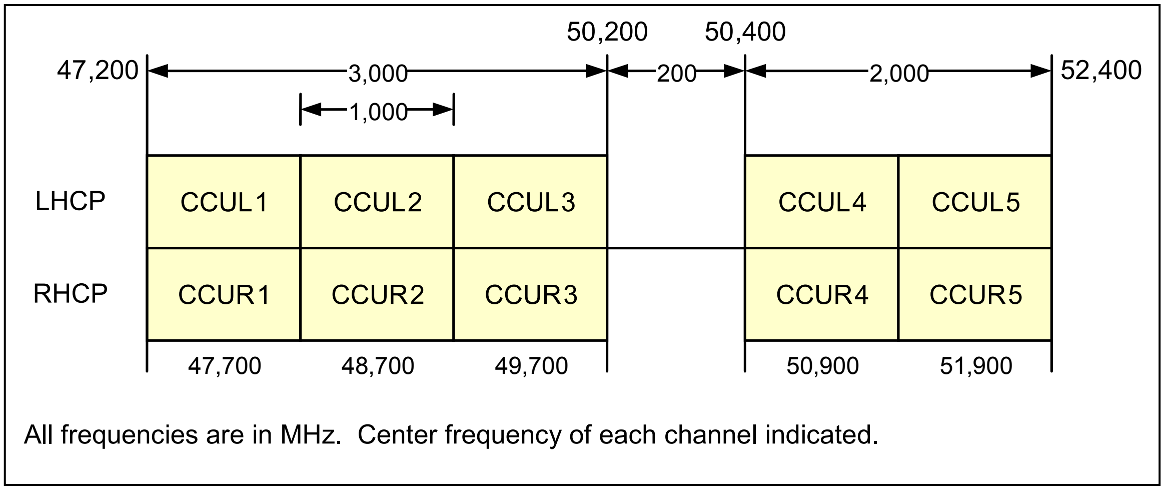
All NGSO System earth stations (both gateways and user terminals) would use advanced digital modulation and coding, along with adaptive modulation coding and power control, to achieve high spectral efficiencies and availability while efficiently managing the use of earth station and satellite transmission power. The NGSO System would dynamically assign carriers, 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 user demand across the coverage footprint.

B. System Frequency Usage and Frequency Plan

The uplink and downlink frequency plans for the NGSO System are shown in Figures II-19 through II-22, and Table S2 of Schedule S. The communication channels (CC), beacon channels (CB) and telemetry and command channels (CT) associated with these frequency bands are described in Table S9 of Schedule S.

1. Uplink Frequency Plan—Communication Channels

Uplink data communication channels would consist of five 1 GHz channels per polarization as shown in Figure II-19. These channels would be used both for gateway-to-satellite forward uplinks and for user-to-satellite return uplinks. Each of these channels may be partially or fully occupied by one or more of the carriers described in Table S11 of Schedule S.



The channel designations follow the following format:

- "C" – channel
- "C/T/B" – C = Communications T = Telemetry & Command B = Beacon
- "U/D" – U = Uplink, D = Downlink
- "L/R" – L = LHCP polarization, R = RHCP polarization
- # = ID of channel (numeric) – used for multiple channels

Figure II-19. Communication Channel Uplink Frequency Plan

2. Uplink Command Channels

One 250 MHz satellite command channel would be allocated to support up to fifty 5 MHz uplink command carriers as shown in Figure II-20 (channel CTUL, LHCP only). Each command carrier would allow robust, low-rate commanding from a single gateway site to a multiplicity of NGSO satellites within the field of view of the gateway. The command channel (CTUL) would partially overlap one of the communication uplink channels (CCUL1). Shared command and communication channel usage would be managed by the GNOC during system deployment and throughout the operational lifetime of the constellation.

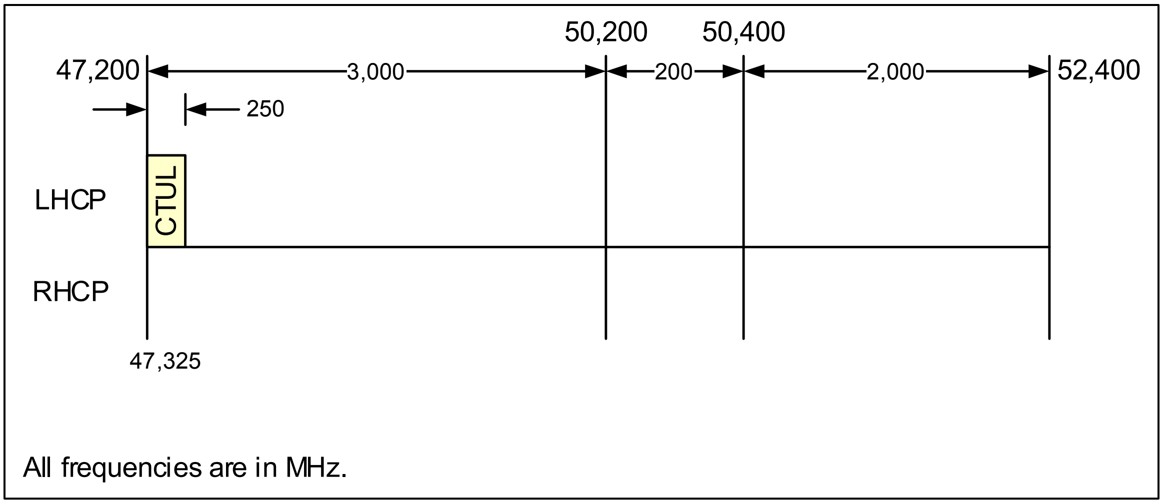


Figure II-20. Command Channel Uplink Frequency Plan

3. Downlink Frequency Plan—Communication Channels

Downlink data communication channels would consist of five 1 GHz channels per polarization as shown in Figure II-21. These channels would be used both for satellite-to-user forward downlinks and for satellite-to-gateway return downlinks. Each of these channels may be partially or fully occupied by one or more of the carriers as described in Table S11 of Schedule S.

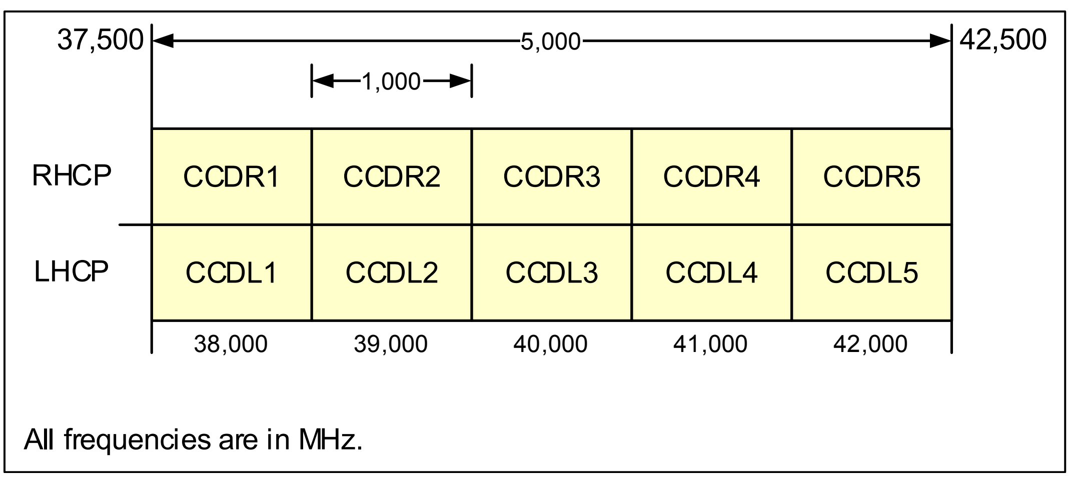


Figure II-21. Communication Channel Downlink Frequency Plan

4. Downlink Telemetry Channel

One 50 MHz downlink telemetry channel would be allocated to support up to forty 1.25 MHz carriers (CTDL) as shown in Figure II-22 (channel CTDL, LHCP only). Each telemetry carrier would provide a robust, low-rate telemetry stream from each NGSO satellite within the field of view of a single gateway. Similar to the command channel, the telemetry channel would partially overlap one of the communication channels (CCDL5). Shared telemetry and communication channel usage would be managed by the GNOC during system deployment and throughout the operational lifetime of the constellation.

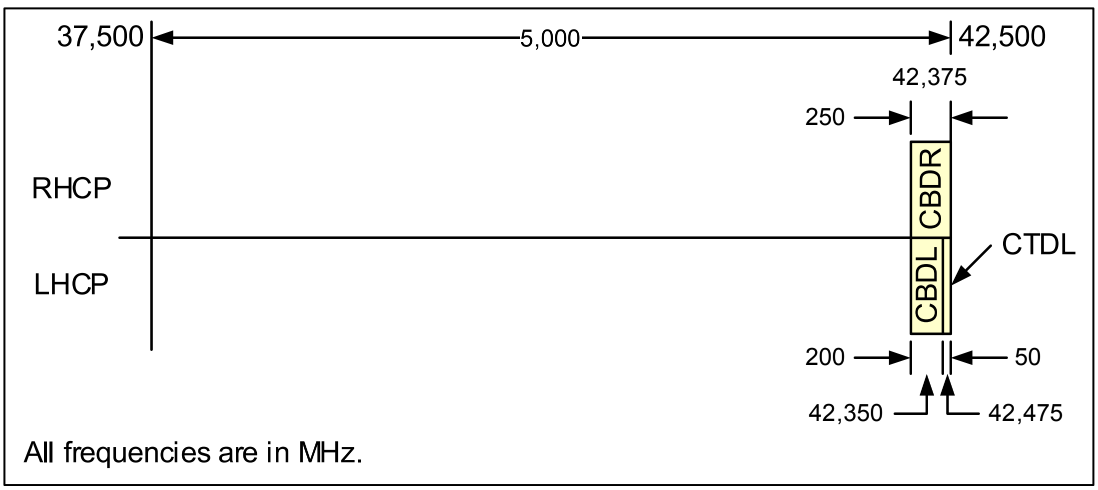


Figure II-22. Telemetry (CTDL) and Beacon (CBDL and CBDR) Channels Downlink Frequency Plan

5. Downlink Beacon Channels

The satellites would also use a downlink beacon transmission operating over the satellite coverage footprint-wide beacon beam (service area 'B' in Table S6 of Schedule S and beams BBCNL and BBCNR in Table S7). The beacon signal would operate on both polarizations (LHCP and RHCP) using a 200 MHz channel on LHCP and a 250 MHz channel on RHCP as shown in Figure II-22 (channels CBDL and CBDR).

These beacon channels would support up to twenty 10 MHz modulated beacon signals, which would enable rapid satellite acquisition by the system earth stations and robust NGSO system operation and handovers. The beacon channels would overlap communication channels CCDL5 and CCDR5. Shared beacon and communication channel usage would be managed by the GNOC using combinations of the carriers described in Table S11 of Schedule S.

6. Uplink to Downlink Communication Channels and Frequency Band Connectivity

Each satellite uplink or downlink beam may carry up to five 1 GHz communication channels, for up to 5 GHz total bandwidth depending on the instantaneous capacity needed by the cell being served by the beam. To support service within the entire satellite coverage area, the active satellite spot beams would be switched across the cells within the satellite footprint.

Any uplink channel in any uplink beam may generally be connected to any downlink channel in any downlink beam according to the connectivity described in Table S10 of Schedule S, as illustrated in Figure II-23.

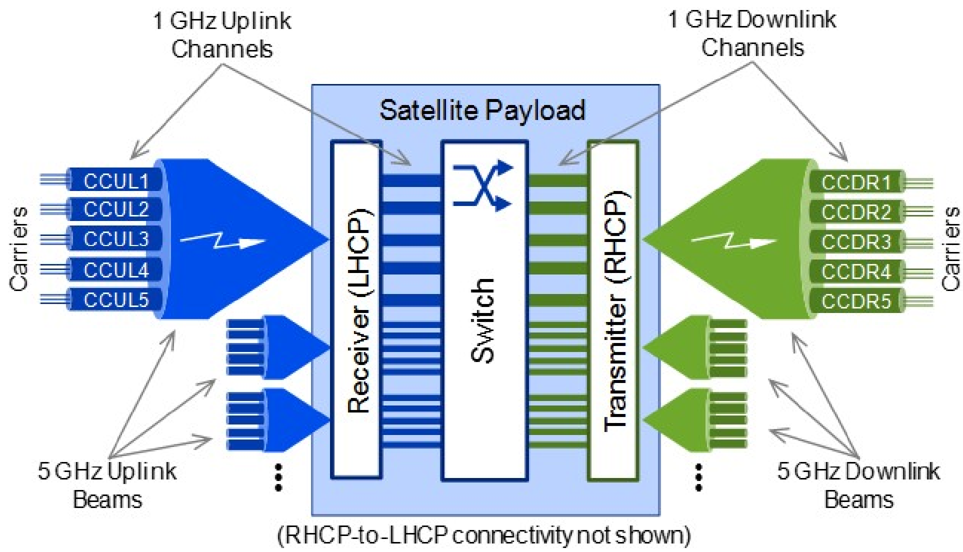


Figure II-23. Communication Channel Uplink/Downlink Connectivity

The NGSO System would align the satellite capacity with NGSO satellite motion and could accommodate the varying nature of the user traffic demand across the footprint.

§ 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.

A. Control of Debris Released During Normal Operations

The NGSO System would use satellites that generate no debris during deployment and would not generate any debris during normal operation in compliance with the U.S. Government Orbital Debris Mitigation Standard Practices (objective 1-1), which dictates that there will be no release of debris larger than 5 millimeters in any dimension that remains on orbit for more than 25 years. In addition, the satellites would not use exterior materials or designs that may generate debris due to environmental factors (*e.g.*, radiation degradation, thermal fatigue, *etc*.).

Boeing has assessed and limited the probability of the proposed NGSO satellites becoming a source of debris due to collisions with small debris or meteoroids that could cause loss of control and prevent post-mission disposal, by employing standard debris shielding techniques, including bumper shields, debris blankets, and redundancy for vulnerable and critical spacecraft elements.

B. Minimizing Debris Generated by 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, on-board storage of energy in the satellites would be limited to:

- Lithium ion batteries,
- Reaction wheel assemblies,
- Pressurized fuel tank (1 per satellite),
- Constant conductance heat pipes, and
- Pumped-fluid thermal control systems.

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.*). The constant conductance heat pipes would be standard space-qualified designs, which contain low pressure ammonia working fluids, not conducive to explosions when damaged, and have had no prior explosive incidents on-orbit. The pumped-fluid thermal control system would operate at a lower pressure than the heat pipes and has a correspondingly lower risk.

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, deactivation of the pump fluid system, 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 that the fuel tank would be completely depressurized with subsequent venting.

C. Selection of Safe Flight Profile and Operational Configuration

Boeing has vast experience with LEO satellite management, including Collision On Launch Assessment ("COLA"), through its extended stewardship of the Iridium constellation for more than 15 years. Consistent with this experience, Boeing has assessed and taken steps to limit the probability of the NGSO satellites becoming a source of debris by collisions with large debris or other operational space stations. All satellites would, by orbit design, have a minimum close approach of 10 kilometers with other satellites in the constellation.

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. The total delta-v for a collision avoidance maneuver is nominally 0.4 m/sec and it is estimated that each satellite would need to perform 1.6 maneuvers per vehicle-year.

Boeing understands that a large LEO constellation has been proposed by WorldVu Satellites Limited ("WorldVu") that would also operate at a nominal orbital altitude of 1,200 kilometers. Boeing would work with WorldVu to develop an analysis of the potential risk of collision and a description of what measures Boeing and WorldVu plan to take to avoid in-orbit collisions. The parties would also ascertain the likelihood of successful coordination of physical operations between the two systems, which Boeing anticipates can be coordinated between the parties.

The Boeing satellites would be designed to operate in the small debris environment, and 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).

D. Post-Mission Disposal of Space Structures

Disposal of the satellites would be performed with propulsion. Sufficient propellant (approximately 90 percent of the propellant budget) would be allocated such that propulsive deorbit maneuvers insert the spacecraft into a drag-intensive disposal orbit, with an altitude of below 500 kilometers, resulting in the subsequent passive reentry of the satellite. The total deorbit would be completed in less than five years. Boeing standard design practices would provide sufficient redundancy to ensure a high reliability of successful deorbit for all satellites at completion of mission or in the event of individual spacecraft element failure. NASA Debris Assessment Software (DAS) has been used to calculate the probability of collision for the vehicle during the disposal process, which was determined to be less than 1.3×10^{-4}. This probability is bounding, as it assumes that there are no evasive COLA maneuvers performed by active assets in possible conjunction with the deorbiting vehicle. This disposal process is consistent with NASA and international guidelines for LEO satellites, which require deorbiting in less than 25 years following completion of the spacecraft mission.

The satellites would be designed so that they can be disposed of by reentry into the Earth's atmosphere. Due to specific selections of materials with highly limited survivability in the atmospheric reentry environment, the risk of human casualties from reentry disposal of the satellites would be less than 1 in 10,000. This was established by a preliminary assessment using NASA DAS and is consistent with requirement 4.7-1 of NASA-STD 8719.14.

§ 25.143(b)(2) Geographic Coverage Requirements

The NGSO System would comply with the default geographic service rules applicable to NGSO FSS systems operating in the V-band. Compliance would be achieved concurrently with the completion of the "Initial Deployment" of the NGSO System, and would be supplemented by the "Final Deployment" of the system, as both of these terms are defined in Section A.1. of the narrative associated with Section 25.114(d)(1).

With respect to Section 25.143(b)(iii) (domestic coverage), Boeing would employ specific constellation design elements to ensure continuous coverage of the United States and its territories, including the States of Alaska and Hawaii. To ensure adequate coverage of Alaska, Boeing would operate 276 of the satellites in its Initial Deployment at a 55-degree orbit inclination, which would provide continuous service to Alaska, including its northern most community of Barrow. With respect to Section 25.143(b)(iii) (international coverage), both the Initial Deployment and the Final Deployment of the NGSO System would include at least one satellite that would be visible above the horizon at an elevation angle of at least 5 degrees for at least 18 hours each day to all locations as far north as 70 degree north latitude and as far south as 55 degree south latitude.

Although the NGSO System would comply with the strict language of the Commission's geographic coverage rule, Boeing acknowledges that providing service in high latitude regions would require certain operational adjustments, including the use of larger user terminals and slower data rates. Out of an abundance of caution, Boeing therefore requests in Part IV of this Application a waiver of the Commission's geographic coverage requirement to the extent that the Commission determines that such a waiver is necessary.

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

Boeing is requesting a waiver of this rule section, which is addressed in Part IV of this Application.

§ 25.156(d)(5) NGSO Versus GSO Systems

Boeing is requesting a waiver of certain aspects of this rule section, which are addressed in Part IV of this Application.

§ 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 of this Application. As Boeing explains in Part V of this Application, the NGSO System could share the V-band with other NGSO satellite systems.

§ 25.164(b) Construction Milestones

Boeing anticipates that, by the time the Commission issues a license for the launch and operation of the NGSO System, the revised satellite construction milestones for NGSO systems that were recently adopted by the Commission will have taken effect.[4] Section 25.164(b) of the Commission's recently adopted rules requires licensees of NGSO systems to "launch the space stations, place them in the assigned orbits, and

[4] Comprehensive Review of Licensing and Operating Rules for Satellite Services, IB Docket No. 12-267, *Second Report and Order*, FCC 15-167 (2015) ("*Part 25 Second Report and Order*").

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." Given the phased deployment plan for the NGSO System, Boeing herein requests that the Commission establish a modified approach that ensures the launch and operation 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 in response to increased demand.

As discussed previously in this Application, Boeing proposes to launch the NGSO System in two phases, the Initial Deployment phase and the Final Deployment phase. The Initial Deployment of the NGSO System would include sufficient satellites to satisfy the Commission's domestic geographic coverage requirements (including coverage to Alaska and Hawaii) and would provide enough capacity to meet the anticipated needs of the initial customers. The Final Deployment configuration would provide additional capacity as needed.

Boeing seeks authority to launch and operate the Initial 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. Boeing seeks further authority to launch the Final Deployment on a phased basis as the need arises. 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 Initial Deployment of 1,396 satellites within six years would not constitute warehousing of orbital or spectrum resources. Instead, the Initial Deployment would use the entire 5 GHz of paired V-band spectrum to provide a comprehensive service and would satisfy the Commission's geographic coverage requirements.

Further, it would not serve the public interest to require the launch of the Final Deployment before such additional capacity is needed. Each satellite would have a finite lifetime and, as a result, satellites that are launched prior to their need would increase the cost of the satellite system, without any corresponding benefit. Launching satellites in advance of when they are needed would also unnecessarily increase the constellation management requirements and the environmental impact of such launches without any corresponding benefit. Instead, the Commission should only require that the launch and initiation of operation of the Initial Deployment of 1,396 satellites be completed by the sixth year milestone deadline and permit the launch of the remainder of the Final Deployment on a phased basis in response to the needs of the market.

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[5] *Id.*, ¶ 53 (*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 2d 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)).

Such an approach 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] Such an approach would also be effective in preventing warehousing, while being cognizant of cost constraints, operational considerations and the needs of the environmental concerns associated with the launch and operation of large NGSO constellations.

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

As noted above, Boeing is requesting authority to operate the NGSO System in the United States using the 37.5-42.5 GHz (space-to-Earth) and the 47.2-50.2 and 50.4-52.4 GHz bands (Earth-to-space). The 42.0-42.5 GHz and the 51.4-52.4 GHz bands are not identified in either Sections 2.106 or 25.202(a)(1) of the Commission's rules as allocated or available for FSS in the United States. In addition, although Section 2.106 of the rules does identify the 50.4-51.4 GHz band as allocated for FSS, the band is not identified in Section 25.202(a)(1) as available for FSS. In addition, footnote 3 of Section 25.202(a)(1) restricts the use of the 37.5-40.0 GHz band by FSS to gateway earth station operations. Boeing requests a waiver of each of these allocation and operational restrictions in Part IV of this Application.

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[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); *see also* 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) (authorizing Spire Global to launch and operate an additional 20 satellites without imposing milestones or bond requirements on the additional deployment).

Boeing acknowledges that the International Table does not include an allocation for FSS in the 51.4-52.4 GHz band. The ITU-R study process, however, pursuant to Resolution 162 (WRC-15), is currently considering whether to add a co-primary allocation for FSS in the 51.4-52.4 GHz band, which could be completed by WRC-19.[7] Although these studies are focused in part on creating an FSS allocation to support feeder links for GSO satellites, *resolves 1* of Resolution 162 calls for studies on "the additional spectrum needs for development of the fixed-satellite service, taking into account the frequency bands currently allocated to the fixed-satellite service, the technical conditions of their use, and the possibility of optimizing the use of these frequency bands with a view to increasing spectrum efficiency."[8] Any such comprehensive review of the additional spectrum needs for FSS necessarily must include consideration of the spectrum needs for FSS systems operating with NGSO constellations.

§ 25.202(j) 50.2-50.4 GHz Out-of-Band Emissions Limits

As noted above, Boeing is requesting authority to operate the NGSO System in the United States using the 47.2-50.2 GHz and 50.4-52.4 GHz bands (Earth-to-space). These bands are each adjacent to the 50.2-50.4 GHz band, which is allocated for the Earth exploration-satellite and space research services (both passive). ITU Radio Regulation 5.340.1 indicates that the use of the 50.2-50.4 GHz band by these passive services "should not impose undue constraints on the use of the adjacent bands by the primary allocated services in those bands. Nevertheless, Section 25.202(j) of the

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[7] *See* Resolution 162, Studies relating to spectrum needs and possible allocation of the frequency band 51.4-52.4 GHz to the fixed-satellite service (Earth-to-space) (WRC-15).

[8] *Id.*

Commission's rules indicates that out-of-band emissions into the 50.2-50.4 GHz band under clear-sky conditions shall not exceed −20 dBW/200 MHz (measured at the input of the antenna), except that the maximum unwanted emission power may be increased to −10 dBW/200 MHz for earth stations having an antenna gain greater than or equal to 57 dBi. Boeing herein affirms that the NGSO System would comply with these limits.

§ 25.204(e) Uplink Adaptive Power Control

To meet the desired link performance while minimizing interference between networks, earth station transmissions under conditions of uplink fading will utilize 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

As discussed in Boeing's response to Section 25.114(d)(1) of the Commission's rules (System Description), the system GNOC would be able to command and effectuate the cessation of emissions from any or all of the NGSO spacecraft if the need arises.

§ 25.210(f) Frequency Re-use

As illustrated by the frequency plan in the narrative for Section 25.114(d)(1)(i), the NGSO System would use 5 GHz of paired V-band spectrum for both 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 NGSO satellite coverage footprint. 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 approach is based on use of both orthogonal polarizations and would employ a frequency re-use plan as described in the narrative for Section 25.114(d)(1)(i).

The full 5 GHz of internationally allocation V-band uplink and downlink spectrum would be flexibly used by the system in each polarization in 1 GHz increments, and may be sub-divided into the narrower channel bandwidths defined in Table S11 of Schedule S as "Assigned Bandwidth." The entire paired V-band would be re-used thousands of times by each satellite to serve both user terminals and gateways operating within the satellite's coverage footprint.

Figure II-26 illustrates example 3-cell, 4-cell and 7-cell re-use patterns that 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 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 NGSO System would provide a highly efficient re-use of the spectrum, using the 5 GHz paired uplink and downlink spectrum in each polarization many thousands of times, while fully complying with all of the beam characteristics and emissions limitations described in this Application.

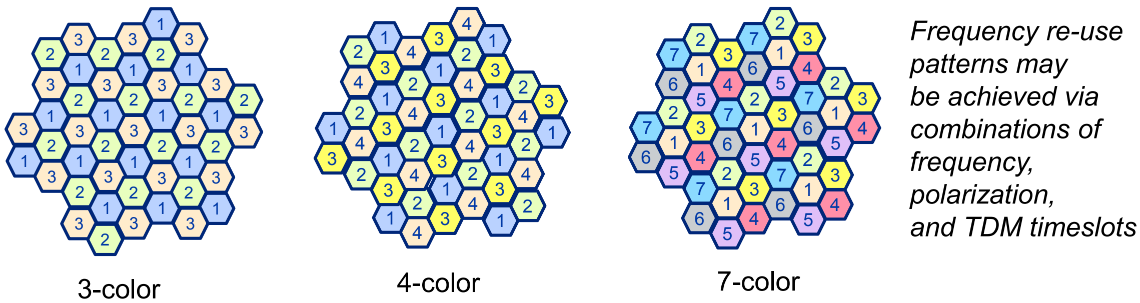

Figure II-26. Frequency Re-use Examples for NGSO System Cells

§ 25.210(i)(1) Cross-Polarization Isolation

Section 25.210(i)(1) includes technical requirements that were made applicable only to space stations in the 17/24 GHz Broadcast Satellite Service pursuant to the Commission's Second Report and Order in the Part 25 proceeding.[9] Boeing requests a waiver of the rule in Part V of this Application because the revised rule is not yet in effect.

III. PUBLIC INTEREST BENEFITS

One of the Commission's most important public interest goals is to foster more widespread and affordable access to broadband Internet access services. As Chairman Wheeler observed, "access to broadband is a powerful motor for lifting people from poverty and reducing economic inequalities."[10] The 2010 *National Broadband Plan* called broadband "the great infrastructure challenge of the early 21st century."[11] There, the Commission explained that broadband "is a modern necessity of life, not a luxury. It

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[9] *See Part 25 Second Report and Order*, ¶ 264.

[10] Remarks of Chairman Tom Wheeler, 19th Annual Satellite Leadership Dinner (March 7, 2016) (*available at* https://apps.fcc.gov/edocs_public/attachmatch/DOC-338135A1.pdf) ("*Chairman Wheeler Speech*").

[11] 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).

ought to be found in every village, in every home and on every farm in every part of the United States."[12] Today, six years later, while 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.[13]

Recognizing the importance of broadband Internet access service in improving educational, economic, civic, cultural, and health care opportunities, the United States has recently launched the Global Connect Initiative, which seeks to bring an additional 1.5 billion people worldwide online by 2020,[14] and that call has been echoed around the world. The United Nations has also set a goal to "[s]ignificantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020."[15]

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[12] *Id.*

[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, 31 FCC Rcd 699, ¶ 12 (2016) ("*2016 Broadband Progress Report*"). 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.

[14] *See* Catherine Novelli, Under Secretary of State for Economic Growth, Energy, and the Environment, "*The Global Connect Initiative: Making the Internet a Development Priority*," Jan. 25, 2016 (*available at:* https://blogs.state.gov/stories/2016/01/25/global-connect-initiative-making-internet-development-priority).

[15] United Nations General Assembly, Seventieth Session, Resolution 70/1, *Transforming Our World: The 2030 Agenda for Sustainable Development*, U.N. Doc. A/RES/70/1, at 21 (Oct. 21, 2015).

As the Chairman has recognized, "satellites will be crucial to the success of both efforts."[16] Boeing's proposal to launch a NGSO LEO system offers nationwide and global access to an extraordinary amount of broadband capacity with data rates that rival terrestrial wired and wireless broadband options. The NGSO System could provide a variety of advanced communications services including broadband data access, multimedia conferencing, video streaming, distance learning and medicine, IP voice and other applications to help ensure that users in rural and urban areas alike enjoy the same level of connectivity, and thus the same level of opportunity, afforded by true broadband connectivity.

A. Bridging the Growing Digital Divide

There is a significant global need for more advanced broadband capabilities. The appetite for broadband Internet access services – fixed and mobile – is growing voraciously, both in the United States and around the world. At the same time, the broadband gap between those who have sufficient access to the Internet and those who do not also continues to grow.[17] The World Bank's recent *Digital Dividends* report found that "[n]early 6 billion people do not have high-speed internet, making them unable to fully participate in the digital economy" and called for nations to "invest in infrastructure and pursue reforms that bring greater competition to telecommunications markets, promote public-private partnerships, and yield effective regulation."[18] The proposed

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[16] *Chairman Wheeler Speech.*

[17] *2016 Broadband Progress Report*, ¶ 126.

[18] World Bank Group, *World Development Report 2016: Digital Dividends*, DOI: 10.1596/978-1-4648-0671-1, at xiii (2016).

NGSO System represents a substantial private investment in space-based broadband infrastructure that will yield significant and lasting public interest benefits in the United States and globally.

The Commission has recognized that alternatives to terrestrial service, such as satellite, are likely to be the most viable option for reaching Americans living in remote areas of the nation,[19] but has struggled with the perception that satellites "can serve *any* given household, [but] satellite capacity does not appear sufficient to serve *every* unserved household."[20] The proposed NGSO System could address the nation's broadband gaps and further the Commission's goal of ubiquitous, affordable broadband Internet access services that are reasonably comparable in price and capability across urban, suburban, rural, and remote areas alike.

B. Promoting Broadband Competition

For decades, the Commission has based its regulatory policies on the central tenet that competition among service providers is the best means of furthering the public interest and it has, therefore, worked tirelessly to create conditions ripe for the emergence of greater market competition. The Commission's policy in this regard has been widely recognized. As the Broadband Opportunity Council explained "[l]owering barriers to

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[19] 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") ("*USF/ICC Transformation Order*") (subsequent history omitted).

[20] *Id.*

deployment and fostering market competition can drive down price, increase speeds, and improve service and adoption rates across all markets."[21] In fact, this policy was recently reaffirmed by the White House, which issued an Executive Order affirming that "[c]ompetitive markets also help advance national priorities, such as the delivery of affordable health care, energy independence, and improved access to fast and affordable broadband."[22]

The broadband services marketplace is not sufficiently competitive. As indicated in the Broadband Opportunity Council report, many local and regional markets today do not have the level of competition required to continue to ensure affordable access to the higher-speed broadband connections that Americans increasingly require.[23] In the market for Internet service that can deliver 25 Mbps downstream – the speed increasingly recognized as a baseline to get the full benefits of Internet access[24] – three out of four American homes either have no provider or do not have a choice between providers.[25]

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[21] *Broadband Opportunity Council Report* at 6.

[22] *See* Executive Order, *Steps to Increase Competition and Better Inform Consumers and Workers to Support Continued Growth of the American Economy* (April 15, 2016) (*available at* https://www.whitehouse.gov/the-press-office/2016/04/15/executive-order-steps-increase-competition-and-better-inform-consumers).

[23] *See Broadband Opportunity Council Report*.

[24] In 2015, the Commission defined "advanced telecommunications capability" to include broadband Internet access service offering 25 Mbps downstream and 3 Mbps upstream ("25/3 broadband")., 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. 14-126 (2015); Broadband Progress Report and Notice of Inquiry on Immediate Action to Accelerate Deployment, FCC 15-10, 30 FCC Rcd 1375, ¶ 26 (2015); The Commission based its conclusion, among other things, on its assessment of contemporary market offerings and consumer demand, as well as its determination that

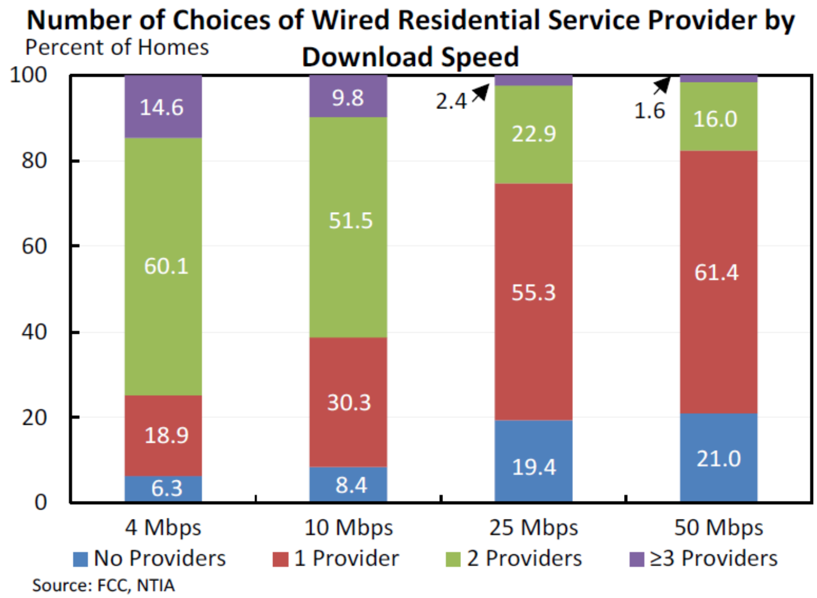

Figure III-24. Broadband Competition versus Broadband Speed

The lack of effective broadband competition is not simply academic. As indicated in the Figure below, it results in U.S. consumers paying significantly higher prices for broadband Internet access than users in other parts of the world.

25/3 broadband is required for households that increasingly run multiple high-quality voice, data, graphics, and video applications performing multiple functions on multiple devices simultaneously. *Id.*, ¶¶ 26 and 29. In light of these considerations, Chairman Wheeler called 25/3 broadband, "'table stakes' in 21st century communications." *Id.*, Statement of Chairman Tom Wheeler.

[25] Community-Based Broadband Solution: *The Benefits of Competition and Choice for Community Development and High-speed Internet access* at 12 (*available at* https://www.whitehouse.gov/sites/default/files/docs/community-based_broadband_report_by_executive_office_of_the_president.pdf) (Jan. 2015).

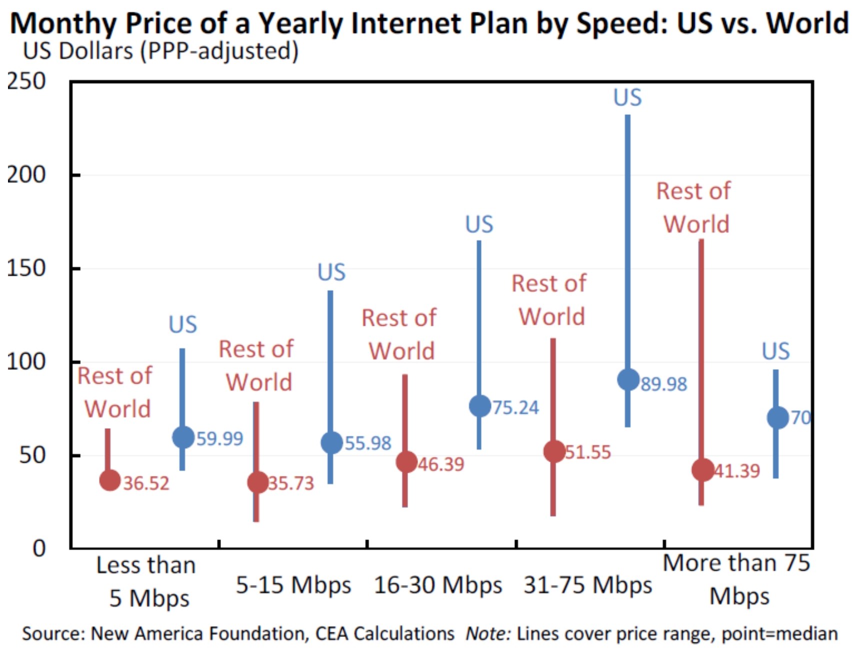

Figure III-25. U.S. versus World Broadband Costs

To address this problem, the proposed NGSO System would be able to offer very high levels of broadband capacity on a competitive basis to all Americans regardless of location through the use of advanced technologies and operational approaches to enhance spectrum efficiency and frequency re-use. These same technologies and approaches also enable the NGSO System to more effectively share spectrum.

C. Broadband Spectrum Sharing

In order to achieve ubiquitous coverage to global populations at high-speed data rates that meet (and exceed) the Commission's broadband goals, the proposed NGSO System would require access to a full 5 GHz of paired spectrum in the V-band both for uplink and downlink communications services. The public interest would be furthered by granting access to these spectrum resources because the NGSO System could share spectrum with existing and future spectrum users. Thus, the proposed use of the spectrum for the NGSO System would not preclude the use of this same spectrum by other important systems and services.

The critical importance of promoting shared uses of scarce spectrum resources has because a central focus of spectrum management policy. As the President's Council of Advisors on Science and Technology ("PCAST") observed in its 2012 Report to the President, spectrum sharing is an "essential element" of the Federal spectrum architecture and "[t]echnology innovations of recent years make this transformation eminently achievable."[26] These findings are equally true with respect to spectrum available for non-Federal services.

The specific techniques that are available to facilitate spectrum sharing in the V-band are discussed in detail in Part V of this Application. Through the use of these techniques the NGSO System could harness the enormous potential of the V-band to provide a new generation of very-high-data-rate services that would be available not just to urban populations, but to consumers in all regions of the United States and the world, including in the most remote and inaccessible locations.

As Chairman Wheeler recently observed, "[t]he pace of innovation is accelerating, and with new technological advances, satellites now have the opportunity to play a much more important role in bringing broadband to underserved and unserved areas around the world."[27] Grant of this Application could provide true nationwide and global broadband

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[26] President's Council of Advisors on Science and Technology ("PCAST"), Report to the President, "*Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth*" (July 2012) (*available at* https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf).

[27] *Chairman Wheeler Speech.*

connectivity that will help bridge the growing 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,
- Sections 25.114(c)(8) & 25.208(r) power flex density limits,
- Section 25.143(b)(2)(ii) international geographic coverage,
- Section 25.156(d)(4) treating feeder links as separate applications,
- Section 25.156(d)(5) NGSO versus GSO license grant,
- Section 25.157(e) band segmentation,
- Section 25.164(b) satellite construction milestones, and
- Section 25.210(i)(1) cross polarization isolation.

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

A. The Waiver Standard

The Commission's rules permit the FCC to grant waivers of its rules on a showing of "good cause."[28] The Commission's waiver authority is an administrative and judicial construct, rather than directly based on statute. Nevertheless, the Commission's authority to grant waivers has a very strong basis. The U. S. Supreme Court has indicated that the FCC not only has the legal right, but also an obligation to consider and grant waivers of

[28] 47 C.F.R. § 1.3 (1999).

its rules.[29] The Court indicated that the Commission's responsibility to consider waivers stems from its statutory obligation to serve the "public interest, convenience, or necessity."[30] The Court explained that

> [i]n each case that comes before it the Commission must still exercise an ultimate judgment whether the grant of a license would serve the "public interest, convenience, or necessity." If time and changing circumstances reveal that the "public interest" is not served by application of the Regulations, it must be assumed that the Commission will act in accordance with its statutory obligations.[31]

In applying this directive, the courts have created a "hard look" requirement, which encourages the Commission to consider the potential benefits of "new services" that can serve the public interest. The courts have explained

> 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.[32]

The judicial reference to applications for *new services* underscores the applicability of the Commission's waiver authority to this Application for the NGSO

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[29] National Broadcasting Co. v. U.S., 319 U.S. 190 (1943) (upholding the Commission's "chain broadcasting regulations," which prohibit exclusive arrangements between networks and radio stations, in part because the Commission may still grant waivers of the rules); *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).

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

[31] *Id.*

[32] 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).

System operating in the V-band. 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.[33] As noted previously, the 42.0-42.5 GHz and the 51.4-52.4 GHz bands are not identified in either Sections 2.106 or 25.202(a)(1) of the Commission's rules as allocated or available for FSS in the United States. In addition, although Section 2.106 of the rules does identify the 50.4-51.4 GHz band as allocated for FSS, the band is not identified in Section 25.202(a)(1) as available for FSS. In addition, footnote 3 of Section 25.202(a)(1) restricts the use of the 37.5-40.0 GHz band by FSS to gateway earth station operations. Good cause exists to waive each of these provisions.

37.5-40.0 GHz: With respect to the 37.5-40.0 GHz band, the Commission restricted the use of the band by FCC to gateway operations in order to "strengthen" its "soft segmentation" concept for the V-band and "motivate" satellite system operators to use V-band spectrum above 40.0 GHz rather than below 40.0 GHz, because the lower portion was being designated for high-density fixed services ("HD FS").[34] The

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[33] 47 C.F.R. §§ 2.106, 25.202(a)(1).

[34] Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation

justification for the soft segmentation concept was first adopted by the Commission in 1998 based on its conclusion that the co-frequency operation of ubiquitously-deployed terrestrial "wireless services" and satellite user terminals was not feasible in the V-band, including in the 37.5-40.0 GHz portion of the band.[35] Even in its 1998 decision, the Commission acknowledged that "there are technical sharing studies underway in international fora,"[36] but the Commission concluded that "sharing is not possible at this time without significant technical constraints on both satellite and terrestrial system operations."[37]

Now, nearly two decades later, advanced phased-array antennas, beam-forming and other technologies are facilitating significant new spectrum-sharing opportunities, both on an intra-service and inter-service basis. Recognizing the potential of such technological solutions, the Commission recently acknowledged that it is appropriate to

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of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations, IB Docket No. 97-95, *Third Notice of Proposed Rulemaking*, FCC 10-186, ¶ 31 (2010) (*citing* Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz, and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations, IB Docket No. 97-95, *Report and Order*, FCC 03-296, ¶ 29 (2003) ("*V-band Second Report and Order*").

[35] Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz, and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.0-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations, IB Docket No. 97-95, *Report and Order*, FCC 98-336, ¶ 18 (1998) ("*36-51 GHz Order*").

[36] *Id.* (citing work by then ITU-R Working Parties 4A and 4/9-S pursuant to WRC-97 Resolutions 129, 133, and 134).

[37] *Id.*

review its soft segmentation requirements "in light of evolving technology permitting new options for co-existence of terrestrial and FSS."[38] A further discussion of such newly available sharing solutions is included in Part V of this Application.

Based on these new spectrum-sharing capabilities, the Commission should promote competition in very high data rate mmW communications services by permitting ubiquitously-deployed satellite user terminals to operate on a downlink-only basis in the 37.5-40.0 GHz band with existing and new terrestrial services in that band. Boeing has filed extensive technical materials in the Commission's Spectrum Frontiers proceeding explaining why it is appropriate for the Commission to lift the restriction on satellite user terminals in the 37.5-40.0 GHz band and to adopt rules that promote sharing between terrestrial and satellite services in this spectrum.[39] Accordingly, Boeing requests a waiver of the restriction on satellite user terminals that exists in footnote 3 of Section 25.202(a)(1). Boeing would accept such waiver subject to the eventual outcome of the Commission's deliberations on this issue in the *Spectrum Frontiers* proceeding.

42.0-42.5 GHz: The 42.0-42.5 GHz band is allocated for FSS (space-to-Earth) in the ITU's International Table, but the band is not identified as available for FSS downlinks in either Sections 2.106 or 25.202(a)(1) of the Commission's rules. The Commission has repeatedly proposed to correct this non-alignment by allocating the

[38] Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, GN Docket No. 14-177, Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band, RM-11664, et al., *Notice of Proposed Rulemaking*, FCC 15-138, ¶ 126 (2015) ("*Spectrum Frontiers NPRM*").

[39] *See, e.g.,* Oral Ex Parte Notice of The Boeing Company, GN Docket 14-177, IB Docket Nos. 15-256 and 97-95, RM-11664; WT Docket No. 10-112, at 3 (Jun. 7, 2016) ("*37.5-40.0 GHz Sharing Ex Parte*").

42.0-42.5 GHz band for FSS.[40] Such an allocation would enable the satellite industry to make very efficient use of the spectrum, which is immediately adjacent to the Commission's principal V-band FSS downlink allocation at 40.0-42.0 GHz.

The Commission first proposed to allocate the 42.0-42.5 GHz band to FSS in 2010,[41] acknowledging that the international community, through WRC-03, adopted PFD limits applicable to FSS operations in the 42.0-42.5 GHz band in order to protect radio astronomy services in the adjacent 42.5-43.5 GHz band.[42] The Commission subsequently raised the idea again of allocating the 42.0-42.5 GHz band for FSS in its *Spectrum Frontiers* proceeding, requesting comment on the "relative merits" of allocating the band for FSS, and noting that alternative potential uses for the band, such as 5G mobile services or broadcast satellite services, may have significant difficulty protecting adjacent radio astronomy operations.[43]

Boeing and the Satellite Industry Association filed comments and reply comments expressing support for an FSS allocation in the 42.0-42.5 GHz band.[44] Only one 5G

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[40] *Spectrum Frontiers NPRM*, ¶ 76 (citing Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band et al, IB Docket No. 97-95, *Third Further Notice of Proposed Rulemaking*, FCC 10-186 ¶¶ 12-19 (Oct. 9, 2010) ("*V-Band Third FNPRM*").

[41] *V-Band Third NPRM*, ¶ 17.

[42] *See id.* (*citing* ITU-R Resolution 743). As explained in Section V.A.5.a of this Application, Boeing could employ the identified PFD limits, along with the beam-forming capabilities of the proposed NGSO System, to protect radio astronomy services in adjacent spectrum.

[43] *Spectrum Frontiers NPRM*, ¶¶ 79-80.

[44] Comments of the Boeing Company, GN Docket No. 14-177, at 9 (Jan. 28, 2016); Reply Comments of The Boeing Company, GN Docket No. 14-177, at 19 (Feb. 26, 2016);

proponent filed comments in response to the NPRM expressing any interest in the band.[45] The band was not part of the United States or CITEL proposals for bands to be considered for future mobile use,[46] and the WRC-15 did not include the band in Resolution 238, which identified the bands for studies on possible future use by IMT terrestrial services.[47] Based on the extensive record that was developed in the Commission's Spectrum Frontiers proceeding and in response to its 2010 *V-Band Third NPRM*, good cause exists to waive the FSS allocation restrictions of Sections 2.106 and 25.202(a)(1) in order to permit Boeing to operate the proposed NGSO System to use the 42.0-42.5 GHz band for space-to-Earth transmissions to support end users. Boeing would accept such waiver conditioned on the outcome of the Commission's *Spectrum Frontiers* and related rulemaking proceedings.

50.4-51.4 GHz: The 50.4-51.4 GHz band is allocated for FSS (Earth-to-space) in both the ITU's and the FCC's Table of Frequency Allocations as contained in Section 2.106 of the Commission's rules. The 50.4-51.4 GHz band, however, is not identified as available for FSS uplinks in Section 25.202(a)(1) of the Commission's rules. Good cause

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Reply Comments of the Satellite Industry Association, GN Docket No. 14-177, at 14 (Feb. 26, 2016).

[45] Comments of T-Mobile, GN Docket No. 14-177, at 8 (Jan. 27, 2016).

[46] *Spectrum Frontiers NPRM*, ¶ 79.

[47] Resolution 238 (WRC-15) Studies on frequency-related matters for International Mobile Telecommunications identification including possible additional allocations to the mobile services on a primary basis in portion(s) of the frequency range between 24.25 and 86 GHz for the future development of International Mobile Telecommunications for 2020 and beyond at (d)(2) (available at https://www.itu.int/dms_pub/itu-r/oth/0a/06/R0A0600006C0001PDFE.pdf) (omitting 42.0-42.5 GHz from the bands proposed for studies for future IMT).

exists to waive Section 25.202(a)(1) to permit Boeing to operate a portion of the NGSO System uplinks in the 50.4-51.4 GHz band.

Pursuant to ITU Resolution 159 (WRC-15), the ITU-R is currently studying the development of regulatory provisions to enhance the ability of NGSO FSS systems to operate in V-band spectrum, including the 50.4-51.4 GHz portion of the V-band.[48] Resolution 159 was adopted by WRC-15 based on a proposal and the leadership of the U.S. Administration and acknowledges the need for the implementation of new FSS technologies in higher spectrum bands. Resolution 159 observes that NGSO FSS systems are capable of providing "high-capacity and low-cost means of communication even to the most isolated regions of the world."[49]

Resolution 159 identifies a need for studies to ensure that NGSO FSS systems can protect passive Earth Exploration Satellite Services ("EESS") in the adjacent 50.2-50.4 GHz band and radio astronomy services in the adjacent 51.4-54.25 GHz band. The Resolution also identifies a need for studies on spectrum sharing between NGSO and GSO FSS systems throughout the V-band.

As Boeing explains in Part V of this Application, the NGSO System could protect EESS and radio astronomy operations in adjacent spectrum bands. The NGSO System could also operate in the V-band on a shared basis with other co-frequency GSO and NGSO systems. Therefore, good cause exists to waive Section 25.202(a)(1) to permit the

[48] Resolution 159 (WRC-15), Studies of technical, operational issues and regulatory provisions for non-geostationary fixed-satellite services satellite systems in the frequency bands 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space) (available at http://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A00000C0006PDFE.pdf).

[49] *Id.*

NGSO System uplinks in the 50.4-51.4 GHz band. Boeing has on this date filed a petition for rulemaking seeking the initiation of a Commission proceeding to establish an allocation for FSS uplinks in the 50.4-51.4 GHz band. Boeing would accept a waiver conditioned on the outcome of Boeing's requested rulemaking proceeding and on the Commission's implementation of the outcome of the ITU-R study process for Resolution 159 and its implementation by WRC-19.

51.4-52.4 GHz: Sections 2.106 and 25.202(a)(1) of the Commission's rules do not allocate or authorize FSS Earth-to-space operations in the 51.4-52.4 GHz band. Such an allocation is also lacking in the International Table, but a new FSS allocation is under study for action by WRC-19. The 51.4-52.4 GHz band includes an allocation for the Fixed and Mobile services, both in the U.S. and the International Tables. There are no non-Federal uses of the band and the only reported Federal users are NASA and the military agencies, which have previously reported using the 50.0-55.0 GHz band for radar research and development.[50]

Given the near fallow nature of the 51.4-52.4 GHz band, it is a perfect candidate for FSS Earth-to-space links. The band is conveniently situated adjacent to the existing 50.4-51.4 GHz FSS uplink band and aggregation of the 51.4-52.4 GHz band with the 50.4-51.4 GHz and the 47.2-50.2 GHz band would create 5 GHz of available FSS uplink spectrum[51] to match the 5 GHz of FSS downlink spectrum potentially available in the 37.5-42.5 GHz band.

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[50] *Federal Spectrum Use Summary 2010* at 78.

[51] As a result, the 51.4-52.4 GHz band is far superior for an FSS uplink allocation as compared to the 42.5-43.5 GHz band allocated internationally (but not in the United States) for FSS uplinks.

The ITU-R study process, pursuant to Resolution 162 (WRC-15), is currently considering whether to add a co-primary allocation for FSS uplinks in the 51.4-52.4 GHz band at WRC-19.[52] Although these studies are focused in part on creating an FSS allocation to support feeder links for GSO satellites, *resolves 1* of Resolution 162 calls for studies on "the additional spectrum needs for development of the fixed-satellite service, taking into account the frequency bands currently allocated to the fixed-satellite service, the technical conditions of their use, and the possibility of optimizing the use of these frequency bands with a view to increasing spectrum efficiency."[53] Any such comprehensive review of the additional spectrum needs for FSS necessarily must include consideration of the spectrum needs for FSS systems operating with NGSO constellations.

Boeing has on this date filed a petition for rulemaking seeking the initiation of a Commission proceeding to establish an allocation for FSS uplinks in the 51.4-52.4 GHz band. Concurrently, Boeing requests a waiver of Sections 2.106 and 25.202(a)(1) of the Commission's rules in order to permit the use of the 51.4-52.4 GHz band for Earth-to-space links. As with the other frequency bands identified above, Boeing would accept such a waiver conditioned on the outcome of Boeing's requested rulemaking proceeding on creating an Earth-to-space FSS allocation in the 51.4-52.4 GHz band.

C. Waiver of §§ 25.114(c)(8) and 25.208(r)

Section 25.114(c)(8) of the Commission's rules requires applicants for space station licenses to calculate and provide the maximum PFD levels within each coverage

[52] *See* Resolution 162, Studies relating to spectrum needs and possible allocation of the frequency band 51.4-52.4 GHz to the fixed-satellite service (Earth-to-space) (WRC-15).

[53] *Id.*

area and energy dispersal bandwidths, if any, needed for compliance with Section 25.208 of the Commission's rules.[54] Section 25.208(r) of the Commission's rules includes PFD limits applicable to NGSO satellites operating in the 37.5-40.0 GHz band in clear sky conditions.[55] These limits are 12 dB more stringent than the PFD limits that exist in the ITU Radio Regulations for NGSO satellites.[56] The PFD limits are also 12 dB more stringent than those that were adopted by the FCC for satellite operations in the adjacent 40.0-42.0 GHz band.[57]

The Commission adopted the more stringent limits back in 2003 with the express intent "to motivate" satellite operators to use the 40.0-42.0 GHz band rather than the 37.5-40.0 GHz band, and to provide "significant protection" to terrestrial operations in the 37.5-40.0 GHz band.[58] The Commission, however, recently recognized that it is

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[54] 47 C.F.R. § 25.114(c)(8) (referring to 47 C.F.R. § 25.208).

[55] *See* 47 C.F.R. § 25.208(r) (specifying a PFD limit of −117 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane).

[56] See ITU Radio Regulations, Article 21, Table 21-4 (specifying a PFD limit of -105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane). Boeing acknowledges that footnote 21.16.4 of Article 21 (Table 21-4) indicates that the PFD limits specified apply to NGSO systems with 99 or fewer satellites and that further study may be needed with respect to the application of the limits to systems with 100 or more satellites. Footnote 21.16.4 was adopted by WRC-2000 and has not been modified since. To the extent that further study is deemed necessary regarding the application of the ITU limits to larger NGSO systems, Boeing will actively participate in such studies.

[57] *See* 47 C.F.R. § 25.208(s) and (t) (specifying a PFD limit of −105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane).

[58] Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands; Implementation of Section 309(j) of the Communications Act – Competitive Bidding, 37.0-38.6 GHz and 38.6-40.0 GHz Bands, ET Docket No. 95-183 and PP Docket No. 93-253, *Third Notice of Proposed Rulemaking*, 19 FCC Rcd 8232, 8242 ¶ 31 (2004) ("*37/42 GHz Third NPRM*") (*citing* Allocation and Designation of Spectrum for

appropriate to review this plan "in light of evolving technology permitting new options for co-existence of terrestrial and FSS."[59] Incumbent terrestrial fixed service systems and future 5G systems can successfully operate in the 37.5-40.0 GHz band. As detailed further in Section V.A of this Application, NGSO FSS downlink operations at the ITU PFD level would introduce less than 0.6 dB *worst-case* interference into terrestrial UMFU or fixed microwave services in this band and would typically introduce much lower-level, transient effects (ranging from less than 0.1 dB to 0.3 dB). All of these impacts are negligible and could be easily overcome by terrestrial systems through the modest use of power control or adaptive coding and modulation, all of which are typically employed in modern cellular and point-to-point microwave systems.

The Communications Act mandates the Commission to manage spectrum resources in order to further the public interest. One of the central tenants of this mandate is that spectrum bands should be shared by multiple services whenever such sharing is possible. Co-primary spectrum sharing of the 37.5-40.0 GHz band is particularly warranted given the fact that incumbent FS are very lightly deployed in the band and have shown no indication of significantly increasing their deployment. Further, although the Commission is considering designating the band as available for terrestrial mobile services in a newly created UMFU service, UMFU proponents have

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Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz, and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations, *Report and Order*, IB Docket No. 97-95, FCC 03-296, ¶ 29 (2003) ("*V-band Second Report and Order*").

[59] *Id.*, ¶ 126.

explained that future UMFU services are unlikely to provide services to consumers outside of dense urban areas. To quote a recent CTIA filing,

> the primary opportunity for mmW deployment is in areas with the greatest population density. This is due to the fact that mmW spectrum is unlikely to deliver extensive coverage in a market but instead will be best suited to providing capacity via small cells and backhaul, particularly in densely populated areas.[60]

Given industry acknowledgment that UMFU services may never exist outside the most densely populated urban areas, it would be exceedingly inefficient to designate the 37.5-40.0 GHz band solely for UMFU without concurrently facilitating spectrum sharing throughout the United States, including urban areas, with co-primary satellite communications services. The Commission can begin to achieve this objective through the grant of Boeing's request for waiver of Sections 25.114(c)(8) and 25.208(r) of the Commission's rules to authorize the NGSO System to operate on a shared co-primary basis in the 37.5-40.0 GHz band at the PFD levels specified by the ITU for satellite space-to-Earth communications without causing harmful interference to incumbent fixed or future UMFU services. Boeing has also requested that the Commission permit NGSO FSS downlink operations at the ITU PFD limits in the context of the Commission's *Spectrum Frontiers* proceeding. Boeing would therefore accept such a waiver conditioned on the outcome of the Commission's *Spectrum Frontiers* proceeding.

[60] Letter from Scott K. Bergmann, Vice President, Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 14-177, et al. (May 20, 2016).

D. Waiver of § 25.143(b)(2)(ii)

Out of an abundance of caution, Boeing requests a waiver of Section 25.143(b)(2)(ii), which specifies the default international geographic coverage requirements for NGSO FSS systems. As noted in a previous section of this Application, the NGSO System would comply with the strict language of the international geographic coverage rule in that the NGSO FSS system would include in its Initial Deployment at least one satellite that would be visible above the horizon at an elevation angle of at least 5 degrees for at least 18 hours each day to all locations as far north as 70 degree North latitude and as far south as 55 degree South latitude.[61] Nevertheless, the level of service that would be available at high latitudes would require the use of larger user terminals and would offer slower data rates.

The Commission granted a similar waiver to O3b Limited ("O3b") permitting its Ka-band NGSO FSS system to access the U.S. market.[62] 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."[63] Thus, the Commission

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[61] *See* 47 C.F.R. § 25.114(b)(2)(ii).

[62] 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).

[63] *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).

balanced the NGSO satellite operator's constellation design decision with the policy desire to maximize U.S. 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. NGSO FSS systems using phased-array antennas and narrow beam-forming, such as the NGSO System, are very capable of sharing orbital and spectrum resources with other satellite and terrestrial systems and, therefore, do not preclude the use of such resources by other service providers. Further, although the level of service that will be provided by the NGSO System along the 70 degree north latitude may not be optimal, the populations in such regions are exceedingly few and often transient. Therefore, good cause exists to grant such a waiver.

E. 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.[64] 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 the same spectrum 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

[64] 47 C.F.R. § 25.156(d)(4).

all (or nearly all) of its authorized spectrum for feeder links operating in separate beams to 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.

F. Waiver of § 25.156(d)(5)

Out of an abundance of caution, Boeing seeks a waiver of Section 25.156(d)(5) of the Commission's rules. The rule states that:

> In cases where the Commission has not adopted frequency-band specific service rules, the Commission will not consider NGSO-like applications after it has granted a GSO-like application, and it will not consider GSO-like applications after it has granted an NGSO-like application, unless and until the Commission establishes NGSO/GSO sharing criteria for that frequency band.

The Commission does not appear to have adopted frequency-band specific services rules or NGSO/GSO sharing criteria for the V-band. Therefore, the above provision may be applicable to this Application.

The Commission has granted two satellite system licenses covering portions of the V-band. The first license, which was granted to Northrop Grumman Space & Mission Systems Corporation ("Northrop Grumman"), was for a hybrid NGSO/GSO system operating in the 37.5-42.0 GHz and the 47.2-50.2 GHz bands.[65] Northrop Grumman, however, never built the satellite system and surrendered the license on March 26, 2009. The second license, which was granted to Hughes Network Systems, LLC, was for a GSO satellite that included a payload for the 39.0-42.0 GHz and the 47.2-50.2 GHz band portions of the V-band.[66] This satellite was also never launched and Hughes surrendered the authorization on August 1, 2014.

Although Section 25.156(d)(5) of the Commission's rules does not so state, it would be appropriate to assume that the above-quoted provision of the rule does not apply to satellite systems that were licensed but never built. Further, the Northrop Grumman license (which was the first one issued by the Commission) was for a hybrid NGSO/GSO system and therefore did not give presumptively priority to either type of constellation. Nevertheless, out of an abundance of caution, Boeing requests a waiver of the above-quoted requirements of Section 25.156(d)(5). Such a waiver is appropriate given the fact that no commercial satellite systems are currently operating in the V-band and therefore no incumbent satellite systems could be harmed by the grant of such a waiver.

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[65] Application of Northrop Grumman Space & Mission Systems Corporation for Authority to Operate a Global Satellite System Employing Geostationary Satellite Orbit and Non-Geostationary Satellite Orbit Satellites in the Fixed-Satellite Service in the Ka-band and V-band, File Nos. SAT-LOA-19970904-00082 et al., *Order and Authorization*, DA 09-428 (Feb. 23, 2009) ("*Northrop Grumman Order*")

[66] Application of Hughes Network Systems, LLC, for Authority to Construct, Launch and Operate a Ka-band and V-band Geostationary Orbit Space Station, Jupiter 77W, and the 77.3º W.L. Orbital Location, File Nos. SAT-LOA-20111223-00248 (Aug. 3, 2012).

G. Wavier of § 25.157(e)

Section 25.157(e) of the Commission's rules includes three concepts regarding the processing of NGSO FSS satellite applications, each of which pre-date recently developed capabilities in co-frequency spectrum sharing between multiple NGSO FSS satellite systems. The first concept, addressed in Section 25.157(e)(1), establishes as a default spectrum management procedure 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.

The second concept, addressed in Section 25.157(e)(2), establishes that, if a processing round results in the grant of licenses to only one or two NGSO FSS systems, each licensee will be assigned only one third of the available spectrum, leaving the remaining spectrum potentially fallow for later entrants. The third concept, addressed in Section 25.157(e)(3), establishes that, if a processing round results in the grant of more than three licenses for NGSO FSS systems, each licensee will be assigned the lesser of either the amount of spectrum that it requested, or the amount of spectrum that would have been assigned to each licensee if the available spectrum were divided equally among the licensees.

Boeing requests a waiver of each of these three concepts because a licensing process that divides the V-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 (*i.e.*, 25/3 Mbps and above) 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.

Boeing also requests a waiver of each portion of Section 25.157(e) because modern NGSO FSS systems can employ spectrum-sharing techniques, such as those described in Part V of this Application, to enable co-frequency spectrum-sharing with other NGSO FSS systems and thereby avoid the need for highly 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.[67] 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.[68] 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

[67] *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*").

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

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

The grant of a waiver to Boeing is particularly appropriate with respect to Section 25.157(e)(2) of the Commission's rules, which would effectively leave fallow either one- or two-thirds of the V-band solely to ensure that it remains available for future NGSO FSS system applicants. A more forward-thinking policy would be to permit each NGSO FSS licensee to use the entire V-band on a shared basis with existing and future NGSO FSS systems. Such an approach would ensure that spectrum is used in a highly-efficient and intensive manner, both in the near-term and as future systems are developed. Importantly, such an approach would not preclude future entry by additional NGSO FSS systems. In fact, by ensuring long-term access to the entire V-band for future NGSO FSS systems, the Commission would enhance the business case for the operation of such systems and thereby help facilitate future options for consumers. Given these facts, good cause exists to grant a waiver to Boeing of each of the three provisions of Section 25.157(e) of the Commission's rules.

H. Waiver of § 25.164(b)

Section 25.164(b)(5) of the Commission's current rules requires licensees of NGSO systems to "[b]ring all the satellites in the licensed satellite system into operation" within six years of license grant.[69] To the extent that Section 25.164(b)(5) of the current rules (as opposed to the recently adopted rules) is applied to Boeing's system, which seems unlikely, Boeing herein requests a waiver of the rule in order to permit Boeing to satisfy the current rule using the Initial Deployment of the NGSO System and retain the flexibility to undertake phased implementation of the Final Deployment of the system as market demand requires. The justifications for the grant of such a wavier is provided above in the discussion related to Section 25.164(b) of this Application.

I. Waiver of § 25.210(i)(1)

Section 25.210(i)(1) includes cross-polarization isolation requirements that were made applicable only to space stations in the 17/24 GHz Broadcast Satellite Service pursuant to the Commission's Second Report and Order in the Part 25 proceeding.[70] The Commission eliminated the requirements for FSS systems because they were intended to protect analog video transmissions and such transmissions "are routinely coordinated

[69] 47 C.F.R. 25.164(b)(5).

[70] *See Part 25 Second Report and Order*, ¶ 264.

between operators and have become infrequent."[71] The Commission's revisions to Section 25.210(i)(1), however, have not yet taken effect as of the date of this application. Therefore, out of an abundance of caution, Boeing herein requests a waiver of Section 25.210(i)(1) as the rule exists today. Good cause exists to grant such a waiver given the diminishing use of analog transmissions, particularly on NGSO FSS systems.

V. SPECTRUM-SHARING CAPABILITIES

The NGSO System is designed to operate without causing harmful interference to other users of the V-band. This section describes the interference-mitigation techniques that would be employed by the NGSO System and the interference analysis that demonstrates the NGSO System could operate on a shared basis with other co-primary users of the spectrum.

A. Space-to-Earth Communications

1. Existing and Proposed Use of the 37.5–38.6 GHz Band

The 37.5-38.6 GHz ("37 GHz") band is allocated to the Fixed, FSS, and Mobile services on a co-primary basis. Pursuant to the "soft segmentation" band plan adopted by the Commission in 2003, FSS is subject to more stringent space-to-Earth PFD limits in the 37.5-40.0 GHz band to accommodate high-density fixed terrestrial systems.[72] This said, the Commission's records indicate that there are currently no incumbent non-Federal terrestrial authorizations in the 37 GHz band. Further, the Commission recently

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[71] *See* Comprehensive Review of Licensing and Operating Rules for Satellite Services, *Further Notice of Proposed Rulemaking*, FCC 14-142, ¶ 181 (Sept. 30, 2014).

[72] *Spectrum Frontiers NPRM*, ¶ 38.

acknowledged that it is appropriate to review the soft segmentation decision in light of evolving technology, which permits new options for co-existence of terrestrial and FSS.[73] The Commission made this observation in the context of its *Spectrum Frontiers NPRM*, in which the Commission proposed to authorize mobile terrestrial wireless operation pursuant to its UMFU service across the 37.5-40.0 GHz band.[74]

NTIA reports that the lower portion of the 37 GHz band (from 37.0-38.0 GHz) is used by the military for fixed microwave point-to-point communications systems at military test ranges and for transportable communications systems.[75] In addition, NASA has proposed to use the 37.0-38.0 GHz band for exploration of the solar system and for the wideband data return links to the very long baseline interferometer. There is no indication that NASA has yet commenced such operations. NASA has previously used this band to conducting research into sensor and navigational systems. The National Science Foundation ("NSF") uses this band for radio astronomy research.

a) Sharing with Proposed Upper Microwave Flexible Use Services

As described in sections III.B and III.C, Boeing seeks a waiver of the current 25.202(a)(1) restriction on earth stations operating in the 37.5-40.5 GHz band based on the proposal of this Application to operate user earth stations without seeking

[73] *Id.*, ¶ 125.

[74] *See id.*, ¶ 42.

[75] 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*").

coordination with existing and proposed future UMFU services operating in the spectrum. The NGSO System provides significant features that would enable sharing of the 37.5-40.5 GHz band with potential UMFU services.

The UMFU systems and services proposed for study and deployment in the 37.5-40.0 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 UMFU 5G systems would operate bi-directionally, utilizing the 37.5-40.0 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. Figure V-1 illustrates the spectrum-sharing scenarios for proposed UMFU usage and NGSO FSS shared usage of the 37.5-40.0 GHz band.

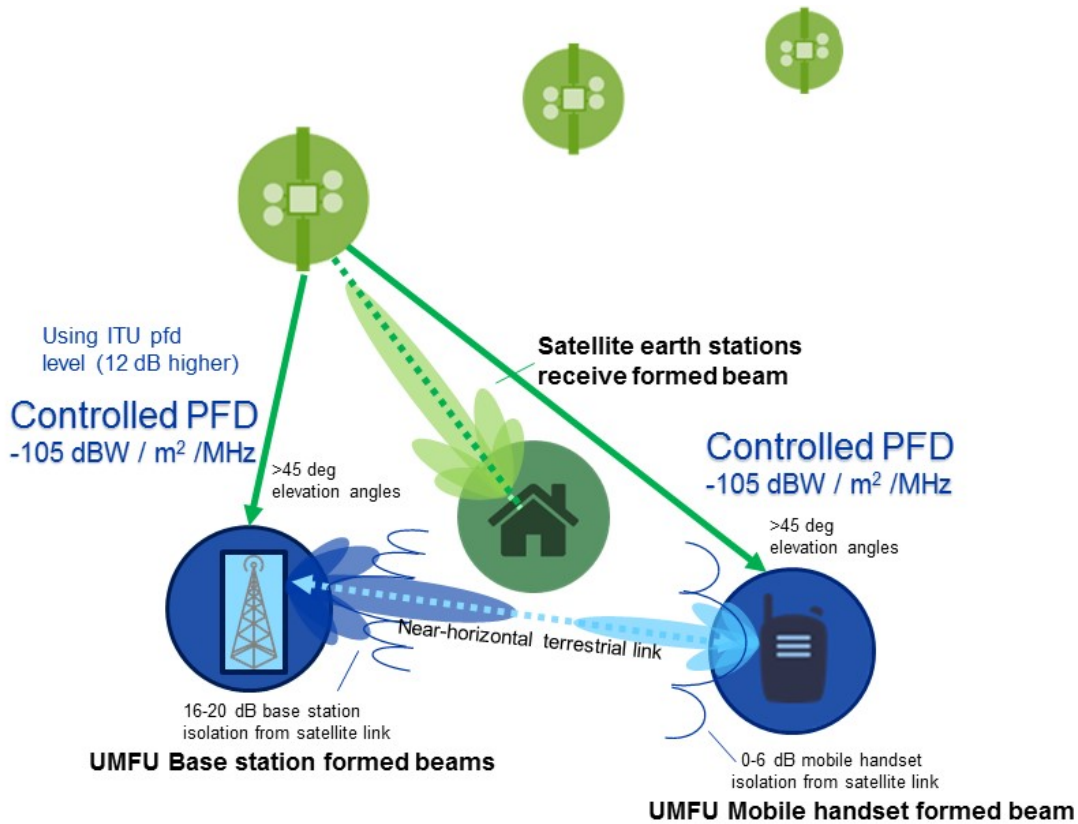

Figure V-1 - NGSO FSS and Terrestrial UMFU 5G Sharing Scenarios

For FSS systems, the 37.5-40.5 GHz band is a designated space-to-earth downlink band, and is governed by operations within the PFD limits as described in ITU Radio Regulations Article 21 and the more restrictive limits in the United States contained in Section 25.208(r). Hence, the most relevant cases to examine for spectrum sharing in the 37.5-40.0 GHz band are the impacts of satellite downlink emissions into the 5G system base station receivers (return links) and satellite downlink emissions into the mobile handset receivers (forward link). Boeing has performed detailed parametric analyses of interference into 5G system operations for each of these cases, with the results shown in Table V-1 and Table V-2.

5G Return Link - Mobile to Base Station	Sat PFD	Worst-case	Worst-case	Typical	Typical
	5G Isolation	Worst-case	Typical	Worst-case	Typical
PARAMETER	UNITS	VALUE	VALUE	VALUE	VALUE
Satellite PFD at Base Station	$dBW/m^2/MHz$	-105.0	-105.0	-111.0	-111.0
Antenna Rx Gain at 5G Base Station [1]	dBi	27.0	27.0	27.0	27.0
5G Base Station Rx Isolation to Sat signal [1]	dB	16.0	20.0	16.0	20.0
Satellite Received Power density after base station antenna gain	dBW/MHz	-147.3	-151.3	-153.3	-157.3
5G Base Station Noise Figure	dB	5.0	5.0	5.0	5.0
5G Receiver Noise Density	dBW/MHz	-139.0	-139.0	-139.0	-139.0
Interference to Noise ratio, I_{SAT}/N_{5G}	dB	-8.3	-12.3	-14.3	-18.3
	%	14.8	5.9	3.7	1.5
Interference Degradation	dB	**0.60**	**0.25**	**0.16**	**0.06**

Table V-1 - NGSO FSS interference into UMFU 5G - Return Link examples

5G Forward Link - Base Station to Mobile	Sat PFD	Worst-case	Worst-case	Typical	Typical
	5G Isolation	Worst-case	Typical	Worst-case	Typical
PARAMETER	UNITS	VALUE	VALUE	VALUE	VALUE
Satellite PFD at Base Station	$dBW/m^2/MHz$	-105.0	-105.0	-111.0	-111.0
Antenna Rx Gain at 5G Mobile/Handset [1]	dBi	13.0	13.0	13.0	13.0
5G Mobile Rx Isolation to Sat signal [1]	dB	0.0	6.0	0.0	6.0
Satellite Received Power density after mobile/hanset antenna gain	dBW/MHz	-145.3	-151.3	-151.3	-157.3
5G Mobile/Hanset Noise Figure	dB	7.0	7.0	7.0	7.0
5G Mobile Receiver Noise Density	dBW/MHz	-137.0	-137.0	-137.0	-137.0
Interference to Noise ratio, I_{SAT}/N_{5G}	dB	-8.3	-14.3	-14.3	-20.3
	%	14.8	3.7	3.7	0.9
Interference Degradation	dB	**0.60**	**0.16**	**0.16**	**0.04**

Table V-2 - NGSO FSS interference into UMFU 5G - Forward Link examples

The results indicate that terrestrial 5G UMFU services and NGSO FSS systems that observe the more flexible ITU PFD limit can operate on a co-primary basis with less than 0.6 dB worst-case degradation (and typically less than 0.2 dB degradation) into the planned UMFU 5G links. This desirable band-sharing performance is achieved under the following highly-conservative operating conditions:

i) *The satellite downlink transmissions are operating at the maximum ITU PFD limit*. Pursuant to Section III.C above, Boeing seeks authority for the NGSO System to operate up to the ITU PFD limit of -105 $dBW/m^2/MHz$.

The worst-case interference results shown in Table V-1 are calculated under these conditions. Although this is the worst-case interference scenario, it is not the typical scenario. The NGSO System operation at the ITU PFD limit would only occur during periods of high rain attenuation, typically less than 5 percent of the time. During remaining periods, normal downlink operations are 6 to 10 dB lower than this maximum ITU PFD limit of -105 dBW/m^2/MHz. The interference results reported in Table V-1 for typical conditions correspond to a 6 dB lower level of PFD operations and can be expected to occur during the large majority (greater than 90 percent) of the time in all areas. In addition, Tables V-1 and V-2 show the range of degradation for NGSO operations at levels below the ITU PFD limit of -105 dBW/m^2/MHz, illustrating the typical degradations of less than 0.1 to 0.2 dB for all 5G link cases.

ii) *The satellite downlinks to user terminals operate at a minimum elevation angle of 45 degrees*. The NGSO System would operate at a minimum elevation angle of 45 degrees only for a small portion of the time, and typically would operate at elevation angles in excess of 50 degrees.

iii) *Terrestrial 5G UMFU mobile handsets provide limited to* <u>*no*</u> *isolation from receive satellite downlink signals.* In proposed terrestrial 5G UMFU systems, the mobile handset terminal must perform a modest amount of beam-forming to direct a beam towards the base station. Typical mobile handset users would experience 6 to 10 dB or greater isolation from satellite downlink signals arriving at an elevation angle of 45 degrees or above. Nevertheless, Boeing's analysis conservatively assumes no resulting isolation.

iv) *Terrestrial UMFU system base stations provide a limited isolation of 16 dB for satellite downlinks* that, as described in ii), arrive at the base station at or above an elevation angle of 45 degrees. UMFU base stations can be anticipated to typically provide isolation of 20 dB or more for near-horizontal 5G link operation, leading to less than 0.2 dB degradations for UMFU return links.

These technical analyses of band-sharing and the minimal interference resulting from shared operations provide a sound technical rationale for the Commission to grant Boeing's waiver requests in Sections III.B and III.C regarding the removal of restrictions on user earth station receivers in the 37.5-40.0 GHz band, and a waiver of Section 25.208(r) to allow operation at the ITU Article 21 PFD limit. Removal of these restrictions and the grant of these requests would allow efficient use of the complete allocated V-band FSS spectrum allocation and enable the widespread availability of broadband services by the NGSO System on a co-primary basis with terrestrial UMFU services.

b) Sharing with Federal Fixed Systems

NTIA records indicate that the 37.0-38.0 GHz band is used by the military for fixed microwave point-to-point communications systems at military test ranges and for transportable communications systems.[76] With regard to NGSO FSS satellite operations,

[76] *See id.*.

Section 8.2.36 of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management ("NTIA Manual") allows FSS operations at PFD levels similar to those authorized by ITU Article 21, in particular, up to -105 dBW/m^2/MHz at angles of 25 degree or above.[77] NTIA therefore apparently anticipates Federal FS systems designed for operations within the 37.0-38.0 GHz band will be designed to withstand incident NGSO FSS satellite signals operating up to the ITU PFD limit. The NGSO System would operate within the ITU and NTIA required PFD limits, ensuring protection of all Federal FS users consistent with the assumptions and guidelines in the NTIA Manual. Nevertheless, Boeing has been communicating with NTIA to provide updated information on Federal FS band usage and will coordinate with Federal FS users as needed on a case-by-case basis.

c) Sharing with Federal Space Systems

Federal Space Systems may use the 37.0-38.0 GHz band in support of various space-based missions. Recently, NASA proposed to use the 37.0-38.0 GHz band for exploration of the solar system and for the wideband data return links to the very long baseline interferometer. NASA has previously used this band to conducting research into sensor and navigational systems. Boeing has met with NTIA to determine specific plans for band usage by Federal Space Systems, including the types of usage, locations and characteristics of potential earth stations operating in the downlink band.

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[77] *See* Manual of Regulations and Procedures for Federal Radio Frequency Management, U.S. Department of Commerce, National Telecommunications and Information Administration, Section 8.2.36 (May 2014 Revision of the May 2013 Edition) ("*NTIA Manual*").

The NGSO System would provide substantial means to facilitate spectrum sharing and coordination with authorized Federal FSS or MSS space systems, operating in either NGSO or GSO configurations. In particular, the NGSO System would include the following mechanisms and techniques for interference mitigation:

i) *Operation at elevation angles greater than 45 degrees.* The NGSO System constellation is designed to provide service at minimum operational elevation angles of 45 degrees for all earth stations within the range between 60 degrees North and South latitude.

ii) *Highly-directional earth station beams.* The NGSO System earth stations would operate in the V-band with aperture sizes that enable narrow, highly-directional beams on the order of 1.5 to 3 degrees in beamwidth. The earth station beams would be steered to track the NGSO satellite at elevation angles of at least 45 degrees as described in i). Therefore, the NGSO System earth stations would provide significant off-axis isolation to other GSO or NGSO satellites. NGSO earth station antenna gain attenuation of at least 45 dB applies for off-axis angles of 10 beamwidths (15 degrees) or more from the earth station-to-satellite LOS. Narrow beamwidths with strong sidelobe performance ensure that interference events with other satellite systems could only occur in cases when coincident (or near) LOS is present for both systems.

iii) *Ability to select from multiple visible satellites for service.* The NGSO System constellation would include multiple NGSO satellites in the field of view. Selection of specific satellites for handovers may be utilized to avoid potential mainbeam-to-mainbeam interference events with GSO and other NGSO earth-station operations.

iv) *Narrow satellite spot beams and flexible frequency plan operation.* The NGSO System would operate with satellite spot beams corresponding to 8 to 20 kilometer cells in diameter on the Earth. The system can assign frequency and polarization operations to 1 GHz resolution or less within each cell, providing variable frequency plan usage across any portion of the satellite coverage footprint. If necessary, frequency operations could be restricted in Earth-fixed regions of the footprint(s) to provide additional isolation for GSO or other NGSO operations.

With these sharing mechanisms, Boeing is confident that the NGSO System can be coordinated with GSO networks or any subsequently filed NGSO systems by utilizing processes similar to those described in Section 25.261 of the Commission's rules and the measures being studied within the ITU-R under WRC-19 Agenda Item 1.6.

Additionally, Boeing initiated the technical studies being performed in the ITU-R to develop EPFD limits pursuant to Resolution 159 (WRC-15) that would facilitate spectrum sharing between GSO satellite systems and NGSO satellite systems in this frequency segment. The EPFD limits would be documented in Article 22 of the ITU Radio Regulations and would identify the required levels to protect GSO satellite networks. These EPFD limits will be developed through a consensus-based process involving both GSO and NGSO system proponents and should therefore ensure an equitable spectrum sharing arrangement between these two categories of systems.

d) Sharing with Radio Astronomy Research

The National Science Foundation ("NSF") uses numerous mmW bands, potentially including the 37.0-38.0 GHz band, for radio astronomy research. Boeing acknowledges the general radio astronomy protections contained in Footnote 5.551H to the International Table, which encourages NGSO FSS space stations in the 42.0-42.5 GHz band to limit emissions to specific EPFD limits applicable to the adjacent radio astronomy band 42.5-43.5 GHz.[78] The NGSO System would comply with the provisions of Footnote 5.551H, and in particular would follow the coordination process described in Resolution 743-2. This Resolution provides a path to complete coordination with specific radio astronomy sites around the world. Currently, Boeing has identified approximately 37 candidate radio telescope sites in the United States, and an additional 88 candidate radio telescope sites located in 35 countries around the world. Boeing has also contacted NTIA for additional assistance in identifying Federal radio astronomy sites within the United States and their potential receive operating bands. For radio astronomy sites that confirm observation capabilities in the 37.5-42.5 GHz band, Boeing fully intends to complete the coordination process to protect observation capabilities at these locations and facilities.

2. Existing and Proposed Use in the 38.6-39.5 GHz Band

The 38.6-39.5 GHz ("39 GHz") band is a non-Federal band allocated to the Fixed, FSS, and Mobile services on a co-primary basis. The primary use of the band is by point-to-point microwave links authorized nationwide in the common-carrier fixed microwave

[78] 47 C.F.R. § 2.106 n. 5.551H.

service and the auctioned 39 GHz service.[79] In the 39 GHz service, out of a possible 2,464 Economic Area licenses, 859 were licensed as of 2015.[80] It is unclear whether these licensees have built out their systems extensively. In addition, there are an additional 229 legacy Rectangular Service Areas ("RSAs"). There are no non-Federal satellite licenses in the band.

There is no Federal allocation in the 39 GHz band. NTIA reports, however, that the U.S. Army has used and may currently use this band for fixed and mobile radio systems.[81] The Commission also notes that there are Federal satellite operations in this band.[82]

a) Sharing with High-Density Fixed Systems

As described in Section V.A.1.a, the NGSO System would provide significant features which enable sharing of the 37.5-40.5 GHz spectrum with terrestrial bi-directional services. The spectrum sharing scenarios discussed for UMFU operation apply equally to terrestrial FS operations, with the following additions and modifications:

1) FS point-to-point links operate over longer distances than proposed UMFU systems, with a correspondingly higher EIRP to enable link performance.

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[79] ULS reports 1777 individual licenses, consisting primarily of 242 licenses in the Common Carrier Fixed Point to Point Microwave (CF) service, and 1515 licenses in the 39 GHz service. (Last accessed May 11, 2016).

[80] *Spectrum Frontiers NPRM*, ¶ 35.

[81] *Federal Spectrum Use Summary 2010* at 75.

[82] *Spectrum Frontiers NPRM*, ¶ 44.

2) Both FS transmitter and receiver utilize highly-directional antennas, on the order of 0.2 to 0.3 meter (8 to 12-inches). Both ends of the FS links are similar to the UMFU base station but with even higher gain and directivity along the near-horizontal link. As a consequence, terrestrial FS transmitters will typically provide higher receive isolation to the satellite downlink transmissions operating at an elevation angle of at least 45 degrees.

The basis for analyzing NGSO FSS interference into HD FS systems is the same as shown for UMFU systems and is based on calculations of the NGSO interference when operating at the maximum ITU PFD level proposed for the NGSO System. Table V-3 shows the impact of NGSO FSS downlink PFD on the bi-directional HD FS microwave link (in this case, both directions in the HD FS case are identical due to identical towers at each location). The results indicate that terrestrial HD FS systems will experience similar or lower degradation to FS operations due to their higher gain and higher isolation towards the high-elevation NGSO satellite signals.

Terrestrial FS microwave link	Sat PFD	Worst-case	Worst-case	Typical	Typical
	5G Isolation	Worst-case	Typical	Worst-case	Typical
PARAMETER	**UNITS**	**VALUE**	**VALUE**	**VALUE**	**VALUE**
Satellite PFD at Base Station	$dBW/m^2/MHz$	-105.0	-105.0	-111.0	-111.0
FS Tower Rx Antenna Gain [1]	dBi	35.0	35.0	35.0	35.0
FS Tower Rx Isolation to Sat signal [1]	dB	25.0	30.0	25.0	30.0
Satellite Received Power density after base station antenna gain	dBW/MHz	-148.3	-153.3	-154.3	-159.3
FS Tower Noise Figure	dB	5.0	5.0	5.0	5.0
FS Receiver Noise Density	dBW/MHz	-139.0	-139.0	-139.0	-139.0
Interference to Noise ratio, I_{SAT}/N_{5G}	dB	-9.3	-14.3	-15.3	-20.3
	%	11.7	3.7	3.0	0.9
Interference Degradation	dB	**0.48**	**0.16**	**0.13**	**0.04**

Table V-3 - NGSO FSS interference into terrestrial FS microwave link examples

In the unlikely event that potential interference would be caused to the NGSO System earth stations by FS activity in an area operating in the 38.6-39.5 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 NGSO satellites are operated at their minimum 45 degree elevation angle. The NGSO System could mitigate interference in these cases. Interference mitigation measures may include adjusting the minimum operational elevation angle, selecting specific NGSO satellites on each pass, adjusting operating power levels, 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 Upper Microwave Flexible Use Service

For UMFU and NGSO FSS co-primary usage, reference is made to the spectrum-sharing discussion above in Section V.A.1.a. The NGSO System would provide minimal interference into planned UMFU systems, even when operated with satellite downlink PFD levels corresponding to the 12 dB higher ITU Article 21 PFD limits.

c) Sharing with Federal Fixed and Mobile Systems

NTIA reports that the U.S. Army has used and may currently use this band for fixed and mobile radio systems.[83] Pursuant to the discussion in Section V.A.1.b, the NTIA Manual allows NGSO FSS operations up to the ITU Article 21 PFD limit, implying that Federal FS user systems may be designed to operate with the maximum FSS interference that may be generated by the NGSO System. Boeing will continue to work with any Federal FS or MS radio users identified by NTIA to ensure protected operations in the shared downlink band.

The Commission also notes that there may be Federal satellite operations in this band.[84] Boeing is in communication with NTIA for additional information regarding any Federal satellite systems operating within these bands. Once identified, Boeing will coordinate with Federal systems regarding their specific system and earth station operating characteristics. In general, such Federal systems should support band sharing and concurrent operations with the NGSO System with each system operating up to the ITU PFD limit as permitted by the NTIA Manual.

3. Existing and Proposed Use in the 39.5-40.0 GHz Band

The 39.5-40.0 GHz band is a shared Federal/non-Federal band. The non-Federal allocation of the band is for co-primary Fixed, FSS, and Mobile. The principal use of the

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[83] *Federal Spectrum Use Summary 2010* at 75.

[84] *Spectrum Frontiers NPRM*, ¶ 44.

39.5-40.0 GHz band is for nationwide FS links in the common carrier microwave service and 39 GHz service.[85]

The 39.5-40.0 GHz band is also allocated for Federal military satellite systems;[86] however, it is not clear to what extent, if at all, this band is actively used by Federal entities. In 1997, the Department of Defense and NASA reported plans for possible use with satellite downlinks and space research,[87] but Boeing has not identified any such systems in operation today. NTIA does not report any Federal users of these services in this band as of 2010.[88] In any case, both the satellite and the wireless sector have indicated that such operations need not be a barrier to more intensive use of this band, because potential interference can be avoided through the use of exclusion zones when and where such operations are identified.[89]

a) Sharing with High-Density Fixed Systems

Reference is made to the spectrum sharing discussion above in Section V.A.2.a. The NGSO System operation would introduce less than 0.5 dB of degradation to FS operations. In addition, Boeing will coordinate with FCC-licensed FS operators to ensure

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[85] ULS reports 126 licenses in the Common Carrier Point-to Point Microwave service and 629 licenses in the 39 GHz service (Last accessed May 16, 2016).

[86] 47 C.F.R. § 2.106, n.G117 and n.US382 (reserving the Federal allocation for military satellites, and precluding Federal MSS Earth stations from claiming interference protection from non-Federal fixed and mobile services); *Spectrum Frontiers NPRM*, ¶ 46.

[87] *Spectrum Frontiers NPRM*, ¶ 37.

[88] *Federal Spectrum Use Summary 2010* at 76.

[89] *Spectrum Frontiers NPRM*, ¶ 46 n.113 (noting the comments of Straight Path that federal FSS receive-only stations could be protected through "Protection Zones" or "Exclusion Zones").

proper operations, including as needed, to obtain locations and databases of their respective transmitters and receivers to facilitate successfully applying interference mitigation measures for affected earth stations within the NGSO System.

b) Sharing with Upper Microwave Flexible Use Service

For UMFU and NGSO FSS co-primary usage, reference is made to the spectrum sharing discussion above in Section V.A.1.a. The NGSO System would provide minimal interference into planned UMFU systems, even when operated with satellite downlink PFD levels operating at the 12 dB higher ITU Article 21 PFD limits.

c) Sharing with Federal Military Satellite Systems

The 39.5-40.0 GHz band is also allocated for Federal military satellite systems,[90] however it is not clear to what extent, if at all, this band is actively used by Federal entities. Pursuant to the discussion in Section V.A.2.c, Boeing is in discussions with NTIA regarding any Federal satellite systems operating within these bands, and once identified, Boeing will coordinate with Federal systems regarding their specific system and earth station operating characteristics. Boeing is confident that the sharing mechanisms described in the discussion in Section V.A.2.c will enable sharing with any identified Federal FSS users (GSO or NGSO systems). Further, the operation of any Federal GSO network would be protected by the V-band EPFD limits that are being developed by the ITU-R pursuant to Resolution 159 (WRC-15).

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[90] 47 C.F.R. § 2.106, n.G117 and n.US382 (reserving the Federal allocation for military satellites, and precluding Federal MSS Earth stations from claiming interference protection from non-Federal fixed and mobile services); *Spectrum Frontiers NPRM*, ¶ 46.

4. Existing and Proposed Use in the 40.0-42.0 GHz Band

The 40.0-42.0 GHz range covers several sub-bands with different allocations but broadly similar usage that can be considered together for efficiency. Each sub-band within this range contains a primary status FSS allocation for Federal and non-Federal users, accompanied by various co-primary services. In the 40.0-40.5 GHz band, MSS is the co-primary service; in the 40.5-41.0 GHz band, Broadcasting and BSS are co-primary to FSS; and in the 41.0-42.0 GHz band, Fixed, Mobile, Broadcasting, and BSS are all co-primary. This band is subject to the "soft-segmentation" plan adopted by the Commission pursuant to WRC-2000, in which the rules for this band favor FSS by permitting clear-sky PFD levels 12 dB higher than the level allowed in the 37.5-40.0 GHz band that is soft-segmented in favor of terrestrial services.[91] There do not, however, appear to be any active non-Federal users of these bands, satellite or terrestrial. The only satellite systems licensed by the Commission in this band were the previously surrendered Northrop Grumman and Hughes systems.[92] There are no non-Federal terrestrial operations in the band.[93]

The primary use of this band appears to consist of NASA and NSF programs for solar system exploration and radio astronomy, including the Very Large Baseline Array

[91] *Spectrum Frontiers NPRM*, ¶ 125 (citing *V-Band Second Report and Order*, 18 FCC 25428, 25432, ¶¶ 8, 12-14 (2003)).

[92] *See notes 97 and 98, supra.*

[93] ULS search reports no active licenses in the 40-42 GHz band. (last accessed May 15, 2016).

(“VLBA”), which operates receivers in the 41.0-45.0 GHz range.[94] The 40.0-41.0 GHz sub-bands include an allocation for military FSS and MSS systems,[95] but Boeing has not identified any current Federal systems operating in this band.

a) Sharing with Future GSO Satellite Networks

There are no GSO satellite systems currently licensed by the Commission or granted market access in the United States that operate within the V-band frequency ranges to be used by the NGSO System. As described in Section III.E, the Commission has not yet enacted frequency-band specific service rules or NGSO/GSO sharing criteria for the V-band. Boeing is confident that the sharing mechanisms described in Section V.A.2.c of this Application will enable sharing with future V-band GSO networks. In particular, the NGSO System would include high minimum-elevation angle operation, highly-directional user terminal and gateway beams, multiple NGSO FSS satellite LOS paths, and narrow, low-sidelobe satellite spot beams, all of which help to avoid in-line events with GSO networks.

Additionally, Boeing supports the technical studies being performed to develop EPFD limits pursuant to Resolution 159 (WRC-15) that would facilitate spectrum sharing between GSO and NGSO satellite systems in this frequency band segment. The EPFD limits would identify the required levels to protect GSO satellite networks. These EPFD limits will be developed through a consensus-based processes involving both GSO and

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[94] *Federal Spectrum Use Summary 2010* at 76-77; *Spectrum Frontiers NPRM*, ¶ 173 (noting that VLBA receivers include the 41.0-45.0 GHz band).

[95] 47 C.F.R. § 2.106 n.G117; *see also Spectrum Frontiers NPRM*, ¶ 169 (discussing protection measures for Federal MSS and FSS downlink, but not identifying any specific Federal users).

NGSO system operators and should therefore ensure an equitable spectrum sharing arrangement between these two categories of systems.

b) Sharing with Future NGSO Satellite Systems

There are no other NGSO satellite systems currently licensed by the Commission or granted market access in the United States that operate within the V-band frequency ranges proposed to be used by the NGSO System. As described in section III.E, the Commission has not yet enacted frequency-band specific services rules or NGSO/GSO sharing criteria for the V-band. The sharing mechanisms described in Section V.A.2.c of this Application would enable effective band-sharing with future V-band NGSO FSS systems. In particular, the NGSO System would include high minimum-elevation angle operation, highly-directional user terminal and gateway beams, multiple NGSO FSS satellite LOS paths, and narrow, low-sidelobe satellite spot beams, all of which help to ensure interference during in-line events with the NGSO FSS earth stations communicating with other NGSO FSS satellites.

c) Sharing with Space Research and Radio Astronomy

Regarding space research downlink usage, reference is made to the discussion in Section V.A.1.c. Boeing has contacted NTIA and NASA for assistance in identifying space research downlink sites, including the types of usage, locations and characteristics of potential earth stations operating in the downlink band. Regarding radio astronomy usage, reference is made to the discussion in Section V.A.1.d. The NGSO System would comply with the provisions of ITU Footnote 5.551H, and in particular would follow the coordination process described in Resolution 743-2. For radio astronomy sites that confirm observation band capabilities in the 37.5-42.5 GHz band, Boeing intends to complete the coordination process to protect observation capabilities at these locations and facilities.

5. Existing and Proposed Use in the 42.0-42.5 GHz Band

The 42.0-42.5 GHz band is a non-Federal only band, allocated for Fixed, Mobile, Broadcasting, and BSS on a co-primary basis. There are, however, no service rules in place for terrestrial operations,[96] and no existing operations in this band by any of the allocated terrestrial or satellite services. Thus, although there is no FSS allocation in this band, Boeing requests a waiver of the allocation table to permit operation of the NGSO System in this otherwise unused spectrum. This is consistent with the Commission's proposal that the existing BSS allocations be eliminated in favor of an FSS allocation to better protect adjacent radio astronomy in the 42.5-43.5 GHz band.[97]

NTIA records do not indicate any Federal operations specific to this band, although it appears that this band is among the frequencies used by the VLBA for radio astronomy observations,[98] and Footnote US211 of the U.S. Table requires any operations in this band to take all practicable steps to protect radio astronomy in this band.[99] FSS operations are therefore appropriate in this band because, as discussed above, FSS systems have demonstrated the ability to avoid interference to sensitive scientific

[96] *Spectrum Frontiers NPRM*, ¶ 75.

[97] *See id.* (*citing V-Band Third FNPRM*, ¶¶ 12-19).

[98] *Federal Spectrum Use Summary 2010* at 77; *Spectrum Frontiers NPRM*, ¶ 173 (noting that VLBA receivers include the 41.0-45.0 GHz band).

[99] *See* 47 C.F.R. § 2.106, n.US211.

operations such as VLBA and other federal users through the use of appropriate exclusion zones.

a) Sharing with Radio Astronomy

Regarding radio astronomy usage, reference is made to the discussion in Section V.A.1.d. The NGSO System would comply with the provisions of Footnote 5.551H and, in particular, would follow the coordination process described in Resolution 743-2. For radio astronomy sites that confirm observation band capabilities in the 37.5-42.5 GHz band, Boeing intends to complete the coordination process to protect observation capabilities at these selected locations and facilities. Boeing will also suppress out-of-band emissions above 42.5 GHz to comply with the protection criteria identified in ITU Recommendation RA.769-2 to protect radio astronomy observation in the 42.5–43.5 GHz band.

B. Earth-to-Space Communications

1. Existing and Proposed Use in the 47.2–48.2 GHz Band

This band is allocated to non-Federal fixed, FSS, and mobile services on a co-primary basis. The only satellite systems licensed by the Commission in this band were the previously surrendered Northrop Grumman and Hughes systems.[100] There are no non-Federal terrestrial operations, nor any Federal operations in this band.

[100] *See notes 97 and 98*, *supra*.

a) Sharing with Future GSO Satellite Networks

There are no other GSO or NGSO satellite systems currently licensed by the Commission or granted market access in the United States that operate within the V-band frequency ranges proposed to be used by the NGSO System. As indicated in Section V.A.4.a of this Application, Boeing plans to coordinate with future GSO satellite operators and is confident that the sharing mechanisms described in Section V.A.2.c will enable sharing with any future V-band GSO networks.

In addition, Boeing will support the development of uplink EPFD limits pursuant to Resolution 159 (WRC-15) to ensure that GSO networks are sufficiently protected in this frequency band segment. The EPFD limits will be considered for approval at WRC-19.

b) Sharing with Future NGSO Satellite Systems

There are no NGSO FSS satellite systems currently licensed by the Commission or granted market access in the United States that operate within the V-band frequency ranges proposed to be used by the NGSO System. As indicated in Section V.A.4.b, Boeing plans to coordinate with future NGSO satellite system operators, and is confident that the sharing mechanisms described in Section V.A.2.c will enable sharing with future V-band GSO networks.

2. Existing and Proposed Use in the 48.2–50.2 GHz Band

This is a shared band between Federal and non-Federal users, with co-primary allocations for Fixed, FSS, and Mobile. The 48.2-50.2 GHz portion of the V-band is designated for NGSO FSS use.[101] As with the 47.2-48.2 GHz, the surrendered Northrop Grumman NGSO/GSO network and the surrendered Hughes GSO network are the only non-Federal satellite systems that have been licensed by the Commission in this band.[102] There is no terrestrial use of the band.

NSF conducts radio astronomy observations in this band, and NASA and the United States military agencies have previously reported using the 50-55 GHz band for radar research and development. Boeing acknowledges that FSS earth stations in this band are subject to power limits to protect NASA and NOAA operations in the adjacent 50.2-50.4 GHz band.[103]

a) Sharing with Radio Astronomy

Footnote 5.555 to the International Table identifies the 48.94-49.04 GHz band as available for radio astronomy service. Boeing will use ITU Recommendation RA.769-2 to protect radio astronomy sites that operate in this band. In general, the NGSO System would position its gateways, which provide the highest uplink power transmission capability, outside of areas with known radio astronomy operations. The NGSO System could also use flexible frequency assignment on the uplink to avoid use of this band by

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[101] *See* Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz, and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band, and Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band, IB Docket No. 97-95, FCC 97-85 (March 24, 1997).

[102] *Northrop Grumman Order.*

[103] 47 C.F.R. § 1.06 n. US156.

user terminals in selected cells and footprint regions near known radio astronomy operations.

b) Sharing with Federal Systems

The 50.2-50.4 GHz band is adjacent to FSS bands that are proposed to be used by the NGSO System, and is allocated for EESS (passive). Boeing will comply with US 156 to protect EESS operations in the 50.2–50.4 GHz band and will complete coordinate with EESS facilities as appropriate. The NGSO System earth stations provide low out-of-band emissions and selected frequency operations can be managed by earth station locations as well as in LOS conjunctions with the EESS operations in a manner similar to the above discussions in Section V.B.2.a.

3. Existing and Proposed Use in the 50.4–51.4 GHz Band

This is a shared band between Federal and non-Federal users, with co-primary allocations for Fixed, FSS, Mobile, and MSS. There are no non-Federal terrestrial or satellite networks licensed in this band. The only reported Federal users are NASA and the military agencies, which have previously reported using the 50.0-55.0 GHz band for radar research and development.[104]

Boeing will coordinate with these agencies as necessary to avoid interference to any such operations. Boeing acknowledges that FSS earth stations in this band are subject to power limits to protect NASA and NOAA operations in the adjacent 50.2-50.4 GHz band.[105]

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[104] *Federal Spectrum Use Summary 2010* at 78.

[105] *Id*.

a) Sharing with Radio Astronomy

See spectrum sharing discussion above in Section V.B.2.a.

b) Sharing with Military Systems

See spectrum sharing discussion above in Section V.B.2.b.

4. Existing and Proposed Use in the 51.4–52.4 GHz Band

The 51.4-52.4 GHz band is a shared Federal/non-Federal band substantially identical to the 50.4-51.4 GHz band in allocation and usage, except that this band does not include an allocation to the FSS and MSS.[106] As with the 50.4-51.4 GHz band, there are no non-Federal terrestrial or satellite networks licensed in this band. The only reported Federal users are NASA and the military agencies, which have previously reported using the 50.0-55.0 GHz band for radar research and development.[107] Thus, although there is no FSS allocation in this band, Boeing requests a waiver of the U.S. Table to permit operation of the NGSO System in this otherwise unused spectrum.

a) Sharing with Federal Systems

Boeing is in discussions with NTIA and NASA regarding the Federal operations in the 51.4-52.4 GHz band. Additionally, Boeing will support the studies identified in Resolution 162 (WRC-15) that will consider the additional spectrum needs for the development of the FSS and the technical conditions of their use. These studies will

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[106] The 51.4-52.4 GHz band requested herein is a one gigahertz sub-set of the 51.4-52.6 GHz band reflected on the United States Table of Frequency Allocations. 47 C.F.R. § 2.106.

[107] *Federal Spectrum Use Summary 2010* at 78.

consider compatibility and sharing with existing services, including adjacent bands as appropriate. Boeing can employ the above discussed spectrum sharing measures to protect NASA and military systems, including coordinating with sensitive uses at specific locations as necessary.

b) Sharing with Future GSO Satellite Networks

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

c) Sharing with Future NGSO Satellite Systems

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