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VIA ELECTRONIC FILING

Jose P. Albuquerque
Chief, Satellite Division
International Bureau
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: The Boeing Company
IBFS File No. SAT-LOA-20170301-00028
Call Sign S2993

Dear Jose:

On behalf of The Boeing Company ("Boeing"), please find attached a corrected copy of our response to the questions raised in your letter dated June 22, 2017.[1] This version corrects the description of a line item in the link budget in Figure 2 in our response to question 9. The line item currently reads "Expected PFD at adjacent GEO (single XL)" and should read "Expected PFD at adjacent GEO (12 sources)."

As a result of Boeing's responses, Boeing is making the following revisions to its Schedule S for the above-referenced application:

Filing Description:	Reworded description to add inter-satellite service in Ka- and V-band.
Operating Frequency Bands:	Added the Ka- and V-band inter-satellite service frequency bands.
Receiving Beam:	Added the Ka- and V-band inter-satellite service beams.
Receiving Channels:	Added the Ka- and V-band inter-satellite service channels.

[1] Letter from Jose P. Albuquerque, Chief, Satellite Division, to Bruce A. Olcott, Jones Day, IBFS File No. IBFS File No. SAT-LOA-20170301-00028 (Call Sign S2993) (April 11, 2017).

Transmitting Beam:	Added the Ka- and V-band inter-satellite service beams and updated the GXT files for G0L0, G0R0, G1L0 and G1R0 to designate them as transmitting beams.
Transmitting Channels:	Added the Ka- and V-band inter-satellite service channels.

1. *Boeing requests that the Commission establish a different launch schedule for its satellite system, and proposes to launch its constellation in two distinct phases with initial deployment completed within six years, and final deployment completed after twelve years. Boeing states that "initial deployment would include a sufficient number of satellites to satisfy the Commission's domestic geographic coverage requirement to provide service on a continuous basis throughout all fifty states, Puerto Rico and the U.S. Virgin Islands." Please clarify how many satellites Boeing plans to launch during the initial deployment.*

As indicated at page 29 of the Narrative for Boeing's Application, the initial deployment of Boeing's constellation would include the five non-geostationary satellite orbit ("NGSO") spacecraft operating in a highly inclined "high-altitude" orbit to serve North and South America. The final deployment would add an additional ten highly inclined NGSO satellites and 132 satellites in LEO.

2. *In Table III-1 of its application, Boeing includes minimum gain-to-temperature ratio values for eighteen receiving beams, including beams G2L1 and G2R1. These two beams are not included in Schedule S. Please explain this inconsistency and, if warranted, include the necessary Schedule S information for these beams.*

The beams labeled G2L1 and G2R1 were inadvertently included in the narrative portion of the application in Table III-1 and are not intended to be operated in the V-band constellation. Schedule S as originally submitted was correct, and the revised Schedule S is also correct and does not include these beams.

3. *In its Schedule S attachment Boeing provides information for transmitting beams G0L0, G1L0, G0R0 and G1R0. In the associated antenna gain contour diagrams however, these same beams are labeled as receiving beams. Please either clarify that these beams are in fact transmitting beams, or correct the information in Schedule S, as appropriate.*

The antenna gain contour diagrams and .gxt files for beams G0L0, G1L0, G0R0, and G1R0 were incorrectly labeled and these are in fact transmitting beams. The associated .gxt files have been updated in the revised Schedule S with corrected information.

4. *Section 25.114(c)(4)(vi)(B) of the Commission's rules further requires that for space stations in non-geostationary satellite orbits (NGSO), the applicant specify for each unique orbital plane, the predicted antenna gain contour(s) for each transmit and receive antenna beam for one space station if all space stations are identical in the constellation. If individual space stations in the constellation have different antenna beam configurations, the applicant must specify the predicted antenna gain contours for each transmit and receive beam for each space station type and orbit or orbital plane requested. In its application, Boeing defines a hybrid NGSO space segment consisting of 132 low-Earth orbit (LEO) and 15 highly inclined satellites in the range of GSO altitude operating in three distinct constellation. Although Boeing has provided a set of antenna gain contour diagrams, it is not entirely clear which beams may be associated with which type of satellite. Please confirm whether antenna contour diagrams labeled "IGSO" are associated with satellites in the high-altitude orbits and those labeled "V-Band Constellation" are associated with satellites operating in LEO. Otherwise, please clarify how each of the beams (including ISL beams as discussed below) may be associated with specific satellites in Boeing's constellation. In addition, we ask whether those beams associated with the high-altitude sub-constellations may all be presumed to be representative of space stations in each of the three distinct sub-constellations (i.e., the Americas constellation, the Europe/Africa/ Middle East constellation and the Asia-Pacific constellation.)*

Boeing herein confirms that the antenna contour diagrams labeled "IGSO" are associated with the satellites in the high-altitude orbits and those labeled "V-Band Constellation" are associated with the satellites operating in LEO. Boeing also herein confirms that those beams associated with the highly inclined NGSO satellites in high-altitude are representative of space stations in each of the three distinct sub-constellations (*i.e.*, the Americas constellation, the Europe/Africa/Middle East constellation and the Asia-Pacific constellation).

5. *Boeing states that its LEO satellites will have a primary coverage area defined by a 25° elevation footprint. Boeing does not state the specific coverage areas for satellites in the high-altitude orbit portion of the constellation. In the Schedule S beam pages, however, there are multiple descriptions applied to various beams' service areas. Even if only the beams presumed to be associated with LEO constellation satellites (as described above) are examined, there are inconsistencies in the description of the coverage areas. Furthermore, the meanings of some of these service area descriptions are not entirely clear. The antenna gain contour diagrams provide no further clarification, as they include no descriptions in the fields for Service Area Number/Name. To assist the Commission in evaluation of Boeing's application, please provide the following:*

- *Please verify that the service areas given in Schedule S for each beam are correct.*

- *Please clarify what is meant by the Service Area descriptions Boeing has provided. In particular, please clarify the meanings of "Visible Earth above 90° elevation angle", "Spot Beam" and/or "Beam at Boresight." Please also refer to the instructions for entry of Service Area descriptions in paragraphs 8.a.xvi and 10.a.xv in the Schedule S instructions for additional guidance.*

The LEO satellites in Boeing's V-band NGSO constellation will operate multiple identical steerable and/or shapeable service beams within an area of the visible earth above a minimum elevation angle of 25 degrees. The higher altitude inclined GEO satellites will also operate multiple identical steerable and/or shapeable service beams within an area of the visible earth above a minimum elevation angle of 25 degrees. Both satellite designs will operate telemetry (transmit) and command (receive) beams within the area of the visible earth above a minimum elevation angle of 5 degrees. Therefore, Boeing has modified the Service Area descriptions within Schedule S for all User and Gateway Service Beams to state "Visible Earth above 25 deg elevation angle." The Service Area descriptions for the command beams (GTLC, GTRC and LTLC, LTRC) and telemetry beams (GTLT, GTRT and LTLT, LTRT) have been modified to state "Visible Earth above 5 deg elevation angle."

With regard to the antenna beam contours, the Instructions for Schedule S, section 8.a.xv.7 and 10.a.xiv.7 state that "[f]or non-geostationary satellites with large numbers of identical fixed beams on each satellite, applicants may… specify the predicted antenna gain contours for one [transmit or receive] beam pointed to nadir, together with an area map showing all of the spot beams depicted on the surface of the earth with the satellites' peak antenna gain pointed to a selected latitude and longitude within the service area." Boeing included in its narrative application the beam patterns of the steerable spot beams pointed at nadir as well as beam patterns scanned to a 25 degree elevation for the LEO constellation. The illustrations of collections of spot beams depicted on the surface of the earth are included in the application narrative in Figures III-3 and III-4 (LEO) and Figures III-7 and III-7 (high altitude). This information was also discussed in Boeing's ex parte presentation, dated March 13, 2017.[2]

[2] *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, Federal Communications Commission, IBFS File No. SAT-LOA-20170301-00028 (Call Sign S2993), at Attachment 1 (March 13, 2017).

6. *Section 25.114(c)(4) specifies the information that must be provided in Schedule S for each space station transmitting and receiving antenna beam. In its application, Boeing does not include Schedule S information for any of the transmitting or receiving inter-satellite link (ISL) beams. Instead, Boeing provides certain ISL beam information in Table III-2 and III-3 that includes many, but not all, of the parameters that are required by Schedule S. Although Boeing states that the Commission's current filing requirements for NGSO FSS systems "do not permit including ISL beams within the Schedule S format," it is not clear what Boeing means by this statement, since Schedule S does permit inclusion of information for ISL beams. Accordingly, we request that Boeing update its Schedule S filing to include information on each representative transmit and receive ISL beam. In the alternative, should Boeing seek a waiver of section 25.114(c) it must specify why it cannot adequately represent its ISL transmitting and receiving beams in the current Schedule S and must also submit the complete information required by Schedule S in another format. In addition to channelization information (including center frequencies, bandwidth and link type), section 25.114(c)(4) requires provision of the following information:*

   - *For each receiving beam: Beam ID; receiving beam frequencies; beam type; polarization; peak antenna gain; antenna pointing and rotational error; polarization alignment; G/T at maximum gain point; service area description; minimum G/T; and 3 dB beamwidth.*

   - *For each transmitting beam: BeamID; transmitting beam frequencies; beam type; polarization; peak antenna gain; antenna pointing and rotational error; polarization alignment; maximum transmitting eirp and eirp density; service area description; 3 dB beamwidth and maximum power flux density values at the Earth's surface needed for compliance with section 25.208 of the Commission's rules.*

As requested, Boeing has updated the Schedule S included with the Application to contain the necessary information for inter-satellite link ("ISL") beams. In order to easily distinguish these beams, the beam designators all begin with the letter "X". There are 16 beams in total accounting for the specific use of up to four different contiguous frequency bands (two in the Ka-band and two in the V-band), dual/selectable polarizations, and the transmit and receive beams in each polarization and band. Channel ID designators have likewise been update to include the ISL bands.

7. *Please clarify the following regarding Boeing's planned operation of ISLs between spacecraft in the separate constellations (i.e., LEO and high-altitude orbit) within its system and between various other geostationary-orbit (GSO) satellites:*

- *a) Please provide information regarding the specific Ka-band GSO satellites with which Boeing proposes to communicate.*

Boeing has not yet identified the specific Ka-band GSO satellites with which Boeing's LEO satellites would communicate. From a technical perspective, all Ka-band GSO satellites are capable of receiving signals from Boeing's LEO satellites and are also capable of transmitting signals to Boeing's LEO satellites (just as those satellites transmit and receive signals with earth stations on the ground). Once Boeing has identified operators of Ka-band GSO satellites that are interested in entering into contractual arrangements to support such communications, Boeing and those operators will seek Commission authority for such specific communications to the extent such additional authority is deemed necessary by the Commission.

- *b) Boeing proposes to operate its Ka-band inter-satellite transmissions "via any number of Ka-band GSO satellites deployed around the world." Will these transmissions occur only between Ka-band GSO satellites and Boeing's LEO spacecraft as suggested by Table III-2, or will they also occur between GSO satellites and Boeing's high-altitude orbit satellites?*

Boeing's high-altitude satellites will not communicate through Ka-band ISL transmissions with Ka-band GSO satellites.

- *c) Does Boeing propose to operate V-band inter-satellite links only between satellites in its own constellation? If so, will these links operate only between its LEO and high-altitude orbit satellites, or will there be LEO-to-LEO transmissions and/or inter-satellite transmissions between spacecraft in the high-altitude orbit constellations of Boeing's system?*

Boeing is seeking authority to operate its V-band ISL transmissions both within its constellation and also with any GSO satellites that operate using V-band spectrum. Boeing obviously has not identified any specific V-Band GSO satellites for such communications. With respect to operations within its own constellation, Boeing is proposing to operate its V-band ISL transmissions between its LEO and its high-altitude satellites and between its individual LEO satellites. Boeing is not proposing to operate any ISL transmissions between its high-altitude satellites.

8. *Boeing proposes to operate its Ka-band ISLs on a non-conforming, non-interference basis relative to other users of the band. Please clarify the following with regard to these operations:*

- *a) Does Boeing seek to operate its V-band ISLs on a similar basis?*

Boeing is requesting authority to operate its V-band ISL transmissions from LEO to GSO and from LEO to high-altitude NGSO on a co-primary basis with other communications in the fixed-satellite service ("FSS"). To this end, Boeing observes that Sections 2.1 and 25.103 of the Commission's rules indicate that the definition of FSS can include in some cases satellite-to-satellite links.

- *b) Boeing acknowledges that "portions of the 17.8-19.3 GHz band do not currently include an allocation for FSS, or, in some portions, a designation for NGSO FSS operations." Boeing states further that "[it] is not requesting a waiver of the Commission's Frequency Allocation Table for these ISL operations, however, because Boeing's LEO satellites will not transmit and will only receive signals from GSO satellites that have been authorized by the Commission to operate in all or portions of this spectrum." Boeing provides no specific justification as to why such waivers are not necessary for receiving space stations. Accordingly, please clarify Boeing's rationale, including specific cites to the Commission's rules or Commission precedent supporting this argument. In the alternative, please clarify whether Boeing plans to seek waivers of sections 2.106 and 25.202(a)(1) of the Commission's rules, and/or the Ka-Band Plan for its ISL operations in these bands.*

Boeing anticipated that a waiver of the Commission's rules would not be necessary for the space-to-Earth reception function of Boeing's satellite because the inter-satellite link ("ISL") in question would be transmitted by another satellite that had already been authorized by the Commission to operate in the 17.8-18.3 GHz band, possibly pursuant to a waiver. Boeing now recognizes, however, that some satellites that may transmit using the 17.8-18.3 GHz band may not be operating pursuant to a waiver of the Commission's rules because they may not be within view or have coverage of the United States and therefore a waiver of the Commission's rules would be appropriate.

Good cause exists to grant a waiver of the Commission's Table of Frequency Allocations in Section 2.106 and the list of available frequencies for FSS in Section 25.202(a)(1) to permit Boeing's LEO satellites to receive signals from other satellites operating in the 17.8-18.3 GHz band. Boeing's satellites will receive signals from other satellites that have coverage of the

United States using the 17.8-18.3 GHz band only if those other satellites have been authorized by the Commission (pursuant to a waiver or otherwise) to operate in the United States using those frequencies. Therefore, the Commission will have already determined that such transmissions will not cause harmful interference to terrestrial services in the United States. The reception of those transmissions by Boeing's satellites could not alter this favorable conclusion.

Boeing anticipates that the Commission may amend its rules to permit additional satellites to transmit signals in the 17.8-18.3 GHz band. The Commission is currently considering such a change to its rules as a part of its NGSO rulemaking proceeding. As the NPRM explained, the adoption of a secondary allocation for FSS operations in the 17.8-18.3 GHz band would likely be appropriate because the ITU's PFD limits for FSS to protect terrestrial networks "are sufficient to protect U.S. terrestrial fixed users, without generally requiring coordination." Given the significant support that has been expressed for the Commission's proposal, the Commission may adopt a secondary allocation for FSS in the 17.8-18.3 GHz band prior to the launch of Boeing's satellite system, thus making Boeing's waiver request moot. Nevertheless, Boeing herein requests such a waiver and urges the Commission to conclude that its grant would serve the public interest.

9. *Article 22 of the ITU Radio Regulations specifies equivalent power flux-density (epfd) limits that are applicable in several frequency bands in which Boeing proposes to operate. These include* $epfd_{up}$ *limits in the 27.5-28.6 GHz and 29.5-30 GHz bands. Please provide a showing demonstrating the Boeing satellite system's compliance with the applicable epfd limits specified in Article 22 of the ITU Radio Regulations in these frequency bands.*

Boeing will to operate its LEO-to-GSO Ka-band ISL in accordance with the FCC rules and ITU regulations for space-to-earth communications with satellites authorized to operate within the Ka-band. The number of LEO satellites in the Boeing system that will operate using Ka-band ISLs will vary and is not intended to be necessary for every LEO satellite and will be driven by the nature of the specific communications service, the LEO satellite location, and the availability of V-band ISLs as an option.

Currently, there is no approved ITU software that can compute an EPFDup level with sources operating on LEO satellites. Nevertheless, Boeing has computed the EPFDup generated by its proposed Ka-band ISL operations in a scenario that reflects heavy usage of Ka-band ISLs by Boeing's LEO constellation. The specific scenario, shown in Figure 1, assumes a total of twelve LEO satellites using ISLs to transmit to two relay satellites in geostationary orbit ("GSO"), which are each spaced at two degrees east and west of a separate Ka-band GSO satellite, which represents the "victim" Ka-band GSO satellite experiencing interference from the

Boeing ISL operations. Six LEO satellites are communicating with each GSO relay satellite and are operating a maximum uplink PFD level consistent with the EIRP density in the Boeing application and taking into account free-space path loss to the GSO satellite(s). The Boeing LEO satellite ISL beam patterns are consistent with a 1.2 degree beamwidth and use the ITU-R S.1428 beam patterns (for earth stations), while the victim GSO satellite beam is consistent with the 1.55 degree ITU-R S.672-4 beam pattern specified in the ITU Radio Regulations for EPFDup computations. The victim GSO beam is pointed at the worst-case location, which is directly overlapping one of the LEO satellite(s). Figure 2 below illustrates the results of the EPFDup modeling over the LEO constellation orbit variations.

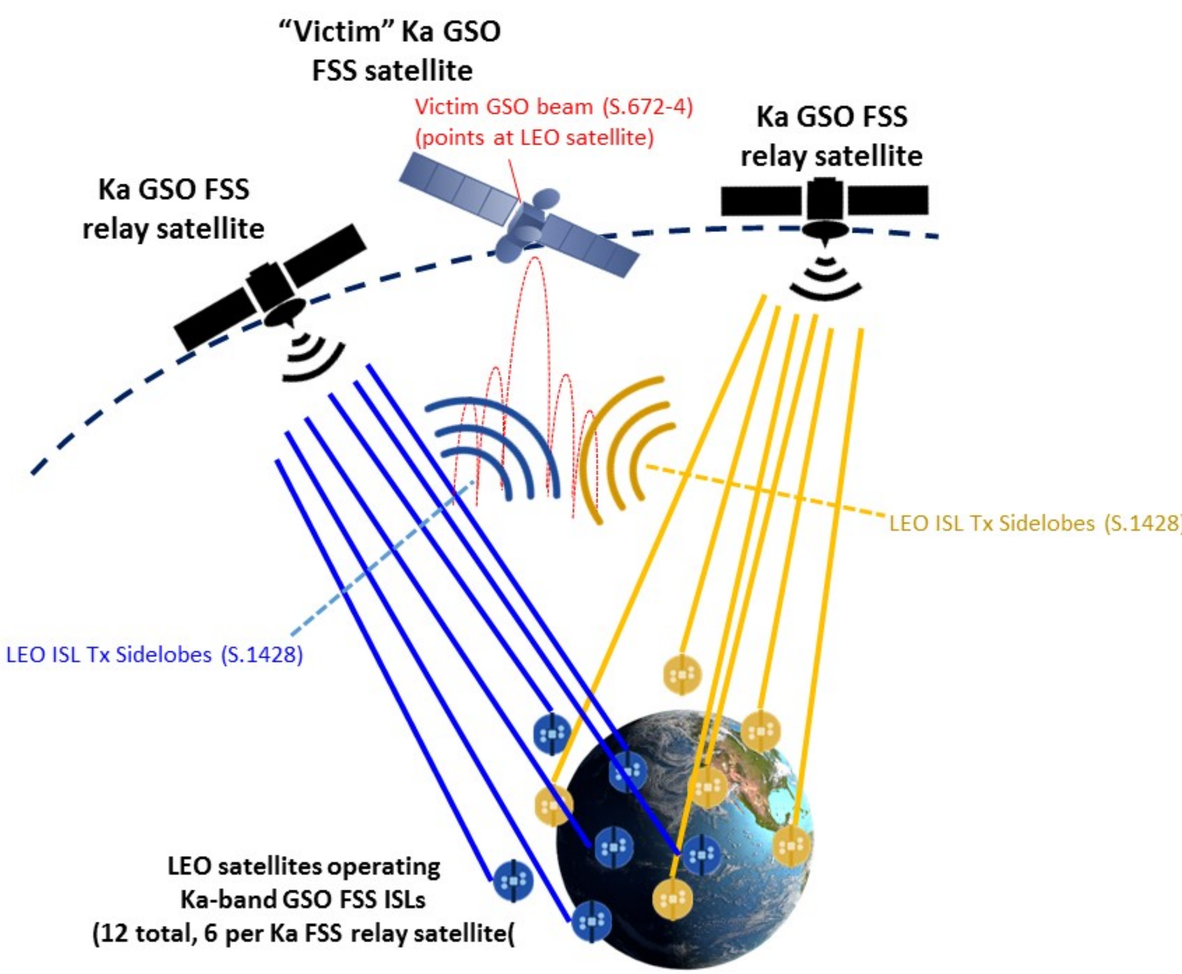

Figure 1 – LEO to Ka-band GSO Relay and Ka-band GSO "Victim" Satellite Scenario

Ka GSO ISLs – EPFDup Calculation

LEO Ka TX EIRP	61.0	dBWi
LEO Ka Tx Bandwidth	500.0	MHz
LEO Ka TX EIRP density	34.0	dBWi/MHz
Range to GEO relay	39205.8	km
Spreading loss to GEO relay	-162.9	dB
Max PFD (single XL) at GEO relay	-128.85	dBW/m2/MHz
Worst-case combined Tx+Rx isolation (12 sources)	-19.2	dB
Expected PFD at adjacent GEO (12 sources)	-148.0	dBW/m2/MHz
EPFDup limit	-162.0	dBW/m2/40 kHz
EPFDup limit	-148.0	dBW/m2/MHz
Margin to limit	0.0	dB

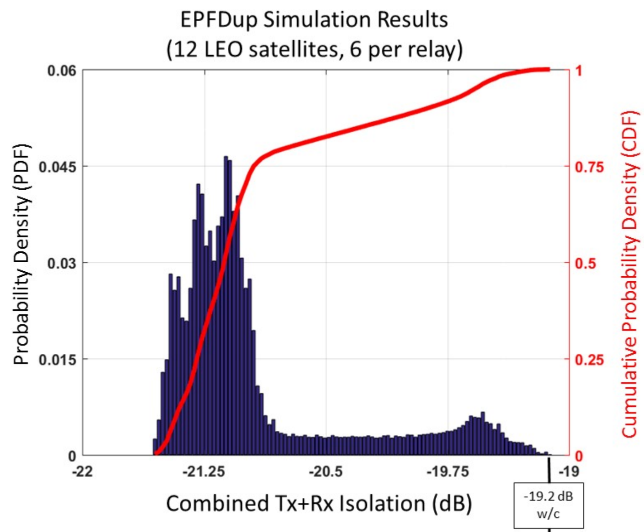

Figure 2 – EPFDup Results Summary

As Figure 2 indicates, the maximum EPFDup that can be generated by this scenario is compliant with the required -162 dBW/m2/40Khz level in Article 22 of the ITU Radio Regulations. Boeing believes that this is a worst-case scenario in terms of the number of simultaneously operating Ka-band LEO ISLs and the alignment of GSO relay satellite locations. Boeing anticipates that its actual constellation will operate at lower power levels and with less frequency in terms of the number of LEO satellites simultaneously operating ISLs toward the GSO arc.

10. *Section 25.114(d)(14) of the Commission's rules further requires that the applicant provide a description of the design and operational strategies that will be used to mitigate orbital debris. Please provide the following additional information and clarifications with respect to orbital debris mitigation:*

- *a) Please clarify, as described in section 25.114(d)(14)(ii), whether all fuel line valves will be left open after post-mission maneuvers.*

For both the high altitude and LEO vehicles, the fuel line thruster valves are used to enable fine vehicle maneuvers positioning control and, since they are solenoid driven, they require power to operate. The use of power to open thruster valves is typical in the industry. As power cannot be guaranteed over all post mission time, these valves will be closed. The post-mission disposal maneuver is intended to deplete all fuel remaining in the vehicle fuel tanks.

- *b) Please provide information, as described in section 25.114(d)(14)(iii), regarding the accuracy to which the NGSO space station orbital parameters will be maintained, including apogee, perigee, inclination, orbital altitude, and right ascension of the ascending node(s).*

For the high-altitude vehicles the semi-major axis and the right ascension of the ascending node will be controlled such that the longitude of the ascending node is maintained to +/- 0.5° of the desired longitude. The eccentricity will be maintained to +/- 0.01 of its nominal value. The inclination and argument of perigee will be maintained to +/- 0.5° and +/- 2° respectively.

The LEO constellation will use "frozen orbits" to minimize the long-term changes in eccentricity and argument of perigee. The eccentricity of the constellation will be maintained to within $5x10^{-4}$ of the planned value. The inclination will be permitted to vary within a range of +/-0.15 degrees. The right ascension of the ascending node ("RAAN") will be allowed to drift freely. The altitude (radial semi-major axis, including apogee and perigee) of each spacecraft will vary within a range of +/-11 kilometers. To control the mean parameters of the orbit over the constellation life, spacecraft station keeping will be utilized to maintain relative position of the satellites to within +/-3 kilometers in the radial direction, +/-10 kilometers in the in-track direction, and +/-2 kilometers in the cross-track direction.

- *c) With regard to the LEO portion of Boeing's constellation, Boeing does not state whether the space stations will be launched into low-Earth orbits that are identical, or very similar, to an orbit used by other space stations. Please address this question, and if so, please include an analysis of the potential risk of collision and a description of what measures the space station operator plans to take, including coordination with other operators to avoid in-orbit collisions as required by section 25.114(d)(14)(iii).*

The challenges of coordinating mixed-altitude constellations is well understood by Boeing and through the use of "frozen-orbits," altitude variations will be kept to a minimum. As Boeing has presented previously to the Commission, the anticipated operating altitude of the Boeing constellation will not overlap with other constellations.[3] Other spacecraft operators have filed for lower altitudes and, as such, the orbit insertion and deorbit process will take spacecraft through their altitude regimes. Launch window coordination for orbit insertion is a typical

[3] *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, Federal Communications Commission, IBFS File Nos. SAT-LOA-20160622-00058 & SAT-AMD-20170301-00030 (Call Sign S2966), Attachment 1 at 5 (March 13, 2017).

activity that will be required for all operators transitioning through multiple constellations that may be deployed. For deorbit operations, the de-orbiting vehicles will spend little time in the altitude regimes of other constellations, and it is likewise anticipated that coordination with these operators will take place in order to best minimize the risk of collisions.

- *d) Boeing states that sufficient propellant will be reserved to perform the disposal maneuvers for the LEO portion of its constellation. Boeing makes a similar statement that an appropriate amount of fuel will be reserved to move the high-altitude orbit satellites into an appropriate disposal orbit at end of life. Please provide information, as described in section 25.114(d)(14)(iv), regarding the quantity of fuel (in kg) that will be left for each of these post-mission disposal maneuvers.*

Boeing's high-altitude satellites will maintain sufficient fuel to conduct a post-mission disposal maneuver that corresponds to an orbit change maneuver of a minimum delta-v of 350 m/s. The fuel retained for this maneuver exceeds the minimum value required for the maneuver by at least five percent. The LEO constellation vehicles are allocated 386 m/s of delta-v to perform their post-mission disposal maneuver.

- *e) Please specify what value of C_R was used in calculating the graveyard orbit altitude.*

The estimated value for the product of coefficient of reflectivity and area-to-mass ratio was 0.094 m^2/kg. This conservative value has been used to assist in the design of the final disposal orbit.

- *f) With regard to the post mission disposal of the high-altitude orbit satellites in Boeing's proposed constellation, please provide a statement and/or analysis with respect to the long-term stability or instability of post-mission storage orbit. Such analysis should address any measures, such as selection of orbital parameters that may affect the long-term evolution of orbital parameters, with particular attention to addressing any such evolution that would result in the satellites entering the geostationary protected region, i.e., the area defined by the geosynchronous altitude, plus or minus 200 kilometers, and plus or minus 15 degrees from the equatorial plane, or the LEO protected region, i.e., the area below 2000 km.*

Boeing acknowledges that the formula for calculating minimum initial perigee for a GSO disposal, as found at 47 C.F.R. § 25.283(a), is insufficient for determining the disposal orbit parameters. Boeing is currently studying the long-term stability of a variety of disposal orbits to ensure non-interference with the geostationary protected region (+/-200km and +/- 15 degrees latitude) for in excess of 100 years. The disposal orbit's key parameters and disposal date will be chosen to include consideration for the orientation of the orbital plane with respect to the Sun and Moon and resulting perturbations over the full disposal period.

- *g) Boeing states that following a lowering of the orbital altitude to 500 km, passive reentry of the LEO portion of its constellation will be realized resulting from drag within an estimated five years. Please clarify whether Boeing will meet the reliability metric of 90 percent as described in the technical standards developed by NASA, and specify how high Boeing's deorbit reliability value is anticipated to be. Please clarify how many satellites will not be expected to achieve successful atmospheric reentry in five years following the end of the spacecraft mission, based on reliability targets. In addition, please calculate and provide an estimated probability of collision for each spacecraft during the disposal process using the NASA Debris Assessment Software (DAS).*

Boeing will maintain a high level of reliability through inherent redundancy in critical de-orbit subsystems, including in propulsion, mechanisms, sensors, spacecraft computer and the power subsystems. As such, Boeing fully expects that the probability of a failed satellite to be less one percent per spacecraft. Boeing has revised its NGSO constellation de-orbit plan to lower the NGSO vehicle disposal altitude from 500 kilometers to 330 kilometers. At this altitude and below, Boeing will continue to adjust the orientation of the vehicle to either maximize or minimize the area in order to use drag to maneuver around any piece of tracked debris or any operational spacecraft. The orbital lifetime for Boeing's spacecraft at this revised disposal altitude will be less than three months. The probability of a single spacecraft collision with a piece of orbital debris greater than one centimeter during this period at this altitude is estimated to be less than 3e-5, or less than 0.003 percent.

- *h) Boeing states that the risk of human casualties would be less than 1 in 10,000 in accordance with NASA-STD 8719.14, requirement 4.7-1. Please provide that assessment. Please also provide a figure for the aggregate casualty risk from disposal of all satellites in the constellation.*

Boeing has performed the necessary analyses on its NGSO system design as indicated using the NASA DAS. The analysis identified the presence of certain high risk items due to the contents of certain materials. As a result, the "demiseability" of these elements is a key requirement for the ongoing design process for the satellites. As two examples: one particular material was verified to burn up at an altitude of 66 kilometers, while another item had a potential to survive re-entry, but this probability was sufficiently small to result in a risk of human casualties of 1 in 90,700 per spacecraft. For the entire constellation, the risk of human casualties is a probability of 0.0015. Boeing is continuing to improve the design of its spacecraft to further reduce potential aggregate risk. A final assessment can be made after the spacecraft design is finalized at PDR.

Thank you for your attention to this matter. Please contact the undersigned if you have any questions.

Sincerely,

Bruce A. Olcott
Counsel to The Boeing Company