Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the matter of	)	
Space Exploration Holdings, LLC	)	File No. SAT-MOD-20200417-00037
	)	Call Signs: S2983/3018
Application for Modification of Authorization for the SpaceX NGSO Satellite System	)	

COMMENTS OF ONEWEB

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WorldVu Satellites Limited, Debtor-in-Possession ("OneWeb"), pursuant to Section 25.154(a) of the Commission's rules,[1] hereby submits these comments on the above-captioned application for modification filed by Space Exploration Holdings, LLC ("SpaceX").[2]

INTRODUCTION AND SUMMARY

For the third time in the last eighteen months, SpaceX seeks to modify its previously authorized non-geostationary orbit, fixed-satellite service system ("NGSO FSS") space station license to relocate 2,824 of its satellites "currently authorized to operate at altitudes from 1,110 km to 1,325 km down to altitudes ranging from 540 km to 570 km."[3] While SpaceX characterizes this request as merely a "modest adjustment,"[4] that description glosses over the fact that SpaceX has proposed significant changes to its network architecture. While OneWeb agrees that SpaceX has adequately demonstrated it will protect terrestrial operations in the Ka-band, SpaceX proposes

[1] 47 C.F.R. § 25.154(a).

[2] *See* Application for Modification of Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20200417-00037 (filed April 17, 2020) (the "Third SpaceX Modification").

[3] Third SpaceX Modification, Legal Narrative, at 3.

[4] *Id.* at i.

certain changes that could (i) increase the risk to the orbital environment considering the current satellite failure rate of the SpaceX constellation and (ii) significantly degrade the NGSO spectrum sharing environment. Thus, as explained below, OneWeb respectfully requests the Commission sufficiently address these issues prior to any grant of the Third SpaceX Modification.

I. ONEWEB SUPPORTS SPACEX'S REQUEST FOR WAIVER OF SECTION 25.146(a)(1) OF THE COMMISSION'S RULES

In the grant of the SpaceX 2016 License Application, the Commission included a condition requiring that SpaceX "file a modification application before starting operation with a technical showing that demonstrates that its operation will protect a fixed-service station with the characteristics described in Recommendation ITU-R SF.1483."[5] SpaceX provides such a showing in the Third SpaceX Modification and asks the Commission to determine that it has satisfied this condition.[6] As OneWeb recently explained in its own modification application, the current ITU limits in the 18.8-19.3 GHz band require large constellations to have satellites with sidelobe levels that are very difficult to achieve as a result of the "X-factor" applied in the PFD limit formula corresponding to low angles of arrival and is unrealistically constraining.[7] The ITU acknowledged these difficulties at the ITU World Radiocommunication Conference 2019, where the ITU instructed the Radiocommunication Bureau to issue a qualified favorable finding when requested

[5] See *Space Exploration Holdings, LLC, Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System*, Memorandum Opinion, Order & Authorization, 33 FCC Rcd 148, ¶ 35 (2018); *See also* Space Exploration Holdings, LLC, Application For Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System, IBFS File No. SAT-LOA-20161115-00118 (filed Nov. 15, 2016) ("SpaceX 2016 License Application").

[6] Third SpaceX Modification, Attachment A at 17 ("Technical Attachment").

[7] *See WorldVu Satellites Limited, Application for Modification to OneWeb U.S. Market Access Grant for the OneWeb Ku- and Ka-Band System*, IBFS File No. SAT-MPL-20200526-00062, Phase 2 Technical Attachment at 22-24 (filed May 26, 2020); *See also* 47 C.F.R. § 25.146(a)(1).

by the filing administration and invited the Radiocommunication Sector "to study the appropriateness of the equations contained in RR No. 21.16.6 for large NGSO satellite systems."[8]

In light of that framework, OneWeb has reviewed the analysis provided by SpaceX in Annex 3 of the Third SpaceX Modification and agrees that the methodology relied upon by SpaceX is sound. Thus, OneWeb agrees with SpaceX that the Commission should determine that SpaceX has demonstrated that terrestrial services will be adequately protected.

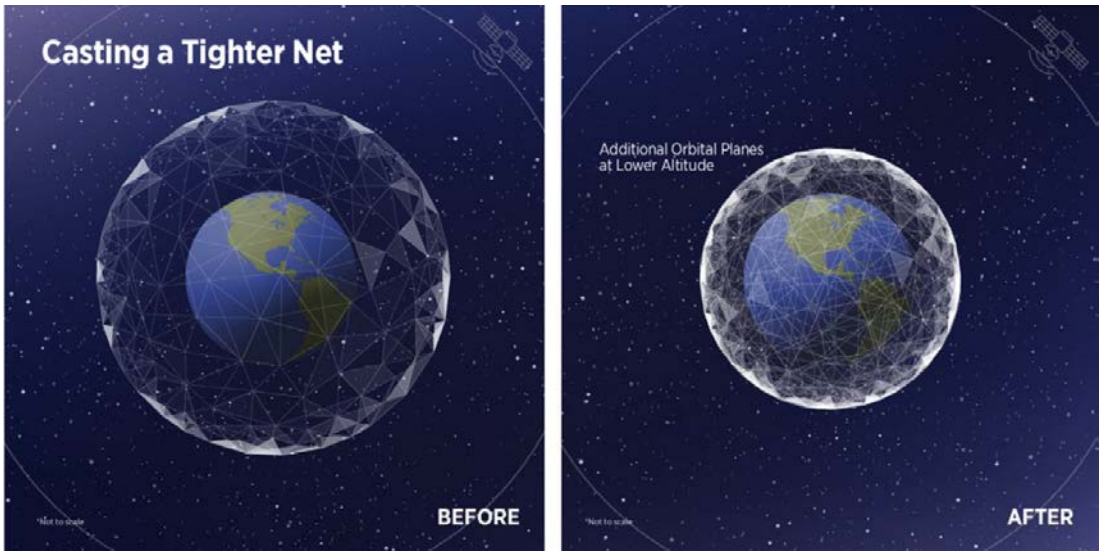
II. GRANT OF THE THIRD SPACEX MODIFICATION COULD INCREASE RISK TO THE ORBITAL ENVIRONMENT

SpaceX proposes to relocate the bulk of its authorized constellation to orbital altitudes of 540 to 570 km.[9] As an initial matter, SpaceX's proposed orbital relocation will result in SpaceX's satellites being condensed into a much smaller volume, as illustrated from a recent submission by DISH Network L.L.C. ("DISH"), figures from which are reproduced below.[10] If the Commission allows SpaceX to relocate its operations to the 540 to 570 km altitude ranges, SpaceX's constellation will become part of a highly congested altitude with the potential for significant debris-generating events:

[8] *See* Circular Letter CIR-015 from Mario Maniewicz, Director, ITU, at 10 (Mar. 6, 2020) *available at* https://www.itu.int/md/R00-CR-CIR-0456/en.

[9] Technical Attachment at 1.

[10] *See* Letter from Jeffrey Blum, Executive Vice President, External and Legislative Affairs, DISH, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-MOD-20200417-00037, at 4 (filed Jun. 16, 2020).



In addition to this general crowding effect, grant of the Third SpaceX Modification could create a nearly complete overlap between SpaceX's different orbital shells, which are at altitudes of 540 km, 550 km, 560 km, and 570 km while "apogee and perigee will be maintained to within 30 km."[11] As Astroscale U.S. Inc. correctly describes, there are already 1,600 additional SpaceX satellites being deployed within this 30 km span.[12] OneWeb joins other important stakeholders in respectfully requesting the Commission consider appropriate steps, as necessary, to ensure deployment of the SpaceX constellation is consistent with basic principles of orbital stewardship prior to any grant of the Third SpaceX Modification.

Pursuant to Section 25.117 of the Commission's rules, the Commission may deny modification of a space station authorization if "[g]ranting the modification request would not

[11] *See* Technical Attachment at 3.

[12] *See* Letter from Charity Weeden, Vice President, Global Space Policy, Astroscale U.S. Inc., to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-MOD-20200417-00037, at 2 (filed Jun. 30, 2020); *See also* Letter from Mariah Shuman, Corporate Counsel, Kuiper Systems, LLC, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-MOD-20200417-00037, at 1 (filed May 1, 2020) (noting the potential for these overlaps to present space sustainability challenges).

serve the public interest, convenience, and necessity."[13] An important reference point to assess whether grant of the Third SpaceX Modification would serve the public interest is the aggregate collision risk presented by the system SpaceX first proposed in the SpaceX 2016 License Application and how that system and the collision risk has morphed over time. In its response to the Commission's inquiry three years ago asking SpaceX to provide an analysis of the collision risk for this system,[14] SpaceX stated that "there is approximately a 1 percent chance *per decade* that *any* failed SpaceX satellite would collide with a piece of tracked debris."[15]

In responding to the First SpaceX Modification, OneWeb cautioned the Commission that it should not allow the low-earth environment to become a test bed for the application of SpaceX's frequently touted "iterative design" principles to a satellite manufacturing context.[16] Specifically, OneWeb explained that SpaceX appeared to be putting a premium on speed to orbit for satellites with no design heritage, warning that although SpaceX's "rapid iteration philosophy may have served it well in the development of its launch vehicles…this 'test and discard' approach may not be as well suited to the crowded LEO operating environment where spacecraft can linger for years."[17] These warnings proved to be prescient in light of the significant number of in-orbit failures already reported by SpaceX.

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[13] 47 C.F.R. § 25.117(d)(2)(ii).

[14] *See* Letter from Jose P. Albuquerque, Chief, Satellite Division, to William M. Wiltshire, Counsel to SpaceX, IBFS File No. SAT-LOA-20161115-00118, at 1 (filed Mar. 21, 2017).

[15] *See* Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Division, International Bureau, FCC, IBFS File No. SAT-LOA-20161115-00118, at 6 (filed Apr. 20, 2017) ("SpaceX Response") (emphasis in original).

[16] Petition to Deny or Defer of WorldVu Satellites Limited, IBFS File No. SAT-MOD-20181108-00083 at 13 (filed Feb. 8, 2020).

[17] *Id*. at 15.

Using the information recently provided in the Third SpaceX Modification, it is possible to determine the aggregate collision risk of the modified constellation's design. While SpaceX originally stated that it "views satellite failure to deorbit rates of 10 or 5 percent as unacceptable, and even a rate of 1 percent is unlikely,"[18] SpaceX has recently indicated to the Commission that twelve of its satellites lost maneuver capabilities above their injection altitude out of 420 satellites.[19] This results in a failure rate of 2.86 percent. In its annual report for 2020, SpaceX also appears to indicate that three additional satellites have failed since responding to the Commission's inquiry.[20] Thus, the current failure rate for the SpaceX constellation stands at 3.14 percent as of last month, assuming none of the recently launched and yet-to-be tested 58 satellites will fail.

SpaceX has recently updated the collision risk assessment it previously provided to the Commission by taking into account the latest version of NASA's Debris Assessment Software.[21] The following collision risk numbers for satellites with sunshade panels that have lost maneuver capabilities were reported: 0.000053 for 540 km, 0.000108 for 560 km, and 0.000103 for 570 km.[22] Using these numbers, it is possible to calculate the aggregate collision risk for the Third

[18] SpaceX Response at 4.

[19] *See* Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Division, International Bureau, FCC, IBFS File No. SAT-MOD-20200417-00037, at 5 (filed May 15, 2020).

[20] *See* Letter from William M. Wiltshire, Counsel to SpaceX, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-LOA-20161115-00118 at 2 (filed June 23, 2020).

[21] *See* Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Division, IBFS File No. SAT-MOD-20200417-00037 (filed July 7, 2020).

[22] *Id.* at 2.

SpaceX Modification over a period of ten years, assuming a replenishment after five years of operation.[23]

Altitude Shell	540 km	550 km	560 km	570 km	Constellation
Initial number of satellites	1584	1584	520	720	4408
Total number of satellites over 10 years	3168	3168	1040	1440	8816
Total number of failed satellites at 3.14% failure rate	99	99	33	45	277
Probability of collision per satellite	0.000053	0.000088	0.000108	0.000103	
Aggregate probability of collision	0.0052585	0.008716	0.0035208	0.0046467	0.0219662

With the current 3.14 percent failure rate, the calculated aggregate probability of collision is 2.2 percent, *i.e.* a *120 percent increase* from the 1 percent risk described in the SpaceX 2016 License Application. The same calculation can be performed for a five percent failure rate, resulting in a 3.47 percent aggregate probability of collision, *i.e.* a *247 percent increase*. OneWeb respectfully submits that these failure rates constitute an unacceptable risk to the orbital environment and therefore would not serve the public interest.

Furthermore, given the Commission's current requirements for post mission disposal, SpaceX could claim a misleading 100% post-mission disposal rate for each failed satellite of the SpaceX constellation at the lower altitudes described in the Third SpaceX Modification without taking any further action.[24] For example, SpaceX's assertions that at lower altitudes "the Earth

[23] An average probability of collision value was used for the 550 km altitude as this information has not yet been provided by SpaceX.

[24] *See Mitigation of Orbital Debris in the New Space Age*, Report & Order and Further Notice of Proposed Rulemaking, 35 FCC Rcd 4156 ¶ 96 (2020) ("For purposes of calculating the probability of successful post-mission disposal, we define successful post-mission disposal for spacecraft in LEO as re-entry into the Earth's atmosphere within 25 years or less following completion of the spacecraft mission.").

and its atmosphere sweep the orbit clean" cause OneWeb to question whether SpaceX, going forward, will be adequately incentivized to improve the failure rate of its constellation.[25]

Based on the data provided by SpaceX and assuming the satellite failure rate remains at the current level, it appears that the aggregate collision risk of the SpaceX constellation could significantly increase with any potential grant of the Third SpaceX Modification. Simply put, OneWeb remains concerned that SpaceX's ongoing series of modifications unnecessarily jeopardize the safety of the orbital environment. To that end, pending further development of the record in this proceeding, the Commission should consider appropriate steps, as necessary, to ensure deployment of the SpaceX constellation is consistent with basic principles of orbital stewardship prior to any grant of the Third SpaceX Modification.[26]

III. SPACEX HAS FAILED TO SATISFY THE BURDEN TO DEMONSTRATE THAT THE THIRD SPACEX MODIFICATION WILL NOT INCREASE THE POTENTIAL FOR INTERFERENCE TO OTHER NGSO FSS SYSTEMS

In the Technical Attachment to the Third SpaceX Modification, SpaceX failed to provide an assessment of the potential interference impacts to the OneWeb NGSO FSS system (the "OneWeb System") in the Ka-band—which OneWeb utilizes for critical gateway connectivity—nor did SpaceX assess the potential for interference into SpaceX's own Ka- and Ku-band receive antennas from the OneWeb System.[27] Consistent with the Commission's approach of granting

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[25] Third SpaceX Modification at 7.

[26] As an example, OneWeb and OneWeb Satellites are leading the satellite industry in ensuring that multiple types of removal technology are developed and embedded in every satellite launched to prevent the creation of Space debris. *See, e.g.* OneWeb, *OneWeb and OneWeb Satellites Bolster Commitment to Responsible Space with Advanced Grappling Technology from Altius Space Machines* (Dec. 10, 2019), *available at* https://www.oneweb.world/media-center/oneweb-and-oneweb-satellites-bolster-commitment-to-responsible-space-with-advanced-grappling-technology-from-altius-space-machines.

[27] *See generally* Technical Attachment Annex 1.

modification applications only when such applications "do not cause interference to other licensed operations," SpaceX must provide such analyses in order to demonstrate that other co-frequency operators will be adequately protected.[28] As SpaceX itself has recognized, assertions of no-interference must be accompanied by "an analysis to support that assertion" or "detailed technical information needed for an analysis to validate such an assertion."[29] As explained in Sections III.A to III.C below, these missing analytical components demonstrate the negative impacts that any grant of the Third SpaceX Modification could have on OneWeb's operations. Thus, in order to demonstrate that grant of the Third SpaceX Modification would serve the public interest, this information must be provided.[30]

An additional outcome of SpaceX's proposal to lower the operational altitude of 2,824 satellites from 1,100-1,330 km to 540-570 km is that it will significantly increase the number of SpaceX gateway sites in the U.S. in order to provide the same level of service. Consequently, this will increase the probability of a SpaceX gateway earth station being collocated, or nearly

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[28] *See, e.g., DigitalGlobe, Inc.*, Order and Authorization, 20 FCC Rcd 15696, 15700 ¶ 9 (2005); *See also Space Exploration Holdings, LLC, Request for Modification of the Authorization for the SpaceX NGSO Satellite System*, Order and Authorization, 34 FCC Rcd 2526, 2530 ¶ 9 (IB 2020) (restating that the Commission's focus in conducting its public interest review is "in avoiding radiofrequency interference is consistent with the purpose of the Commission's processing round procedure, which is designed to establish the interference environment in which participants in the processing round could operate their systems.").

[29] *See* Comments of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20180319-00022, at ii (filed July 30, 2018).

[30] *See, e.g., The Boeing Company*, Order and Authorization, 18 FCC Rcd 12317, 12319 ¶ 7 (IB & OET 2003) ("[T]he Bureau has granted [modification applications] in cases where the proposed modification presents no significant interference problem and is otherwise consistent with Commission policies.");

collocated, with other NGSO operators' gateway earth stations.[31] Thus, as a general matter, the Commission should recognize that, on its own, SpaceX's proposal to significantly reduce the operational altitude of its constellation—resulting in an increased number of gateway earth stations—could materially worsen the NGSO interference environment in Ka-band.

A. The Information Presented in the Third SpaceX Modification Suggests SpaceX Will Increase Interference into OneWeb's Gateway Operations in the Ka-Band

SpaceX's proposed reduction in operational altitude necessarily requires associated changes to the minimum elevation angle of its gateway earth stations that will increase the potential for interference into the OneWeb System. In the SpaceX 2016 License Application, SpaceX stated that its Ka-band gateway earth stations would operate above a 40° minimum elevation angle once the system was fully deployed.[32] However, the Third SpaceX Modification proposes to decrease that minimum elevation angle to only 25°, and even as low as 5° degrees for latitudes above 62°.[33] Because OneWeb's gateway earth stations operate with a typical minimum elevation of 15°, the reduction of the SpaceX gateway earth station minimum elevation angle from 40° to 25° effectively increases the probability of in-line interference events. Additionally, the number of SpaceX satellites transmitting on the same frequency to a given gateway is increased from four to

[31] For example, SpaceX has submitted over 30 applications for gateway earth stations in the last six months. Some of these proposed gateway earth station sites are in close proximity to prior filed OneWeb applications for gateway earth stations. *See, e.g.*, IB File No. SES-LIC-20180727-02076 (OneWeb's application for a gateway earth station in Southbury, CT that is 12 km from SpaceX's proposed site in Litchfield, CT); *see also* IB File No. SES-LIC-20200410-00399 (SpaceX's application for SpaceX gateway earth station in Litchfield, CT).

[32] *See* SpaceX 2016 License Application, Technical Attachment at 13 ("As with user terminals, [SpaceX] gateways communicate only with satellites at an elevation angle of at least 40 degrees.").

[33] *See, e.g.*, Technical Attachment at 4-5.

eight, further contributing to the increase in the interference experienced by OneWeb's gateway earth stations.

In order to offset the degradation of the interference environment and the increase in the probability of in-line interference events, SpaceX proposes to drastically decrease the Ka-band downlink PFD of its system. The SpaceX 2016 License Application described a downlink PFD limit of -116 dBW/m^2/MHz, which the Third SpaceX Modification proposes to reduce by approximately 10 dB.[34] However, the results provided by SpaceX for interference into the Ka-band earth stations of O3b and Telesat are inconsistent with a 10 dB reduction.[35] Given that the operational characteristics of the O3b and Telesat earth stations should ostensibly be the same both before and after the proposed Third SpaceX Modification, OneWeb would expect the change in maximum Interfering-to-Noise Power Ratio ("I/N") to be equal to the reduction in PFD of the SpaceX downlink transmissions: 10 dB. SpaceX should address this discrepancy and precisely explain how its proposed modifications will not negatively impact OneWeb's Ka-band operations.

To assess the potential increase in interference experienced by a OneWeb gateway receiving earth station as a result of the Third SpaceX Modification, OneWeb performed a dynamic interference analysis.[36] In conducting this analysis, OneWeb made the following operational assumptions:

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[34] *Compare* SpaceX 2016 License Application, Schedule S *with* Third SpaceX Modification, Schedule S. SpaceX did not explicitly state the operational basis for its comparisons purporting to demonstrate the lack of interference to other co-frequency NGSO FSS operators as a result of the Third SpaceX Modification. OneWeb assumes such comparisons have been made using the parameters described in the SpaceX 2016 License Application as a baseline, but SpaceX should explicitly state the basis of its comparisons.

[35] *See* Technical Attachment at A1-5, A1-6.

[36] OneWeb notes the results provided by SpaceX for interference into the Ka-band earth stations of O3b and Telesat are inconsistent with such a reduction. Close examination of those results

- The SpaceX and OneWeb gateway earth stations are collocated at a latitude of 41.5°N. This is approximately the latitude where SpaceX has filed for a gateway 12 km away from an existing OneWeb gateway;[37]

- The OneWeb gateway consists of 20 antennas, tracking 20 of OneWeb's visible satellites. The SpaceX gateway consists of 4 and 8 antennas for the original and modified systems, respectively;

- Both the OneWeb and SpaceX systems employ a "longest pass" tracking strategy to select satellites, where the gateway antennas track the satellites that are calculated to be visible (*i.e.*, taking into account the GSO arc avoidance and minimum elevation constraints) for the longest periods of time;

- At each time step, I/N statistics are collected for each OneWeb downlink, noting that all 20 links show a similar behavior; and

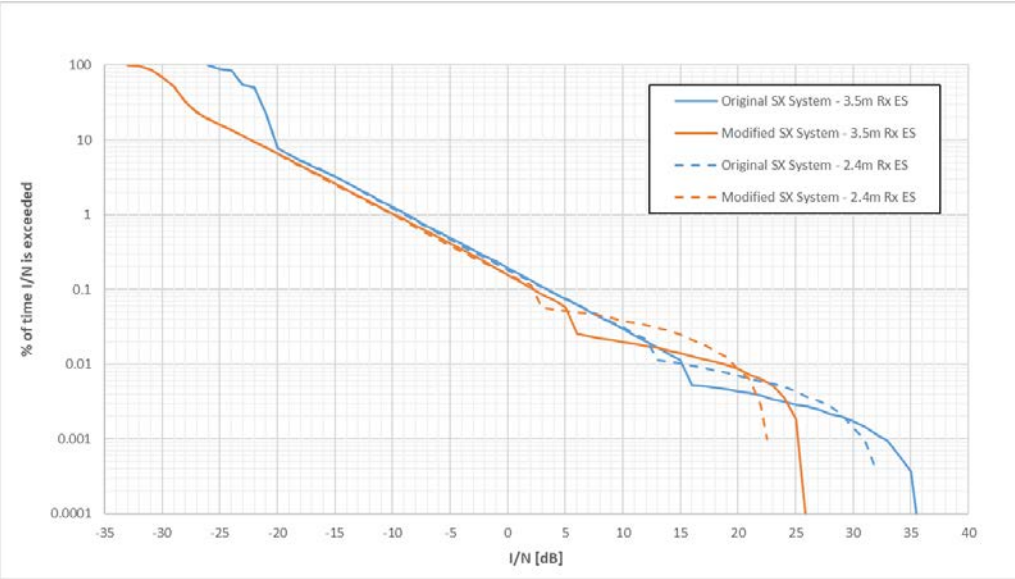
- The original SpaceX system radiates a downlink PFD of -116 dBW/m^2/MHz, while the modified system radiates a downlink PFD of -126 dB/m^2/MHz.

The Cumulative Distribution Functions ("CDF")—which indicate the probability that a given value is exceeded—of the I/N experienced by OneWeb's gateway earth station receive antennas are illustrated in Figure A below. Results for OneWeb earth station antennas of both 2.4m and 3.5m are presented.

shows that the difference in the maximum I/N experienced by the O3b and Telesat Earth stations is approximately 7 dB—not 10 dB. *See* Technical Attachment at A1-5 & A1-6.

[37] *See, e.g.*, IB File No. SES-LIC-20180727-02076 (application for OneWeb's gateway earth station in Southbury, CT that is 12 km from SpaceX's proposed site in Litchfield, CT); *see also* IB File No. SES-LIC-20200410-00399 (application for SpaceX gateway earth station in Litchfield, CT).

Figure A – Interference statistics (I/N) for SpaceX downlink into OneWeb Receive Gateway Earth Station
(Modified SpaceX System PFD = -126 dBW/m²/MHz)

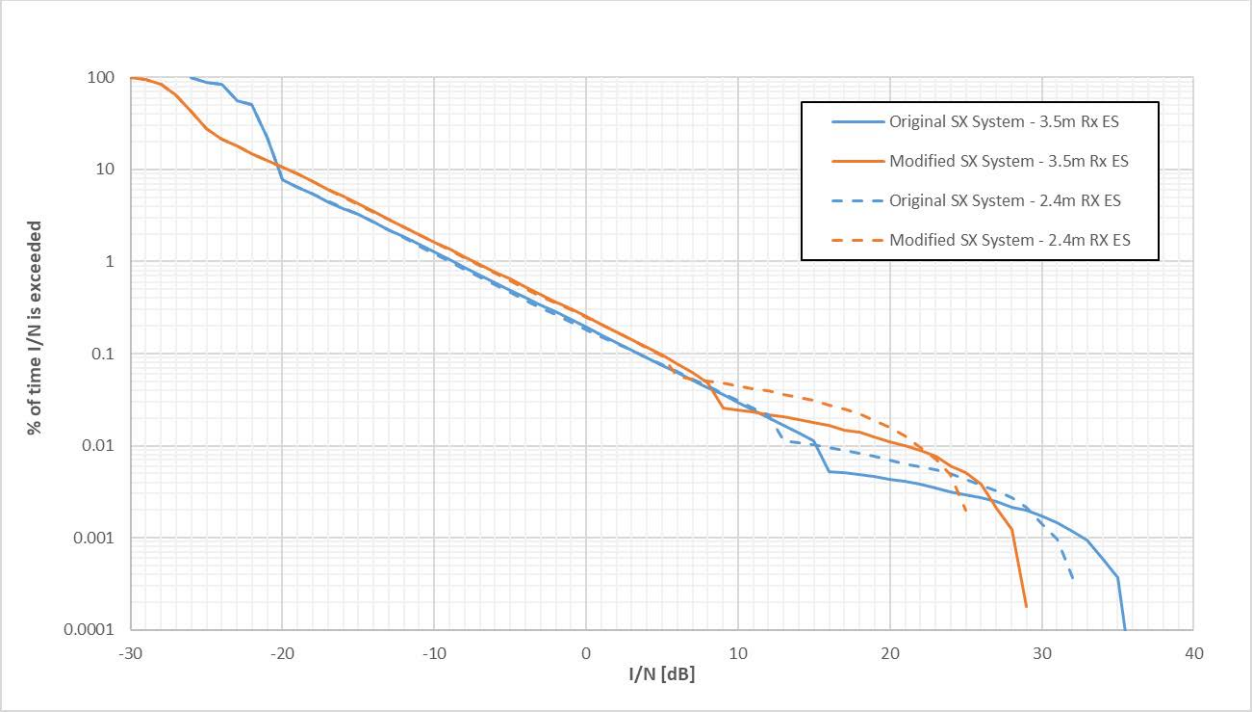


[38]

Figure A demonstrates that the decrease in minimum elevation angle of SpaceX's gateway earth stations—a consequence of lowering SpaceX's system orbit altitude—and the increase in the number of satellites transmitting to a SpaceX gateway would result in a degraded interference environment (*i.e.* the curves for the Third SpaceX Modification are wider), had it not been for the severe decrease in SpaceX's PFD (*i.e.* the curves for the Third SpaceX Modification are shifted 10 dB to the left). Given the inconsistency in PFD levels explained above, OneWeb also performed these dynamic simulations with a PFD for the Third SpaceX Modification of -123 dBW/m²/MHz, a reduction of 7 dB from the PFD stated in the SpaceX 2016 License Application consistent with the results of the analysis in the Third SpaceX Modification using the Telesat and O3b systems:

[38] Given the inconsistency explained in n. 36, *supra*, OneWeb performed these dynamic simulations with a PFD for the modified SpaceX NGSO FSS system using a value of -123 dBW/m2/MHz, *i.e.* a reduction of 7 dB—rather than 10 dB—from the PFD stated in the SpaceX 2016 License Application.

Figure B – Interference statistics (I/N) for SpaceX downlink into OneWeb Receive Gateway Earth Station
(Modified SpaceX System PFD = -123 dBW/m²/MHz



As demonstrated in Figure B, if the downlink PFD of the SpaceX satellites is reduced by 7 dB instead of 10 dB, the Third SpaceX Modification will increase the interference experienced by a OneWeb gateway earth station receiver in Ka-band for wide ranges of I/N values. In the case of an I/N value of -12.2 dB,[39] the percentage of time (*i.e.*, the period during which the I/N exceeds -12.2 dB) increases by *approximately 30 percent* for both the 2.4m and 3.5m gateway receive antennas as a result of the Third SpaceX Modification. Even for higher I/N values up to +5 dB, there is a similar increase in the percentage of time.[40] Thus, the foregoing analysis demonstrates

[39] The -12.2 dB value corresponds to the Commission's use of the ΔT/T exceeding 6 percent metric to define in-line interference events. *See* 47 C.F.R. § 25.261(c).

[40] The only meaningful part of the CDF graph where the percentage of time values are less as a result of the proposed modification is for I/N values less than -20 dB, where the theoretical improvement is irrelevant in practice and thus will have no operational effect. Similarly, the other instances where the percentages of time are improved by the Third SpaceX Modification relate to

that the Third SpaceX Modification has the potential to cause significant negative impacts to the downlink operations of OneWeb's gateway earth stations in the Ka-band.

B. SpaceX Should Clarify the Potential Changes to the Uplink Power Levels Which Could Increase Interference into OneWeb's Gateway Uplinks

SpaceX similarly failed to provide information regarding changes in the operating power levels of its planned Ka-band gateway earth stations as a result of the Third SpaceX Modification. However, based on the results provided by SpaceX for interference into the Ka-band uplink operations of O3b and Telesat, it appears that SpaceX plans to reduce the maximum uplink EIRP density of its gateway earth stations as part of the proposed modification.[41] However, it is unclear how much these uplink power levels will be reduced as the results presented for O3b and Telesat are inconsistent. For example, the change in the maximum I/N level between the SpaceX 2016 License Application and the proposed Third SpaceX Modification is different when comparing the change in I/N level to O3b's satellite receivers to the change in I/N level to Telesat's satellite receivers.[42]

Therefore, OneWeb respectfully requests that SpaceX clarify the extent to which it proposes to modify the uplink power levels from its Ka-band gateway earth stations as compared to the SpaceX 2016 License Application. Such information is critical to enable OneWeb to analyze the potential impacts of the Third SpaceX Modification on its gateway (feeder link) uplink operations in the Ka-band.

I/N values in excess of +24 dB to +27 dB, which are inconsequential because interference mitigation would be required at such high I/N levels..

[41] *See* Technical Attachment at A1-8 & A1-9.

[42] *Compare id*. at A1-8, Figure A1-10 *with id.* at A1-9, Figure A1-12.

C. SpaceX Must Accept Any Increased Interference into its Ka-Band Gateway Earth Stations Resulting from the Third SpaceX Modification

The degradation of the NGSO interference environment potentially caused by the proposed modification of SpaceX's orbital characteristics and associated tracking constraints could also result in higher levels of interference experienced by SpaceX's earth station receivers in Ka-band. SpaceX has indicated that the downlink PFD for Ka-band operations will be reduced by 10 dB in the Third SpaceX Modification.[43] As demonstrated below, such a drastic reduction will significantly impact the robustness of SpaceX's Ka-band downlink operations and materially increase its susceptibility to downlink interference. As a result, SpaceX should accept the operational consequences of this increased interference and not seek additional protection for its Ka-band downlinks.

Consistent with the analysis of the impact on the OneWeb Ka-band downlink operations provided in Section III.A above, OneWeb performed similar simulations to assess the increased interference experienced by SpaceX's Ka-band downlinks and the resulting impacts to the OneWeb system. In conducting this analysis, OneWeb made the following assumptions:

- The SpaceX and OneWeb gateway earth stations are collocated at a latitude of 41.5°N. This is approximately the latitude where SpaceX has filed for a gateway 12 km away from an existing OneWeb gateway;[44]

- The OneWeb gateway consists of 20 antennas, tracking 20 of the visible OneWeb satellites. The SpaceX gateway consists of 4 and 8 antennas for the original and modified systems, respectively;

- Two alternative strategies have been studied for the satellite selection. The first strategy ("highest elevation") assumes that the gateway antennas will communicate with the 20 (for OneWeb) and 4/8 (for SpaceX) satellites with the highest elevation. The second strategy ("longest pass") assumes that the gateway antennas track the satellites that are calculated

[43] *See supra* Section III.A.

[44] *See supra* n. 37.

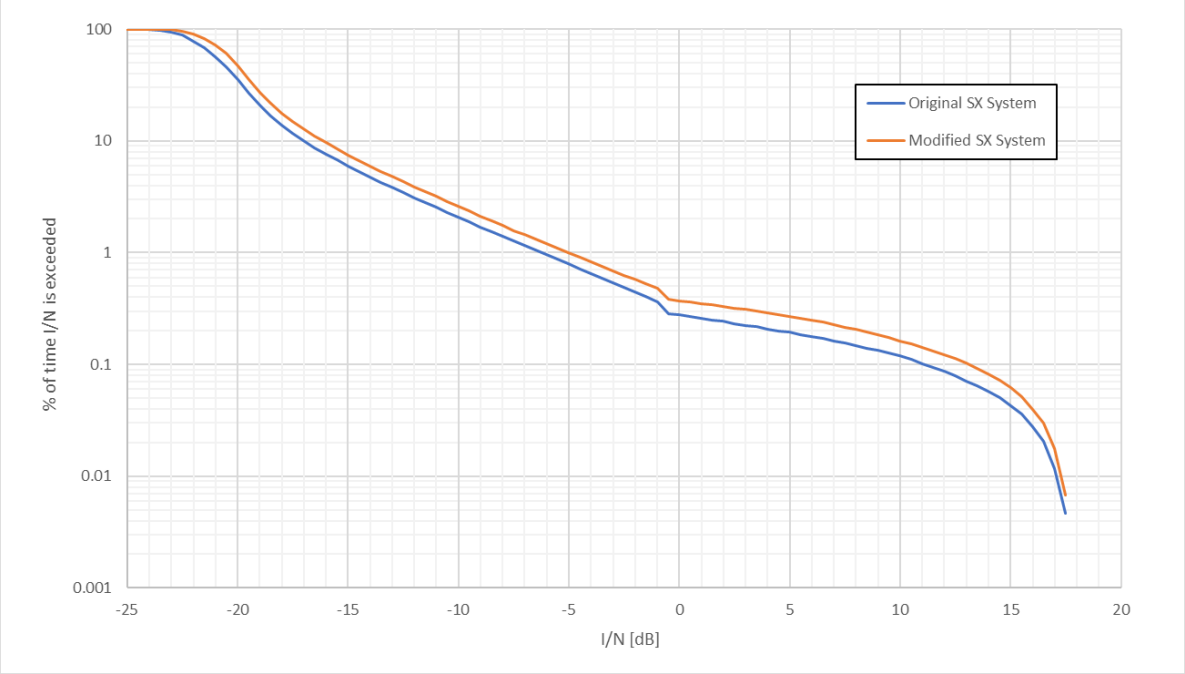
to be visible for the longest periods of time. In both cases, considerations such as the GSO arc avoidance angle and the earth stations' minimum elevation angles are also taken into consideration;

- At each time step I/N and C/I statistics are collected for each SpaceX downlink, noting that all 4 or 8 links show a similar behavior; and

- The original SpaceX system radiates a maximum downlink PFD of -116 dBW/m^2/MHz, while the modified system radiates downlink PFD of -126 dB/m^2/MHz, as stated by SpaceX.[45]

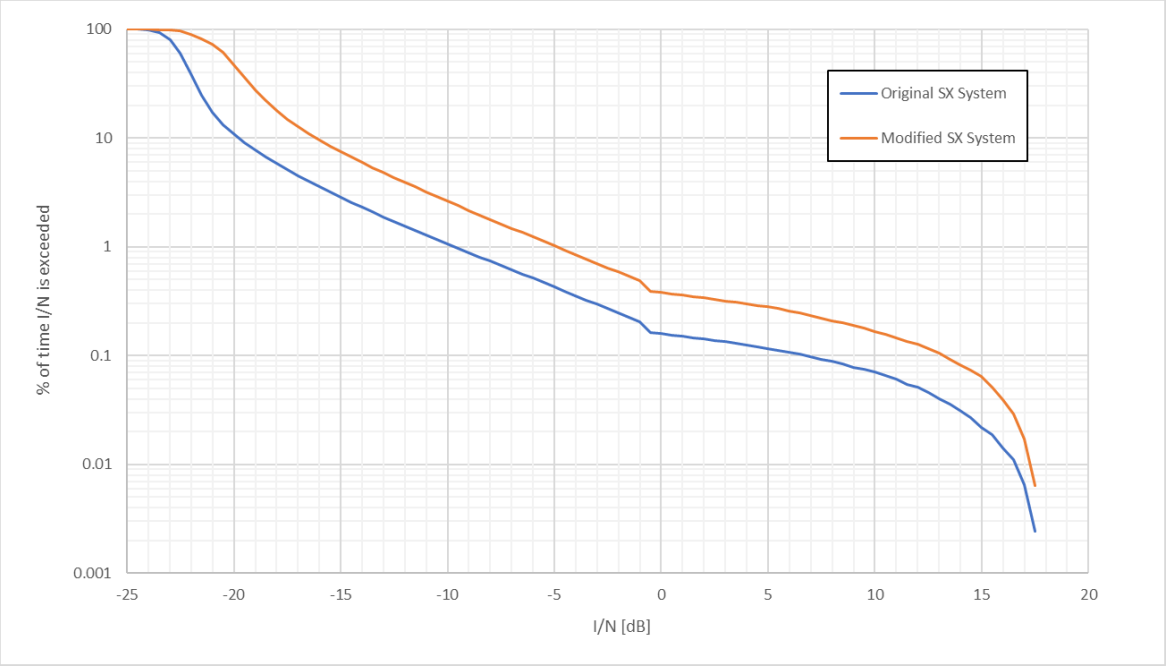
The first set of results presented below are the I/N statistics, which are calculated without considering a reduction in the SpaceX downlink PFD and demonstrate the degradation of the interference environment resulting from the reduction in minimum elevation angle of SpaceX's gateway earth stations. The I/N CDF for one of the SpaceX downlinks is presented in Figure C for the "longest pass" tracking strategy, and Figure D for the "highest elevation" tracking strategy.

Figure C – Interference statistics (I/N) for OneWeb downlink into SpaceX Rx ES (Tracking strategy: "longest pass")



[45] *See* SpaceX 2016 License Application, Schedule S; Third SpaceX Modification, Schedule S.

Figure D – Interference statistics (I/N) for OneWeb downlink into SpaceX Rx ES (Tracking strategy: "highest elevation")



Figures C and D above demonstrate that a grant of the Third SpaceX Modification could result in increased OneWeb downlink interference into the SpaceX receiving earth stations, irrespective of the tracking strategy selected. In the above-referenced case, the interference is worse for all I/N values. In the case of an I/N value of -12.2 dB, the percentage of time increases by *25 percent* when considering a "longest pass" tracking strategy and by *140 percent* with a "highest elevation" tracking strategy.

The negative effects of the Third SpaceX Modification experienced in the Ka-band operations of other NGSO systems is even more apparent when the reduction in the SpaceX downlink PFD is also taken into account. The increased interference susceptibility of SpaceX's gateway operations as a result of the reduction in downlink PFD can be assessed by analyzing the Carrier-to-Interfering Signal Power Ratio ("C/I") experienced by SpaceX's earth station receivers. Figure E below shows the C/I CDFs obtained in the simulation described above. These results

correspond to the operational scenario where both systems employ the "longest pass" tracking strategy. Therefore, this model constitutes a best-case assumption, as demonstrated by Figures C and D above.

Figure E – Interference statistics (C/I) for OneWeb downlink into SpaceX Rx ES (Tracking strategy: "longest pass")

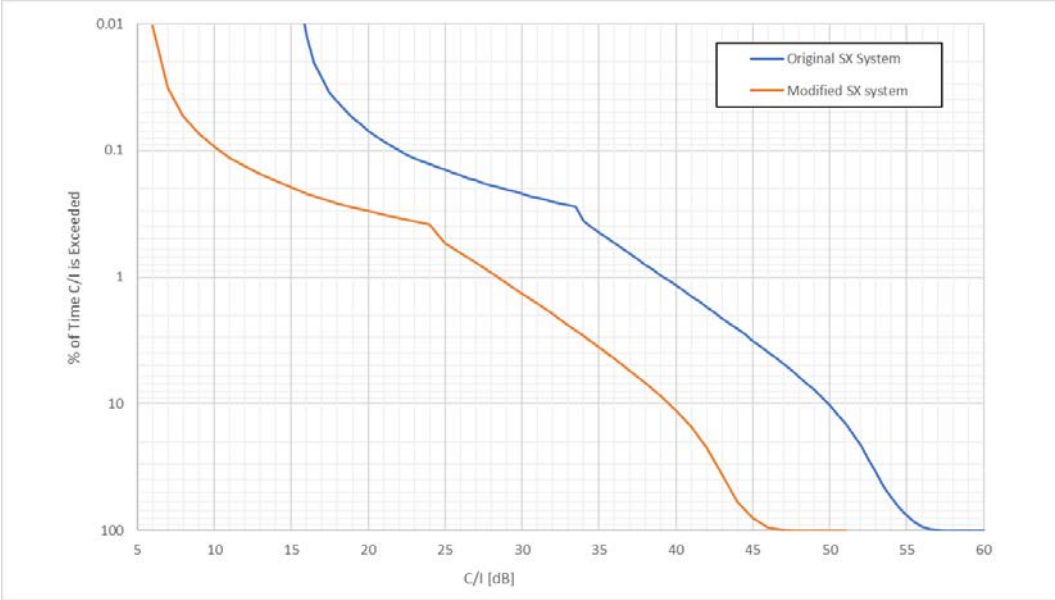


Figure E demonstrates that the SpaceX gateway receiving earth stations will experience significantly lower C/I levels as a result of the combination of the lower altitude orbits and the 10 dB reduction in PFD at the Earth's surface. In the SpaceX system proposed in the SpaceX 2016 License Application (blue line), the C/I experienced by the SpaceX gateway receivers was never below 16 dB, which is a level that should be quite tolerable for small amounts of time for modern satellite networks employing adaptive coding and modulation. However, as a result of the Third SpaceX Modification, the SpaceX system would experience a C/I as low as 6 dB (as shown in the orange line above), representing a significantly worse interference event that carries serious operational consequences. Consequently, OneWeb anticipates that SpaceX may request certain mitigation measures from other NGSO operators to protect its gateway receiving earth stations in

the Ka-band as a result of the proposed Third SpaceX Modification. In other words, OneWeb (and potentially other NGSO FSS operators in the Ka-band) could be unjustly forced to shoulder more stringent operational conditions as a result of any grant of the Third SpaceX Modification.

Therefore, the Commission must condition any grant of the Third SpaceX Modification such that SpaceX must not request additional protection for its Ka-band gateways as a result of the decrease in its Ka-band downlink PFD. Such a condition would protect the operations of OneWeb and other NGSO operators and also align consideration of the Third SpaceX Modification with prior Commission grants of SpaceX modification applications resulting in greater SpaceX susceptibility to interference.[46]

D. The Commission Must Clarify that Any Grant of the Third SpaceX Modification Will Be Conditioned on SpaceX Accepting the Additional Interference Its Space Station Receive Antennas Will Experience in Both Ka- and Ku-Bands

The proposed reduction in the orbital altitude of SpaceX's satellites will also result in its satellite receivers being more susceptible to interference. Given the reduction in free space path loss between the Earth and the SpaceX satellites, OneWeb calculates that the maximum level of interference experienced by the SpaceX user terminal and gateway uplink operations from the OneWeb earth station transmissions will increase by about 6 dB as a result of any grant of the Third SpaceX Modification. However, the impact of the reduction in SpaceX system's orbital altitude is not limited to the maximum level of interference. As demonstrated below, the increased interference susceptibility of the SpaceX K-band and Ku-band receivers is also evident when performing dynamic interference simulations.

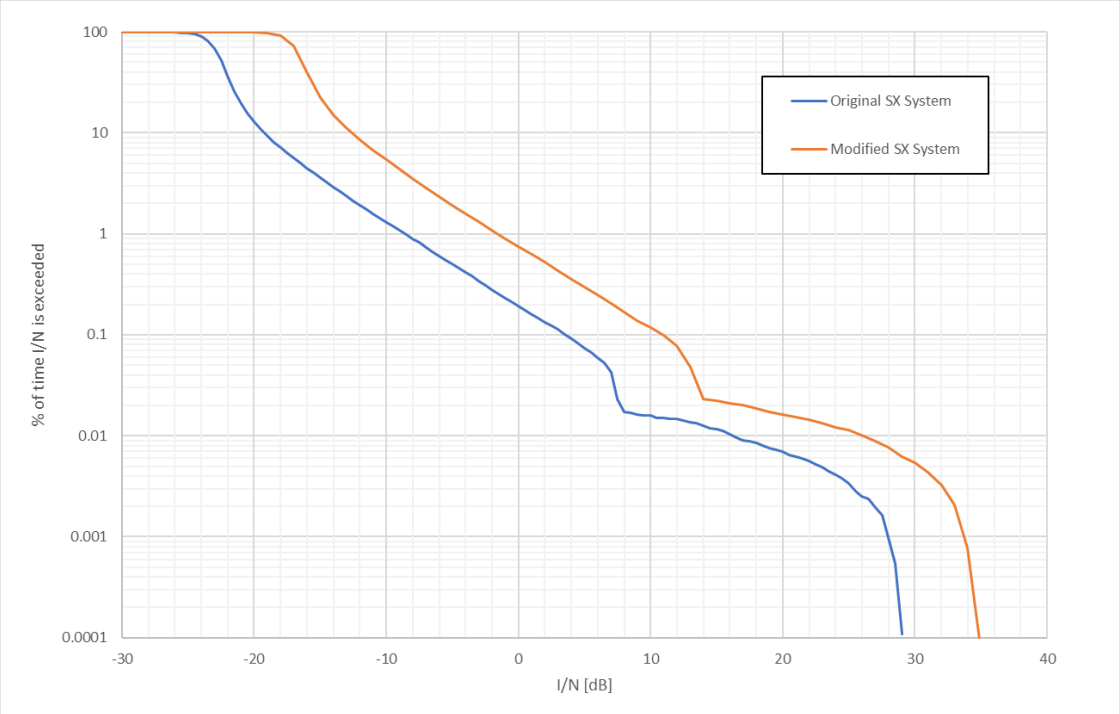
[46] *See, e.g., Space Exploration Holdings, LLC Request for Modification of the Authorization For the SpaceX NGSO Satellite System*, Memorandum Opinion & Order, DA 20-588, IBFS File No. SAT-MOD-20181108-00083, ¶ 16 (rel. June 4, 2020).

Regarding the Ka-band, OneWeb submits below a dynamic analysis evaluating the interference experienced by the Ka-band satellite receivers of the original and modified SpaceX systems from the operations of a collocated OneWeb gateway. In conducting this analysis, OneWeb relied on the operational conditions stated above, and in addition assumed:

- Both the OneWeb and SpaceX systems employ a "longest pass" tracking strategy to select satellites;
- At each time step I/N statistics are collected for each SpaceX uplink, noting that all 4 or 8 links show a similar behavior; and
- The same OneWeb gateway transmission parameters and SpaceX satellite receive system noise are used for both simulations.

The CDF of the I/N experienced by a SpaceX gateway uplink signal in the original and modified systems are presented in Figure F.

Figure F – Interference statistics (C/I) for OneWeb uplink into SpaceX Rx satellite (Tracking strategy: "longest pass")



These results unequivocally demonstrate that grant of the Third SpaceX Modification will result in SpaceX's Ka-band satellite receivers experiencing higher levels of interference. Note that the percentage of time the Commission's -12.2 dB I/N coordination trigger is exceeded increases from about two percent to about 8.5 percent, more than tripling the likelihood of such events. In the absence of successful coordination to resolve this scenario, band splitting would be required pursuant to the Commission's rules.[47] A similar result exists for almost any viable level of I/N that might be agreed upon between co-frequency NGSO operators during inter-operator coordination due to the very similar shape of the two curves in Figure F. Consequently, this outcome could result in SpaceX seeking more stringent operational conditions on OneWeb and other authorized Ka-band operators than those that would have otherwise been required for the system proposed in the SpaceX 2016 License Application.

The increased interference susceptibility of SpaceX's space station receive antennas is not limited to the Ka-band; the Ku-band presents similar issues. In the proceeding addressing the Second SpaceX Modification, SpaceX responded to OneWeb's comments highlighting the increased susceptibility of its Ku-band space station receive antennas to interference by providing in-line interference event statistics purporting to demonstrate that, even though the maximum interference to the SpaceX uplink operations was higher and the angle required to mitigate interference above the threshold establishing an in-line event increased, the actual total amount of time spent within in-line interference events decreased (*i.e*. the percentage of time associated with an I/N above -12.2 dB decreased with the proposed modification).[48] However, OneWeb has

[47] *See* 47 C.F.R § 25.261(c). *See also* Petition for Reconsideration of WorldVu Satellites Limited, IB Docket No. 16-408 (filed Jan. 17, 2018).

[48] *See* Opposition of Space Exploration Holdings LLC, and SpaceX Services, Inc., IBFS File No. SAT-MOD-20181108-00083 *et al.* at 8 & A-1 – A-6 (filed June 10, 2019) ("SpaceX Opposition"). *See also* Space Exploration Holdings, LLC, *Application for Modification of Authorization for the*

performed a fully dynamic interference analysis proving exactly the opposite: the percentage of time exceedance associated with any given I/N level would increase as a result of any grant of the SpaceX Third Modification.

The following study analyzes the dynamic, time-varying interference experienced by the SpaceX satellite receivers over a sufficient time period to produce meaningful statistics. OneWeb performed two sets of simulations to analyze the resulting change in the interference environment. In conducting this analysis, OneWeb has made the following operational assumptions:

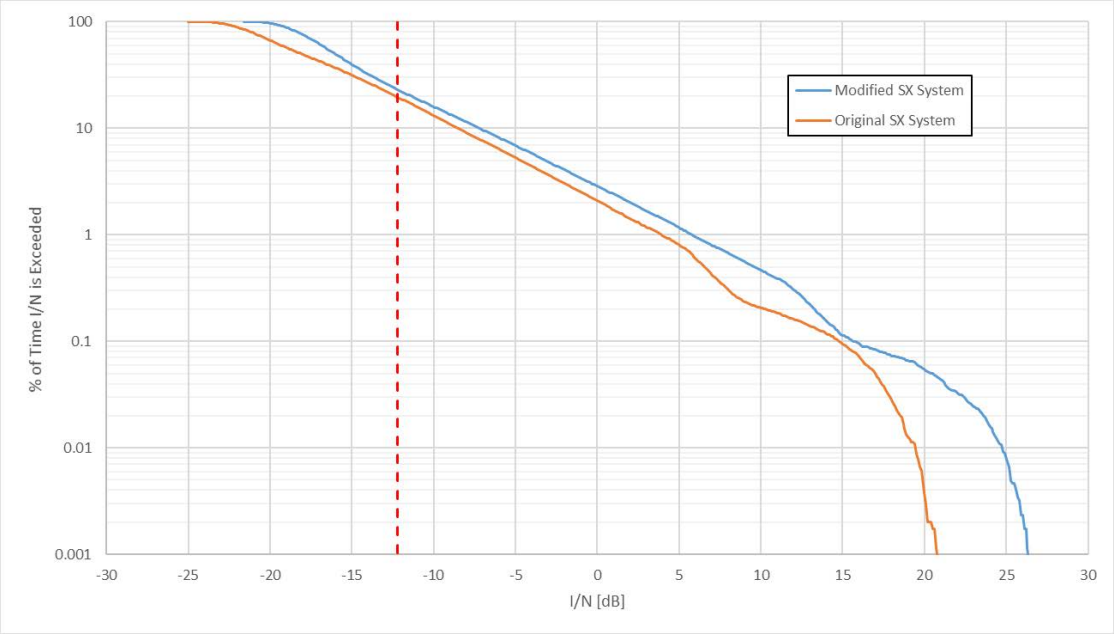
- The SpaceX and OneWeb user terminals (UT) are collocated at a latitude of 40°N;
- The OneWeb UT tracks the highest elevation OneWeb satellite in visibility, while complying with the relevant GSO arc avoidance and minimum elevation constraints;
- The SpaceX UT selects a random satellite at each time step, while complying with the GSO arc avoidance and minimum elevation constraints;[49] and
- At each time step I/N statistics at the satellite receiver are collected for the SpaceX uplink.

The CDF of the I/N experienced by a SpaceX Ku-band satellite receiver in the original and modified SpaceX systems are shown in Figure G.

SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20181108-00083 (filed Nov. 8, 2018) ("First SpaceX Modification").

[49] The minimum elevation angle of the SpaceX UT links was stated to be 40° in the SpaceX 2106 License Application, but this was changed to 25° in the Third SpaceX Modification. *See supra* n. 32-33.

Figure G – Interference statistics (I/N) for OneWeb uplink into SpaceX Satellite Receiver



At the short-term end of the CDF curve (*i.e.*, the highest levels of interference for the shortest percentage of time) the difference in interference between the two curves is approximately 6 dB and is accounted for by the reduced path length and path loss to the SpaceX satellites. However, Figure G demonstrates that the proposed Third SpaceX Modification will increase the interference experienced by the SpaceX Ku-band satellite receivers *for all percentages of time* on the CDF curve.

This is contrary to claims made by SpaceX with respect to the First SpaceX Modification, in which SpaceX erroneously concluded its simulations "demonstrate[d] that the modification substantially reduces both the duration of in-line events and the total percentage of time during which OneWeb would potentially be subject to the Commission's sharing rules."[50] The previous SpaceX analysis of this interference path purported to examine the interference situation only at a

[50] SpaceX Opposition at A-2.

single I/N level.[51] It is unclear how SpaceX's previous analysis failed to provide statistically correct results, but it may be because SpaceX was exploring an interim configuration of its system, where it proposed that only a portion of its constellation operate in lower orbits.

Regardless of the basis for this erroneous conclusion, OneWeb emphasizes that the performance of the fully modified SpaceX system is of critical importance. As demonstrated in Figure G above, the uplink interference into SpaceX from the transmitting earth stations of other Ku-band NGSO systems is increased by the proposed Third SpaceX Modification. Simply put, if this potential interference susceptibility increase is not remediated by the Commission in any grant of the Third SpaceX Modification, then other NGSO operators will be unfairly burdened with resolving interference issues which have been generated as a result of the Third SpaceX Modification. Additionally, in the absence of a coordination agreement between other NGSO operators and SpaceX, the total time that a user terminal would experience an in-line interference event—and during which band-splitting could be required—would increase, resulting in additional burdens for other NGSO operators.

Therefore, OneWeb restates its request that the Commission condition grant of the Third SpaceX Modification such that SpaceX accept any additional interference caused by its orbit altitude modification. Such an outcome would (1) ensure that other NGSO operators are not unfairly required to provide additional interference protection to SpaceX, (2) incentivize the efficient utilization of spectrum resources and (3) appropriately place the burden for addressing these increased interference events on SpaceX.

[51] The previous SpaceX analysis did not include a CDF of the I/N for all percentages of time. This approach is now regularly used in the ITU as a means of assessing the interference caused by time-varying NGSO systems.

IV. CONCLUSION

For the foregoing reasons, OneWeb respectfully submits that grant of the Third SpaceX Modification would negatively impact the NGSO interference environment and create potentially troubling scenarios with respect to in-orbit collision risk and potential debris-generating events. As such, OneWeb urges the Commission to carefully evaluate the record in this proceeding prior to any action on the Third SpaceX Modification, and ensure any grant includes appropriate license conditions to address these critical issues.

Respectfully Submitted,

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July 13, 2020

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

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

Dated: July 13, 2020

/s/ Marc Dupuis

Marc Dupuis
Telecomm Strategies

CERTIFICATE OF SERVICE

I, Eamon Tierney, certify that I have on this 13th day of July, 2020, caused a copy of the foregoing Comments of OneWeb to be served on the persons identified in the Comments via electronic mail:

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Eamon Tierney