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April 15, 2019

BY ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, DC 20554

Re: *Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20181108-00083; WorldVu Satellites Limited, IBFS File No. SAT-MOD-20180319-00022*

Dear Ms. Dortch:

In this proceeding, Space Exploration Holdings, LLC ("SpaceX") seeks to modify its existing authorization to deploy and operate a non-geostationary orbit ("NGSO") satellite system to relocate 1,584 satellites previously authorized to operate at 1,150 km to 550 km and allow a limited number of first-generation satellites to use Ku-band spectrum for gateway operations.[1] SpaceX designed this modification to enhance the already considerable safety attributes of its NGSO system and allow SpaceX to operate at even lower power levels. In reply comments and a recent ex parte,[2] WorldVu Satellites Limited ("OneWeb") has raised shifting arguments to question SpaceX's technical analysis that shows that the proposed modification will not result in additional interference to other NGSO systems, including OneWeb.[3] As discussed below, OneWeb consistently ignores facts on the record and demands new analyses that are neither required under Commission rules nor, tellingly, consistent with the approach that it has used for its own interference analyses. Nonetheless, to alleviate any remaining concerns, SpaceX provides yet more analysis to demonstrate that even under OneWeb's proposed approach, SpaceX's bottom-line conclusion does not change – its proposed modification simply does not increase interference.

Several aspects of the proposed modification combine to further reduce the potential for radiofrequency interference beyond the operations that the Commission already authorized SpaceX to conduct. For example, SpaceX proposes to decrease slightly the number of satellites in its constellation from 4,425 to 4,409. In addition, operating at a lower altitude will reduce radiofrequency interference in two fundamental ways: fewer satellites will be visible above the

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1 *See* Application for Modification of Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20181108-00083 (Nov. 8, 2018) ("SpaceX Modification"). Unless otherwise noted, all submissions cited herein were filed in this same IBFS file.

2 *See* Reply of WorldVu Satellites Limited (Mar. 5, 2019) ("OneWeb Reply"); Letter from Brian D. Weimer to Marlene H. Dortch (Apr. 3, 2019) ("OneWeb Ex Parte").

3 *See* Further Consolidated Opposition to Petitions and Response to Comments of Space Exploration Holdings, LLC (Feb. 21, 2019) ("SpaceX Response").

minimum elevation angle at any particular time at any point in the U.S., and the satellites will transmit and receive at lower power levels. As SpaceX noted in its application, in granting a previous NGSO modification application, the Commission recognized such factors as demonstrating that a modification will not increase interference to other NGSO systems.[4]

OneWeb does not try to address (much less refute) this Commission precedent or the common-sense factors on which it is based. Instead, it offers varying critiques of certain aspects of SpaceX's analysis, but does not – because it cannot – demonstrate that implementation of its preferred approach would yield a different conclusion. To be clear, OneWeb has all the data necessary to provide its own analysis to the Commission, but it repeatedly chooses not to do so. OneWeb's approach to criticize but not analyze seems explicitly designed to sow confusion rather than bring clarity to the record. But despite these efforts, SpaceX's analysis below will show once again that the results are the same regardless of the process.

In its critique, OneWeb takes no issue with the operation of up to one million SpaceX user terminals in the Ku-band.[5] Instead, it has focused on SpaceX's proposal to use as part of its initial operations a few gateways in Ku-band spectrum, involving up to four satellites communicating with a single site at one time. OneWeb consistently repeats its unsupported claim of widespread interference while ignoring the established facts in the record that SpaceX will use only a limited number of gateways communicating with a limited number of satellites in the Ku-band. For example, OneWeb continues its baseless assertion that SpaceX will deploy "hundreds" of Ku-band gateways across the U.S.[6] To the contrary, as SpaceX previewed in its Response, SpaceX has filed applications for ***just six Ku-band gateways*** in the U.S.[7] – and has no current plans to request more.

SpaceX made clear in its modification application that only a limited number of first-generation satellites will use the Ku-band for gateway communications for a discrete period of time, until it transitions to Ka-band for gateways communications. Specifically, SpaceX anticipates that it will deploy ***fewer than 75 satellites*** that use Ku-band spectrum for gateway operations. As a practical matter, four of these first-generation satellites will rarely, if ever, converge and communicate simultaneously with a given Ku-band gateway. Accordingly, the worst-case scenario envisioned by OneWeb is unlikely to ever occur and, even if it did, would only be possible over six locations in the U.S. for a limited period. OneWeb's asserted fear seems even more specious given that it has not even applied for a single Ku-band earth station license in

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4 *See Teledesic LLC*, 14 FCC Rcd. 2261, ¶¶ 13, 17 (IB 1999) ("*Teledesic*").

5 *See* IBFS File No. SES-LIC-20190211-00151 (requesting blanket license for up to 1,000,000 Ku-band user terminals).

6 *See, e.g.,* Petition to Deny or Defer of WorldVu Satellites Limited at i (Feb. 8, 2019).

7 *See* IBFS File Nos. SES-LIC-20190402-00425, -00426, -00427, -00450, -00451, and -00454.

the U.S. that could be affected. Moreover, the possibility of an actual in-line event seems even less likely now that OneWeb has announced it plans to use antennas with "full steerability."[8]

Below we address several specific arguments raised by OneWeb to demonstrate that its critique of the analysis submitted by SpaceX is not valid. As noted above, although the technical details of SpaceX's proposed operations are a matter of public record, OneWeb tellingly has not seen fit to present the results of any alternative interference analysis to substantiate its critique. This notable absence is likely explained by the fact that, as shown below, conducting the analysis as OneWeb would prefer does not change the conclusion that the proposed modification will not increase interference to other NGSO users.

A. Selection of Methodology for Analysis

OneWeb initially criticized SpaceX for framing its analysis based on a worst-case approach (choosing links with the highest absolute I/N values), suggesting that SpaceX should instead use a best-case approach (choosing the lowest I/N at each time step).[9] As SpaceX demonstrated, OneWeb itself does not use this best-case approach when it submitted an interference analysis to the International Telecommunication Union ("ITU") in May 2017 to support its own proposed NGSO system modifications.[10] In its most recent ex parte, OneWeb essentially concedes this point,[11] but now contends that SpaceX should have used some other methodology (*e.g.*, highest elevation, longest hold, or random) to choose the links for assessment.[12]

By presenting the worst I/N for OneWeb from both SpaceX's currently-authorized constellation and under the proposed modification, SpaceX described an envelope that would depict all possible I/N values of a deployed system. In effect, this demonstrates that even in such a worst-case scenario, the I/N from SpaceX's proposed modified constellation would be at least equal to – and often better than – the I/N from the currently authorized system. Such a worst-case analysis is a common approach when evaluating potential interference.[13]

Nonetheless, SpaceX recognizes different methodologies could be used to choose which satellite links to evaluate for purposes of developing a cumulative distribution function ("CDF")

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[8] Tweet by OneWeb CEO Greg Wyler (March 29, 2019) ("Thin is in! Results of the Software Defined Antenna are super encouraging, achieving 19dBi of gain with *full steerability* and true time delay in a small tile. The AI control software is learning more every day, creating surprisingly good performance improvements." (emphasis added)), available at https://twitter.com/greg_wyler/status/1111659447816982535.

[9] *See* OneWeb Reply at 3-5.

[10] SpaceX attached OneWeb's submission (the "OneWeb ITU Analysis) as Exhibit 2 to Letter from William M. Wiltshire to Marlene H. Dortch (Mar. 18, 2019). Notably, OneWeb did not present such an interference analysis *to the Commission* in connection with its own requests for changes to its NGSO systems. *See* IBFS File Nos. SAT-AMD-20180104-00004 and SAT-MOD-20180319-00022.

[11] *See* OneWeb Ex Parte, Presentation at 6 (listing three potential approaches and indicating that the L5 filing does not fall under the "Best-Case I/N").

[12] *See* OneWeb Ex Parte at 4-5 and Presentation at 6.

[13] For example, as the Commission has recognized, the software used to evaluate NGSO systems' compliance with equivalent power flux-density limits in the Ku-band employs worst-case parameters, and "thereby simulates an

of aggregate I/N levels. In an abundance of caution, SpaceX re-ran its interference analysis using two of the alternatives recommended by OneWeb (highest elevation and random) to determine whether doing so would yield a different conclusion. The results are presented in Attachment A hereto. All these methodologies, even those endorsed by OneWeb, confirm that interference will be no worse (and typically better) under the proposed SpaceX modification than under the current authorization. Accordingly, the Commission should reject OneWeb's theoretical critique that does not prove out given SpaceX's practical demonstration.

B. Use of Unrealistic Assumptions

OneWeb also criticizes SpaceX's analysis as not accurately reflecting its own operations, since SpaceX would not choose the worst-case link at each time step[14] – a fact that SpaceX noted itself.[15] However, this is by no means unusual in an interference analysis, where proponents make simplifying assumptions that cut against their case to show that the results are positive nonetheless. Indeed, OneWeb followed this approach in the interference analysis it submitted to the ITU, using what it admitted was an extremely unlikely worst-case scenario for elevation angles to show that the more likely operating conditions would be even more favorable to other NGSO systems.

> Although it is extremely unlikely that, in practice, such low elevation L5 satellites would be transmitting towards this same victim earth station location, this is the approach for calculating the worst-case interference, based on the fact that the L5 satellite antenna beams are steerable in the L5 ITU filing. In reality, the L5 system will operate at much higher elevation angles so the total interference into the victim system will be much less than predicted in this analysis.[16]

Moreover, OneWeb's analysis assumes that all of its satellites above a given elevation angle would be "simultaneously radiating their peak EIRP density towards the victim earth station," even though the NGSO system OneWeb's application states that it intends to deploy does not have steerable Ku-band beams.[17] Thus, the use of counterfactual worst-case assumptions in an interference analysis should be familiar to OneWeb. Moreover, by far the most significant counterfactual assumption in SpaceX's analysis is that there will be thousands of Ku-band-only satellites communicating with gateway earth stations if the modification is granted, when in fact there will be no more than 75 satellites communicating with just six gateways. Revising SpaceX's

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'outer envelope' of acceptable interference by any NGSO FSS system." *Virtual Geosatellite, LLC*, 21 FCC Rcd. 14687, ¶¶ 22-24 (IB 2006).

[14] *See* OneWeb Reply at 4.

[15] *See* SpaceX Response, Attachment A at A-5.

[16] *See* OneWeb ITU Analysis at 5 footnote 2.

[17] *See id.* at 5; Application, IBFS File No. SAT-LOI-20160428-00041, Attachment A at 7 (filed Apr. 28, 2016) ("Each OneWeb satellite will have 16 nominally identical *user beams*, operating in Ku-band, each consisting of a non-steerable highly-elliptical spot beam."). As noted above, however, OneWeb has announced it is now developing antennas with full steerability.

analysis to reflect those facts alone would have revealed significant improvements over the already favorable interference environment for other NGSO systems post-modification.

C. Interference Analysis for OneWeb's User Terminals

OneWeb also asserts that, in order to determine the "true worst-case differences in I/N," SpaceX should provide an analysis using OneWeb's user terminals in addition to the analysis of OneWeb's gateway antennas that SpaceX has already provided.[18] Accordingly, SpaceX re-ran its analysis using a range of antennas from OneWeb's L5 ITU filing. As shown in Attachment A, SpaceX's analysis reveals that the gain of the OneWeb antenna used in the analysis does not alter the bottom-line result. This analysis confirms that the proposed modification will not increase potential interference into OneWeb's earth station antennas of any size – neither user terminals nor gateways – compared to SpaceX's currently authorized constellation.

D. Interference Analysis for SpaceX's Maximum and Minimum Gain Antennas

OneWeb argues that SpaceX's analysis is incomplete because it does not include a range of SpaceX earth station types, and specifically calls for the analysis to consider antennas with maximum and minimum gain.[19] In response to this critique, SpaceX has re-run its analysis using the minimum and maximum gain antennas submitted with its ITU filing. Here again, as shown in Attachment A, the gain of the SpaceX antenna does not alter the conclusion that the proposed modification will not increase interference compared to the currently authorized constellation.

E. Choice of Single Latitude for Analysis

OneWeb argues that SpaceX should have conducted its analysis using more than one latitude for earth station location.[20] For purposes of the I/N analysis, SpaceX assumed that the earth stations of both the SpaceX and OneWeb systems are collocated. To capture the worst-case aggregate interference under the proposed modification, SpaceX selected the latitude for these earth stations at which the greatest number of SpaceX satellites in the modified constellation would be visible. As shown in the figure below, the probability of satellites visible above a 10 degree elevation angle is greatest at 50 degrees North latitude. Accordingly, SpaceX used that parameter for its analysis. SpaceX also conducted the analysis (but did not present results) using other latitudes and found that the impact of this variable was very small – just as OneWeb has recognized in its own analyses.[21]

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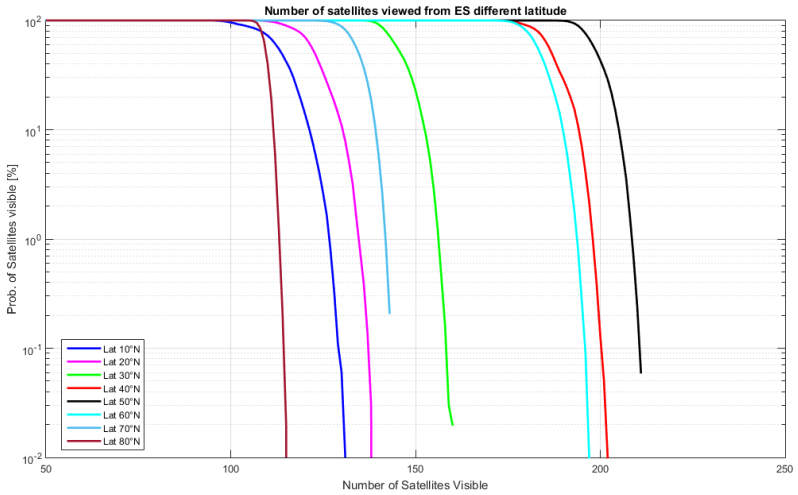
[18] *See* OneWeb Reply at 6.

[19] *See id.*

[20] *See id.*; OneWeb Ex Parte, Presentation at 3.

[21] *See* OneWeb ITU Analysis at 6 (results at varying latitudes "are very similar").



Number of Visible SpaceX Satellites at Various Latitudes

Finally, OneWeb has taken yet a new turn in its most recent ex parte meetings, asking that the Commission act on its own application for modification "contemporaneously" with SpaceX's application.[22] Yet despite OneWeb's repeated demand for increasingly detailed and specific analysis from SpaceX – which SpaceX has consistently provided – OneWeb has resisted providing virtually any analyses of the interference or space safety profiles of its own system as modified to nearly triple the number of active satellites (from 720 to 1,908) in its NGSO constellation. If OneWeb truly seeks regulatory parity, it should provide the same analyses that it has demanded from SpaceX for its own proposed system modification before asking the Commission to act on its still bare-bones application.

* * *

The technical analyses submitted by SpaceX confirm what Commission precedent and common sense already recognize – a modification that proposes to operate fewer satellites at lower power will not increase interference to other NGSO systems. The Commission should reject OneWeb's flawed arguments to the contrary.

Sincerely,

William M. Wiltshire
Counsel to SpaceX

22 *See, e.g.,* OneWeb Ex Parte at 2.

cc: Rachael Bender
William Davenport
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Jose Albuquerque
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Kerry Murray
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ATTACHMENT A

Revised Dynamic Interference Analysis for OneWeb System

SpaceX has previously presented an analysis evaluating whether the proposed modifications to its NGSO system would increase interference to OneWeb's NGSO system. That analysis considered the dynamic, time-varying interference expressed as a cumulative distribution function ("CDF") of the interference-to-noise ratio ("I/N"), for varying percentages of time. The I/N CDF was derived from a time-domain simulation of the two NGSO systems over a long enough time to produce meaningful statistics. To present a worst-case assessment of the interference environment, the analysis made several assumptions. First, the SpaceX and OneWeb earth stations were assumed to be collocated. Second, the collocated earth stations were assumed to be located at 50° N latitude, where the largest number of SpaceX satellites from the proposed modified constellation will be visible. Third, the analysis assumed that the SpaceX earth station was a gateway rather than a user terminal, such that up to four SpaceX satellites could transmit co-frequency, co-polar Ku-band beams at the same time. Lastly, the analysis selected the four interfering SpaceX satellites with smallest off-axis sepration angle from a given OneWeb earth station to communicate with the collocated gateway station at each time step.

OneWeb asserts that this analysis should be conducted using a different approach to this last assumption. Specifically, it suggests that choosing links for analysis based on the SpaceX satellite with the highest elevation, or choosing SpaceX satellites at random, would be more appropriate. In addition, OneWeb argues that SpaceX should consider more than one type of OneWeb earth station antenna, and the lowest and highest gain antennas SpaceX plans to use. In order to determine whether proceeding as OneWeb suggests would affect the analysis, SpaceX re-ran its analysis employing each of those alternative methodologies.

For purposes of this new analysis, SpaceX used the network filings made by SpaceX and OneWeb to determine an appropriate range of earth station antennas to consider. Specifically, the downlink interference analysis considered OneWeb earth station antennas with the lowest gain (21.6 dBi), mid-range gain (31.1 dBi), and highest gain (41.6 dBi) from the L5 ITU network filing. Similarly, the uplink interference analysis considered SpaceX's lowest gain (27 dBi) and highest gain (53.9 dBi) earth station antennas from the STEAM-1 ITU network filing and the lowest gain (19.9 dBi) and highest gain (31.9 dBi) space station antennas from the L5 ITU network filing. For each of these analyses, SpaceX assessed interference using a worst-case satellite approach, a highest elevation satellite approach, and a random selection satellite approach. The results are set forth below. In each case, the figure plots a CDF of aggregate I/N levels for the SpaceX constellation as originally proposed and as modified, using the approach indicated.

As these figures demonstrate, the new interference levels resulting with the modification are no worse (and often better) than the interference levels that would have been experienced with the original constellation for all percentages of time, even using the methodologies suggested by OneWeb. Accordingly, the I/N CDF analysis confirms that the modification will not increase the potential interference into other NGSO systems

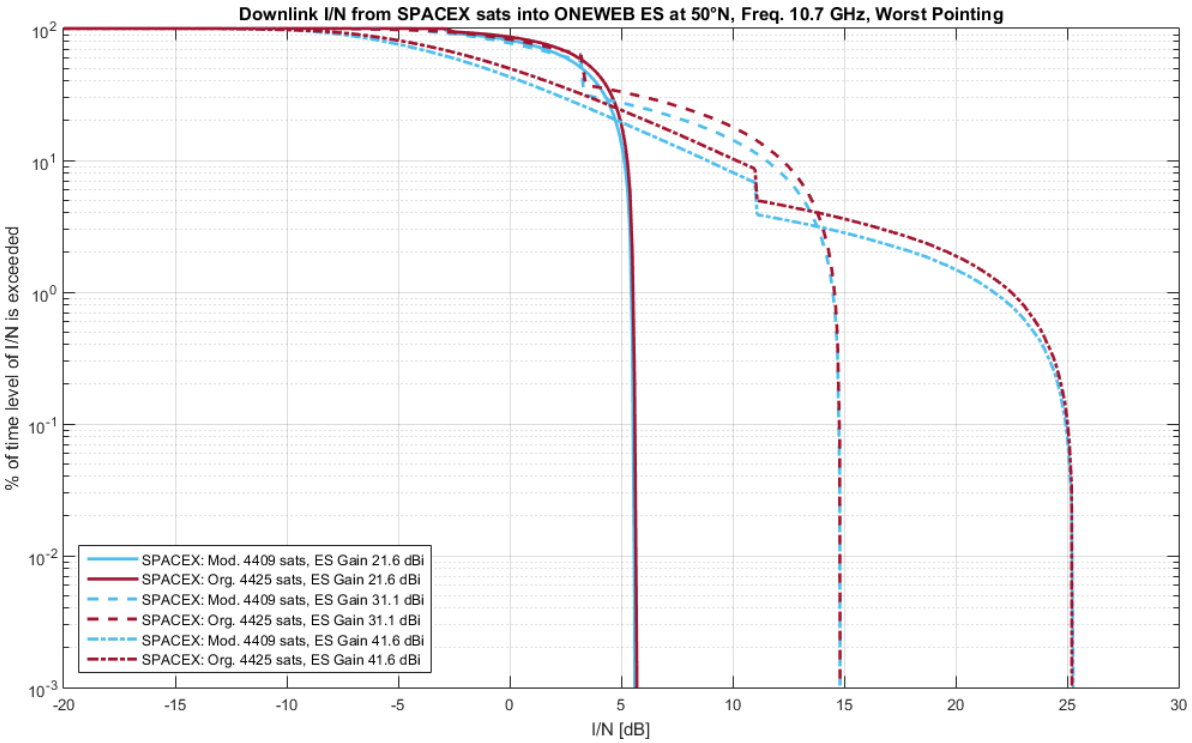

Figure 1. Downlink Comparison for Various OneWeb Antennas – Worst-Case

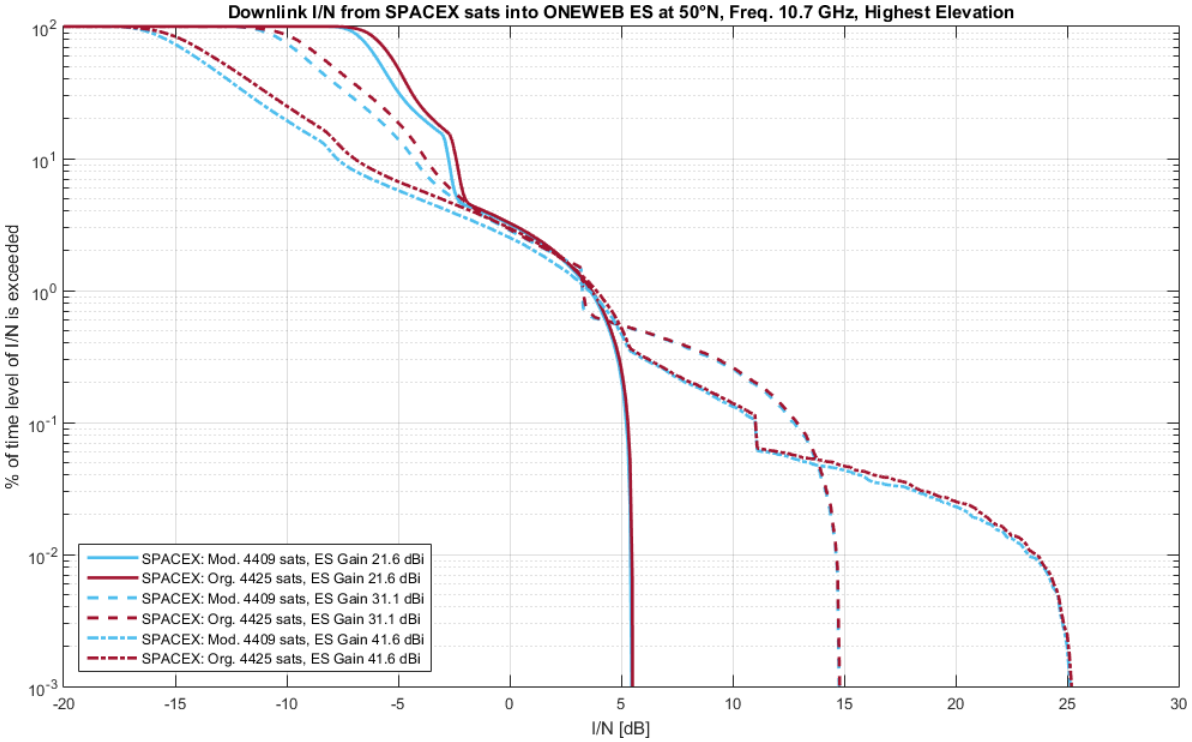

Figure 2. Downlink Comparison for Various OneWeb Antennas – Highest Elevation

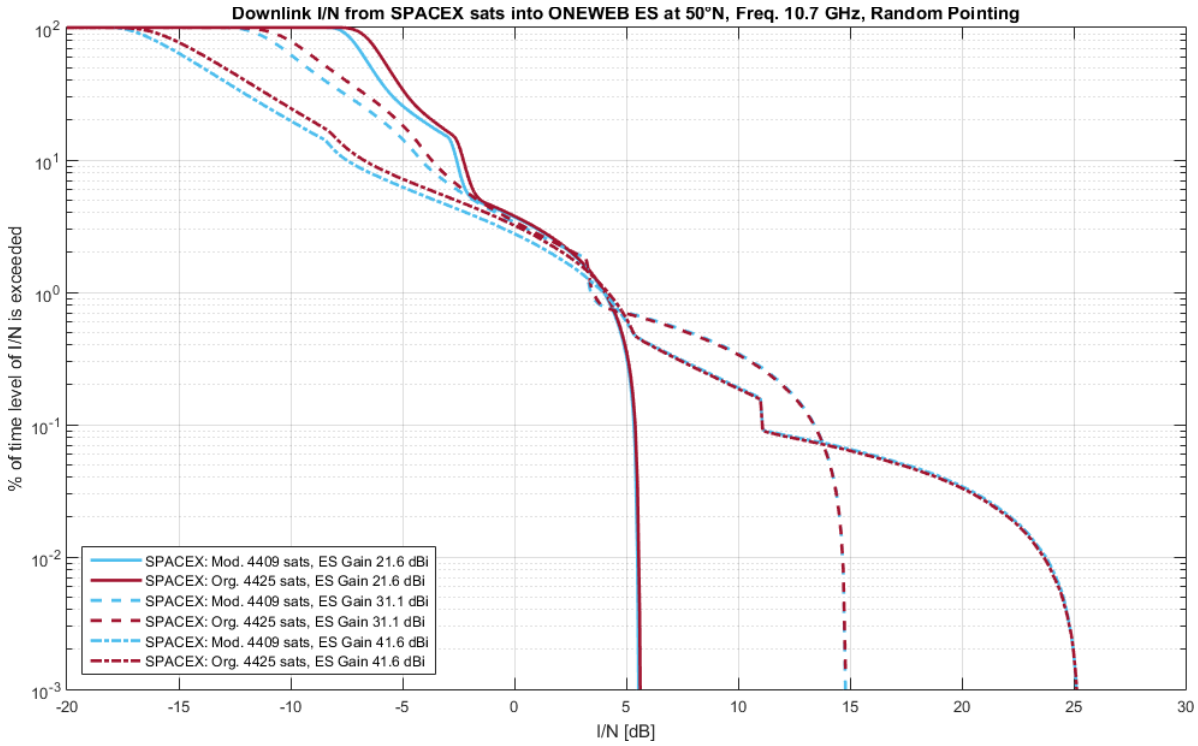

Figure 3. Downlink Comparison for Various OneWeb Antennas – Random

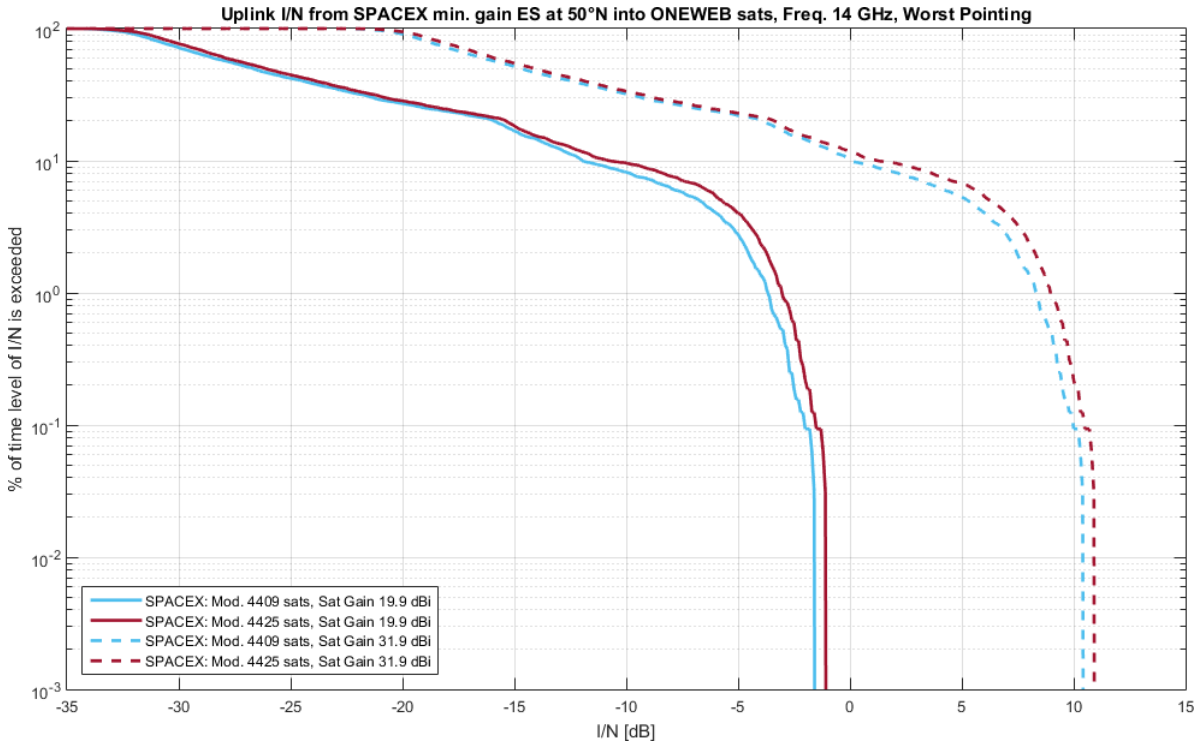

Figure 4. Uplink Comparison for Minimum Gain SpaceX Antenna – Worst-Case

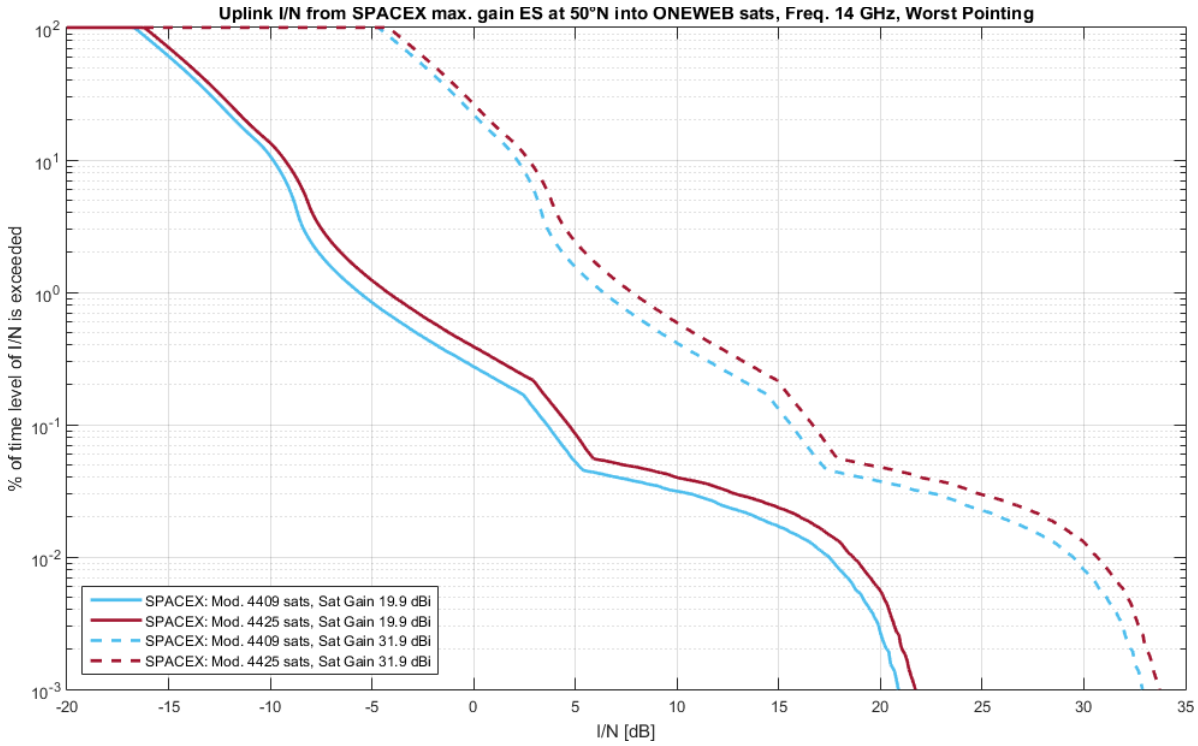

Figure 5. Uplink Comparison for Maximum Gain SpaceX Antenna – Worst-Case

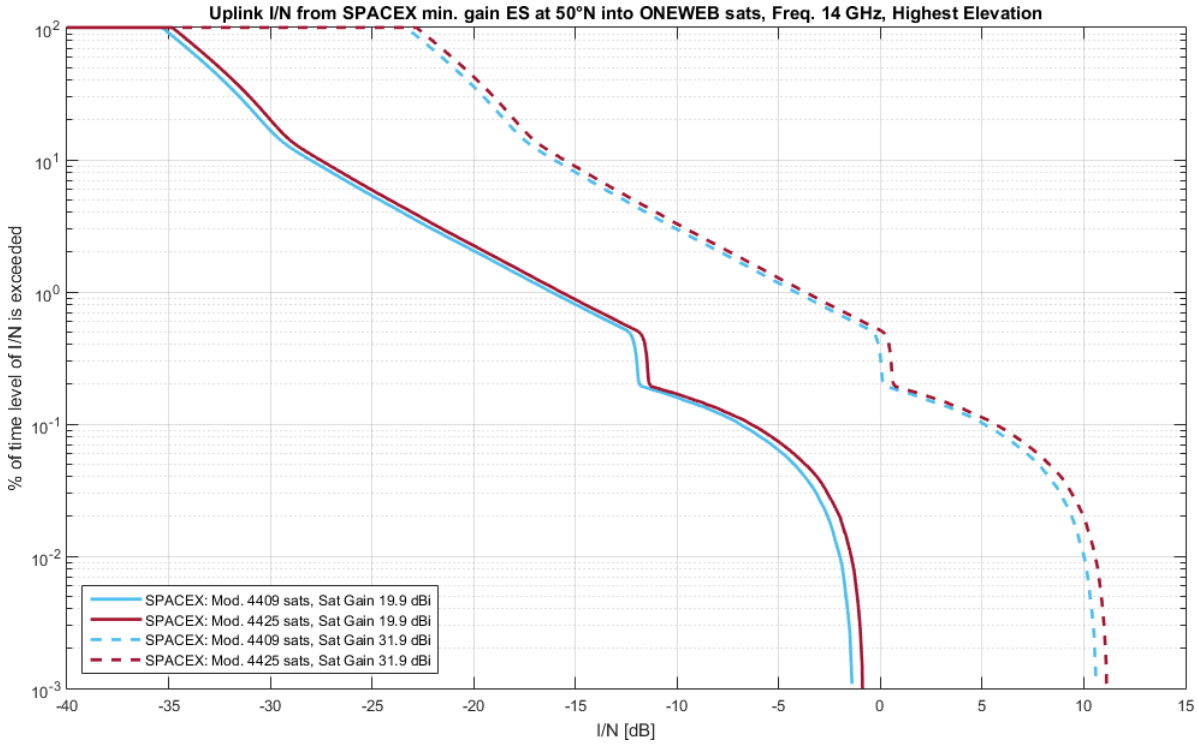

Figure 6. Uplink Comparison for Minimum Gain SpaceX Antenna – Highest Elevation

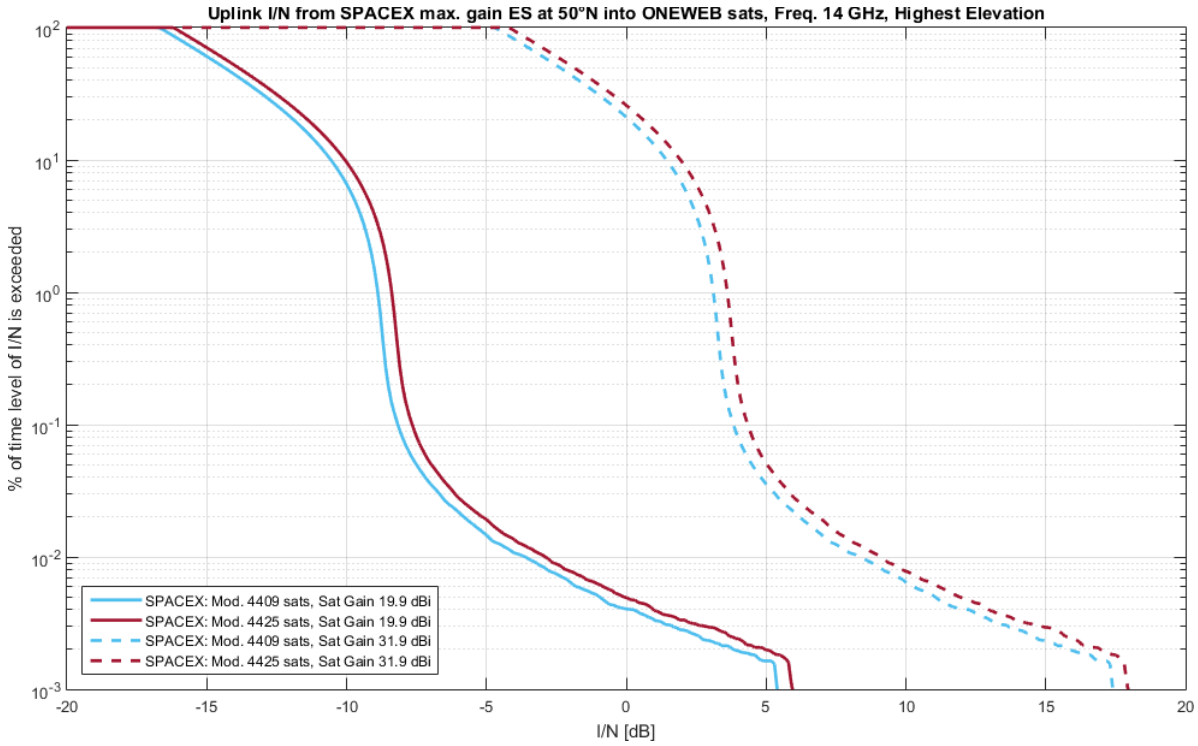

Figure 7. Uplink Comparison for Maximum Gain SpaceX Antenna – Highest Elevation

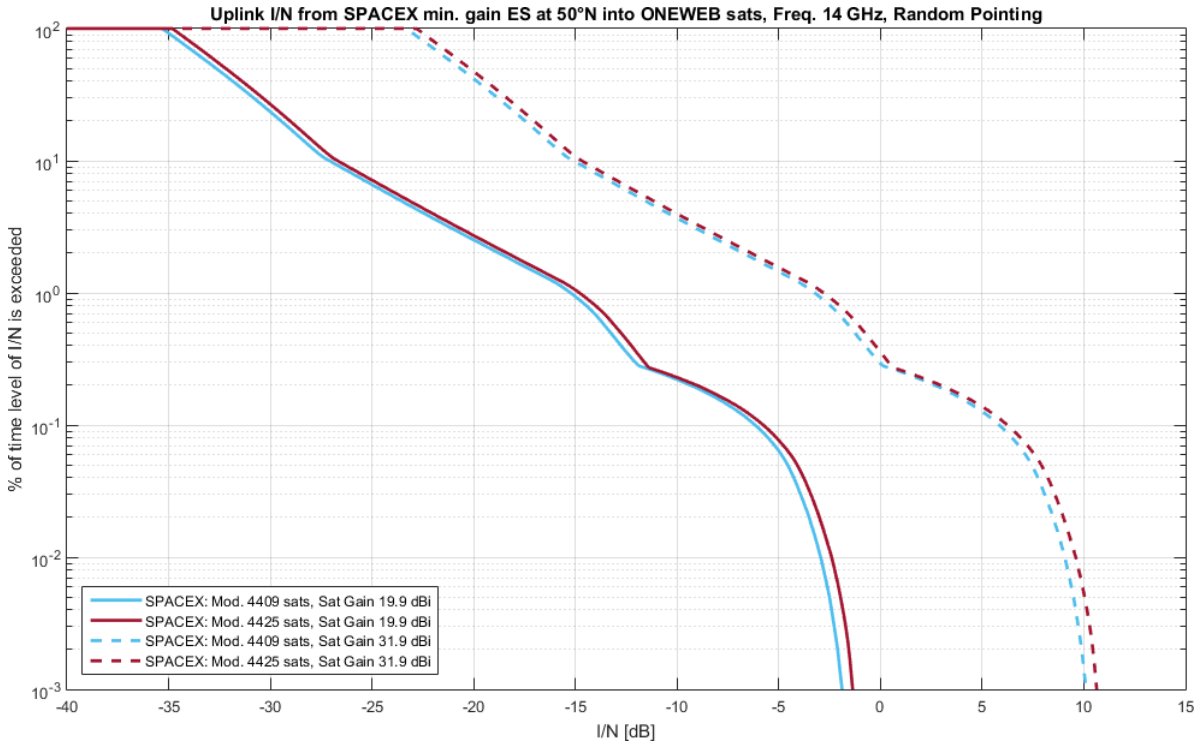

Figure 8. Uplink Comparison for Minimum Gain SpaceX Antenna – Random

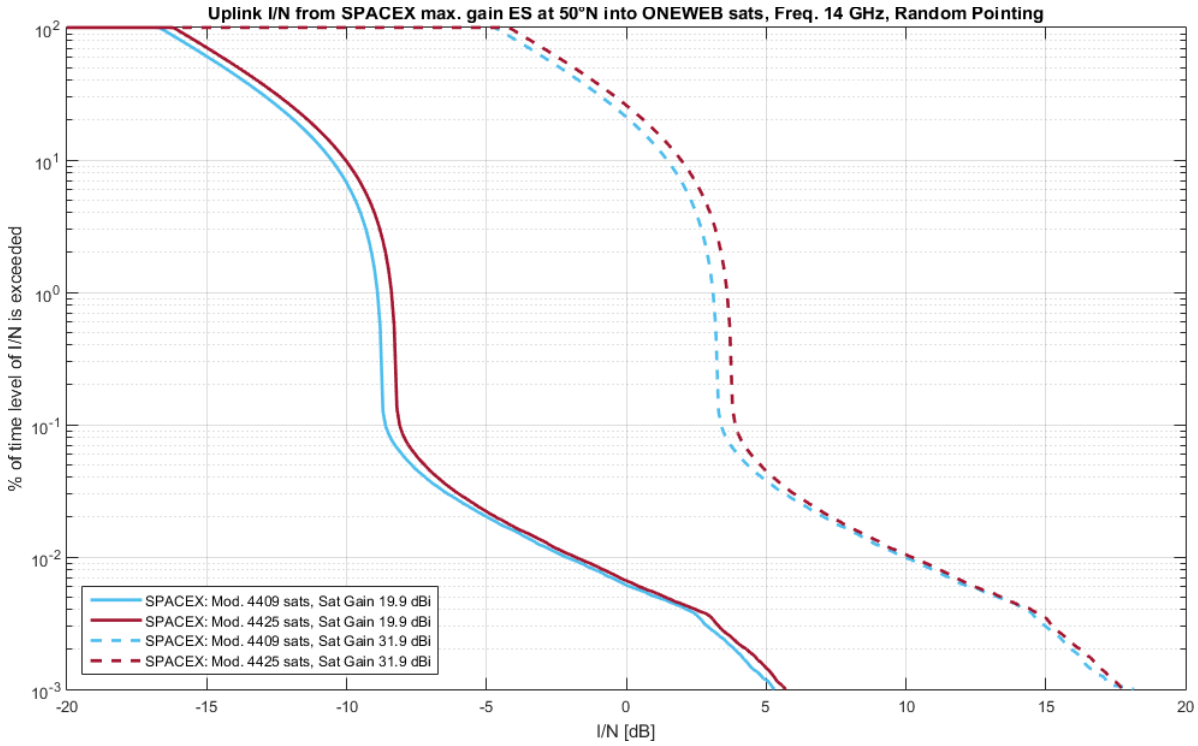

Figure 9. Uplink Comparison for Maximum Gain SpaceX Antenna – Random

ENGINEERING CERTIFICATION

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

/s/ *Mihai Albulet*

Mihai Albulet, PhD
Principal RF Engineer
SPACE EXPLORATION TECHNOLOGIES CORP.

April 15, 2019
Date