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

Application of	)	
SPACE EXPLORATION HOLDINGS, LLC	)	Call Signs: S2983 and S3018
For Modification of Authorization for the SpaceX NGSO Satellite System	)	File No. SAT-MOD-20181108-00083

FURTHER CONSOLIDATED OPPOSITION TO PETITIONS AND RESPONSE TO COMMENTS OF SPACE EXPLORATION HOLDINGS, LLC

William M. Wiltshire
Paul Caritj

HARRIS, WILTSHIRE & GRANNIS LLP
1919 M Street, N.W.
Suite 800
Washington, DC 20036
202-730-1300 tel
202-730-1301 fax

Counsel to SpaceX

Patricia Cooper
Vice President, Satellite Government Affairs

David Goldman
Director, Satellite Policy

SPACE EXPLORATION TECHNOLOGIES CORP.
1155 F Street, N.W.
Suite 475
Washington, DC 20004
202-649-2700 tel
202-649-2701 fax

February 21, 2019

SUMMARY

In this response, SpaceX addresses questions raised by SES/O3b and OneWeb about its proposed modification to its license. SpaceX's proposed modification will enhance the already considerable safety attributes of its system by taking advantage of the self-cleaning properties of a lower altitude. Critically, SpaceX took care in designing these proposed changes to ensure they will not increase spectral interference to any other system. Because nothing in the record undermines this fundamental point, the Commission should reject the requests to defer or deny the application.

The Commission authorized SpaceX early last year to construct, launch, and operate a constellation of 4,425 non-geostationary orbit ("NGSO") satellites. Following on its experience successfully operating its experimental satellites, SpaceX applied to modify its license to improve the safety of the system. Specifically, SpaceX proposed to operate a portion of its constellation at 550 km to capture the benefits of that self-cleaning orbit. SES/O3b and OneWeb both filed in response to SpaceX's proposal.

SES/O3b and OneWeb both challenge SpaceX's interference analysis. SES/O3b presents no analysis of its own, but rather asserts that SpaceX used a representative system in its analysis that may not reflect every other proposed system. But the Commission does not – and should not – impose the extraordinary regulatory burden on anyone wishing to update its system to have to perform exhaustive analysis of any particular configuration for every other satellite system. Instead, the Commission correctly allows an applicant to show analytically that its modification will not increase interference. Here, SpaceX went even further by performing simulations using a representative system to confirm its conclusions. This approach is especially appropriate here because SpaceX proposes to reduce the number of satellites, reduce its altitude, and reduce its

transmit power. Nevertheless, to assuage SES/O3b's concern, SpaceX is submitting herewith an analysis of the impact on O3b's and OneWeb's authorized systems that confirms that the proposed modification will not increase interference.

OneWeb in turn rests its analysis on two faulty assumptions: first, that SpaceX intends to use hundreds of gateways in the Ku-band and second, that SpaceX will operate both gateways and user terminals to transmit in the same Ku-band spectrum at a common given location. SpaceX has made no such claims. Without the support of these assumptions, OneWeb's objections to the modification fall apart. SpaceX's proposed modification would both reduce the number of satellites in view from any point on the Earth and allow SpaceX to operate at reduced power levels, thereby maintaining or improving interference for other licensed spectrum users. Not surprisingly, SpaceX's analysis of the impact of the proposed modification on OneWeb's authorized system submitted herewith shows no greater potential for interference.

OneWeb also raises concerns about space safety that are similarly misplaced. While SpaceX has always intended to operate a capable and reliable system, OneWeb is now challenging SpaceX's plan to reduce altitude to further enhance the space safety attributes of its system. Considering OneWeb's frequent request that SpaceX take this exact step of moving farther away from OneWeb's proposed constellation, one is left to wonder whether OneWeb would be satisfied with SpaceX operating at any altitude whatsoever.

Lastly, SES/O3b and OneWeb ask the Commission to await a determination from the International Telecommunication Union ("ITU") as to whether SpaceX's modification complies with applicable limits on equivalent power flux-density ("EPFD"). Yet the Commission historically made this determination on its own, and only changed this rule recently. As a company that chose to license its system in the United States, SpaceX has confidence that the Commission

remains fully capable of making its own determination now on EPFD compliance, subject to later confirmation by the ITU.

Because neither SES/O3b nor OneWeb raise any reason to deny or defer consideration of SpaceX's modification, the Commission should act expeditiously to allow SpaceX to proceed with its NGSO system that will extend the benefits of broadband service to customers in rural and other areas of the U.S.

TABLE OF CONTENTS

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

Application of	)	
SPACE EXPLORATION HOLDINGS, LLC	)	Call Signs: S2983 and S3018
For Modification of Authorization for the SpaceX NGSO Satellite System	)	File No. SAT-MOD-20181108-00083

FURTHER CONSOLIDATED OPPOSITION TO PETITION AND RESPONSE TO COMMENTS OF SPACE EXPLORATION HOLDINGS, LLC

Space Exploration Holdings, LLC, a wholly owned subsidiary of Space Exploration Technologies Corp. (collectively, "SpaceX"), hereby opposes the Petition to Deny or Defer filed by WorldVu Satellites Limited ("OneWeb") and responds to the Comments filed by SES Americom Inc. and O3b Limited ("SES/O3b") with respect to the above-referenced application for modification of SpaceX's authorization to launch and operate a non-geostationary orbit ("NGSO") satellite system.[1] As discussed further below, SES/O3B and OneWeb fail to present any reason to deny or defer this application, and the Commission should grant it expeditiously. A prompt review will allow SpaceX to proceed with development and deployment of its NGSO system and extend the benefits of broadband service to customers in rural and other areas of the U.S. currently underserved or unserved by other alternatives.

[1] *See* Petition to Deny or Defer of WorldVu Satellites Limited ("OneWeb Petition"); Comments of SES Americom, Inc. and O3b Limited ("SES/O3b Comments"). Both filings were submitted in IBFS File No. SAT-MOD-20181108-00083 on February 8, 2019. SpaceX previously responded to earlier-filed comments and petitions from several small satellite operators. *See* Consolidated Opposition to Petitions and Response to Comments of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20181108-00083 (Feb. 11, 2019).

BACKGROUND

Last year, the Commission authorized SpaceX to construct, deploy, and operate an NGSO constellation consisting of 4,425 satellites operating in 83 orbital planes at five different altitudes ranging from 1,110 km to 1,325 km.[2] That authorization anticipated that SpaceX would use Ku-band spectrum for communications between its satellites and user terminals, while the Ka-band would be used for communications with gateway earth stations. The Commission placed several conditions on that authorization, including (1) submission and approval of an updated orbital debris mitigation plan, and (2) receiving a "favorable" or "qualified favorable" finding by the ITU Radiocommunication Bureau regarding compliance with applicable EPFD limits.[3] In addition, that authorization "is subject to modification to bring it into conformance with any rules or policies adopted by the Commission in the future."[4]

To accelerate its deployment schedule and further improve its space safety profile, SpaceX has proposed a modification of its license that would relocate 1,584 satellites previously authorized to operate at an altitude of 1,150 km to an altitude of 550 km.[5] SpaceX detailed, among other things, how this move will enhance the considerable space safety attributes of SpaceX's constellation by ensuring that any orbital debris will undergo rapid atmospheric re-entry and demise, even in the unlikely event that a spacecraft fails in orbit.[6] It also submitted an analysis showing that operating slightly fewer satellites at a lower altitude would not increase the potential

---

2 *See Space Exploration Holdings, LLC*, 33 FCC Rcd. 3391 (2018) ("SpaceX Authorization").

3 *See id.* ¶¶ 9, 40n, and 40p.

4 *Id.* ¶ 40(r).

5 *See* Application for Modification of Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20181108-00083 (Nov. 8, 2018) ("SpaceX Modification").

6 SpaceX also noted other benefits of operating at lower altitude, including reduced signal latency and improved spectral efficiency. *See, e.g., id.* at 8.

for interference to other NGSO systems. In addition, SpaceX submitted an updated orbital debris mitigation showing and a demonstration of compliance with applicable EPFD limits, with a request that the Commission deem the related conditions of its existing authorization satisfied.[7] SpaceX did not, however, request relief from the obligation to comply with rules adopted in the future.

SES/O3b and OneWeb contend that the Commission should require a further demonstration from SpaceX that its modified system would not increase potential interference to other NGSO systems, or else defer the application to a new processing round. They also argue that the Commission should not deem SpaceX's modified system compliant with applicable EPFD limitations in the absence of an ITU determination to that effect. OneWeb raises additional questions with respect to the effect of SpaceX's proposed operations at 550 km on orbital debris. As discussed below, these concerns either are not well founded from a technical perspective, are within the Commission's competence to resolve, or are the kind of industry-wide issues that are properly resolved in a rulemaking proceeding rather than a licensing determination.

DISCUSSION

I. THE PROPOSED MODIFICATION WILL NOT INCREASE POTENTIAL INTERFERENCE FOR OTHER NGSO SYSTEMS

SpaceX proposes to operate slightly fewer satellites at a lower altitude and at lower power than specified in its initial license. SpaceX would use Ku-band spectrum and Ka-band spectrum for gateway transmissions during different stages of development. As discussed below, concerns raised by SES/O3b and OneWeb that these proposed changes would result in an increase in interference do not withstand scrutiny.

---

[7] *See* SpaceX Modification, Technical Attachment at 23-24, 38-47, and Annexes 1 and 2.

A. SpaceX's Analysis and Commission Precedent Confirm That the Modification Will Not Result in Increased Interference

Several aspects of the proposed modification combine to reduce the potential for radiofrequency interference compared to the operations SpaceX is currently authorized to conduct. First, SpaceX proposes to decrease slightly the number of satellites in its constellation from 4,425 to 4,409. Second, operating at a lower altitude will reduce radiofrequency interference in two fundamental ways: fewer satellites will be visible above the minimum elevation angle at any particular time at any point in the U.S., and the satellites can transmit and receive at lower EIRP power levels.

As SpaceX noted in its application, the Commission previously recognized these as factors that demonstrate that a modification will not increase interference to other NGSO systems.[8] To confirm the Commission's common-sense conclusion, SpaceX submitted an analysis of the potential impact of its modified constellation on a representative NGSO system (IK-NGSO-A10K-1).[9] That analysis considered the dynamic, time-varying interference expressed as a cumulative distribution function of the interference-to-noise ratio for varying percentages of time under worst-case assumptions. The analysis also confirmed that the modification will not increase the potential interference into other NGSO systems by showing that the new interference levels resulting from the modification are no worse (and are often better) than the interference levels under the original plan for all percentages of time.

---

[8] *See Teledesic LLC*, 14 FCC Rcd. 2261, ¶¶ 13, 17 (IB 1999) ("*Teledesic*"). Accordingly, SES/O3b is incorrect in asserting that SpaceX's interference showing rests solely on an analysis of the Intersputnik ITU filing. *See* SES/O3b Comments at 3.

[9] *See* SpaceX Modification, Technical Attachment at Section A.8.

Notwithstanding this analysis and the Commission's prior conclusions, SES/O3b questions SpaceX's showing that its proposed modification would not increase interference to other NGSO systems. Because O3b is authorized to access the U.S. market using an NGSO constellation operating only in Ka- and V-band spectrum,[10] it should not be affected by SpaceX's proposal to operate in the Ku-band during its initial deployment phase. O3b's concern therefore must relate only to the use of Ka-band spectrum for gateway links.

SES/O3b does not challenge the Commission's previous conclusions about modifications with fewer satellites and lower power levels, nor does it provide its own analysis of SpaceX's proposed modification. Rather, it simply asserts that the information submitted by SpaceX is not sufficient because it claims – with no analysis – that SpaceX's interference analysis may not be representative of other systems and that interference analysis should be performed using a system considered in the recent Ku/Ka-band processing round. But the information SpaceX has supplied is consistent with Commission precedent; in fact, it is the very same sort that the Commission found sufficient to grant a modification in *Teledesic*. Commission precedent does not – and should not – require an applicant to make exhaustive demonstrations that a modification will not change interference for any configuration with respect to every other system. Instead, the Commission correctly allows applicants to show analytically that its modification will not increase interference (especially in cases like this when the modification includes factors such as a reduction in number of satellites, reduction in altitude, and reduction in transmit power).

In this case, SpaceX went further and performed simulations using a representative NGSO system designed to operate in both the Ku- and Ka-bands. This should be more than sufficient to demonstrate that the proposed modification will not increase interference. Nevertheless, to

[10] *See O3b Limited*, 33 FCC Rcd. 5508, ¶ 1 (2018).

assuage SES/O3b's concerns about radiofrequency interference on specific systems involved in the Commission's Ku/Ka-band processing round, SpaceX is submitting herewith an analysis of the interference impact on the NGSO systems authorized for O3b and OneWeb.[11] As with the representative IK-NGSO-A10K-1 network, this analysis confirms that the proposed modification will not result in increased interference to either of those systems.

SES/O3b also contends that SpaceX should be required to present an analysis that considers only the initial shell of its constellation proposed in the modification application, rather than the entire constellation as modified. It bases this contention on the fact that SpaceX at one time requested a milestone assessment based on a phased deployment, and the fact that in denying that request the Commission's left open the possibility that SpaceX could seek such relief in the future.[12] To be clear, SpaceX has not requested such relief in this proceeding, and has proposed its modification precisely in an effort to expedite deployment of its entire constellation. Moreover, should SpaceX request such relief in the future, SES/O3b and all other interested parties would have an opportunity to comment on that request and demand any sort of analysis they believe appropriate. Accordingly, there is no reason to require such a limited analysis at this time.

B. Deployment of a Handful of Ku-band Gateways for a Limited Period Will Not Materially Affect the Interference Environment

OneWeb also raises concerns that SpaceX's Ku-band operations during the initial deployment phase will cause actual interference to some future OneWeb service, even though OneWeb has not yet applied for authority to operate a single Ku-band earth station in the U.S. and

[11] *See* Attachment A hereto.

[12] *See* SES/O3b Comments at 4.

is not providing any service in this country with which SpaceX could interfere.[13] OneWeb criticizes SpaceX's analysis that demonstrates temporary gateways operating in the Ku-band will not increase interference to other NGSO systems authorized to use the band, such as OneWeb. OneWeb's concerns are misplaced. In fact, rather than base its critiques on facts in SpaceX's application or evidence in the record, OneWeb relies entirely on a collection of flawed assumptions cobbled together into an equally-flawed fictional scenario.

Specifically, OneWeb claims SpaceX failed to consider the potential effect of allowing up to four satellites to communicate in the same frequency with both a gateway and a user terminal at the same location. OneWeb offers various scenarios to project how this combination of up to five satellites creates in-line interference, first on the downlink and then on the uplink.[14] But this analysis not only rests entirely on two flawed assumptions, it also fails to take into account basic operational differences between gateways and user terminals. Once these defective pillars buttressing OneWeb's claims are removed, the criticism crumbles.

The first flawed assumption supporting OneWeb's analysis is that SpaceX plans to deploy "hundreds" of Ku-band gateways across the U.S.[15] SpaceX has said no such thing. Instead, SpaceX made clear in its application that only a limited number of first-generation satellites will use the Ku-band for gateway communications for a discrete period until it transitions to Ka-band for gateways. Accordingly, SpaceX will only use a handful of Ku-band gateways scattered across the U.S., rather than the hundreds envisioned by OneWeb. By contrast, the Commission already

---

[13] *See WorldVu Satellites Limited*, 32 FCC Rcd. 5366, ¶ 8 (2017) ("OneWeb Authorization") ("A grant of U.S. market access includes no authority to deploy earth stations in the United States. Authority for such earth stations must be requested in an appropriate earth station application.").

[14] *See* OneWeb Petition at 5-8.

[15] *Id.* at i.

anticipated that SpaceX would deploy a very large number of user terminals operating in the Ku-band.[16] OneWeb's dire projections simply do not reflect the actual planned deployment of just a few additional Ku-band gateway earth stations scattered among a far larger population of Ku-band user terminals, which would be highly unlikely to materially affect the coordination environment.

OneWeb's second flawed assumption is that SpaceX will rely on the same Ku-band spectrum for both gateway and user transmissions at a common given location. Once again, SpaceX never made such an assertion. To the contrary, SpaceX's allocation of Ku-band downlink beams between users and gateways will simply divide that finite number of beams between those two applications. SpaceX will not increase the total number of beams in use at any given time. Thus, the extreme interference scenario envisioned in OneWeb's analysis resulting from co-frequency operations of four gateway beams and a user beam at a given location simply will never happen.

Even setting aside this decisive factor, OneWeb's analysis of potential downlink interference fails for at least two additional reasons.[17] First, OneWeb disregards power reductions. When SpaceX uses a downlink beam for gateway communications, it will reduce its power by 6 dB, thus reducing the potential for interference.[18] Although OneWeb noted this fact, its calculations do not appear to have taken it into account.[19] Second, OneWeb exaggerates the impact by disregarding the temporary nature of the proposed gateway operation in Ku-band. As noted in the modification application, SpaceX plans to launch only a limited number of first-generation satellites before it brings a new generation of satellites online with Ka-band capabilities for

---

[16] *See generally* IBFS File No. SES-LIC-20190201-00217 (application for blanket license for the operation of up to 1,000,000 user terminal earth stations to use with SpaceX's NGSO constellation).

[17] *See* OneWeb Petition at 5-7.

[18] *See* SpaceX Modification, Technical Attachment at n.8.

[19] *See* OneWeb Petition at 6.

gateway links. These first-generation satellites are unlikely to converge and communicate with the same gateway earth station at any given time. As a practical matter, four first-generation satellites will rarely, if ever, communicate simultaneously with a Ku-band gateway.

OneWeb's analysis of potential uplink interference is once again based entirely on the incorrect assumption that SpaceX will use the same frequency for user terminal and gateway transmissions in the same spot beam.[20] Even so, OneWeb fails to take into account the very different operations of a user terminal versus a gateway. Although user and gateway uplink beams may transmit at the same EIRP, gateway earth stations use larger antennas with better sidelobe characteristics and therefore reduce the probability of an in-line interference event with another NGSO.

The significance of this operational distinction is clear when contrasting two scenarios. The first scenario considers two collocated user terminals from two different NGSO systems. The unwanted earth station is a user terminal with 33 dBi gain (approximately 0.4 m diameter), 0 dB EIRP at beam peak, and a standard beam pattern described by ITU Radio Regulations, Appendix 8. Assume further that the impacted satellite can accept interference up to a level of -20 dB EIRP. Under these assumptions, the unwanted earth station would need to point away from the impacted satellite by at least 11.3 degrees to avoid creating harmful interference.

Now consider the same scenario above but substituting a gateway as the unwanted earth station. Assuming a higher 41 dBi gain (approximately 1 m diameter), and the same peak EIRP, antenna pattern, and threshold for unacceptable interference at the impacted satellite, the required angular separation to avoid interference is reduced to just 3.75 degrees. In other words, the area

[20] *See id.* at 7-8.

of the protection zone around the satellite for the gateway is only 11% of the area for the user terminal.[21] Even assuming four collocated gateway earth stations transmitting at the same frequency, the total area of the combined protection zone is only 44% of the area for a single user terminal. In other words, the probability of an in-line event involving a gateway is less than half compared to a user terminal.

Looking at the issue in a slightly different way yields a similar result. Making the same assumptions as before, consider the case of a single user terminal communicating with a SpaceX satellite. If the separation angle to the nearest impacted satellite is 11.3 degrees, then interference to the impacted satellite meets the acceptable -20 dB criterion. Now assume instead there are four SpaceX gateways communicating with four SpaceX satellites – and no user terminals operating in the same spectrum from that location, as discussed above – each with a separation angle of 11.3 degrees. In this scenario, interference to the impacted satellite from one gateway is -32 dB and from all four gateways combined is -26 dB – a result that is actually lower than the interference from a single user terminal. OneWeb's analysis takes no account for these dramatic differences in operation between gateways and user terminals.

Overall, OneWeb rested its interference analysis entirely on incorrect assumptions and overlooked basic operational distinctions in the actual effect of the proposed SpaceX modification. By contrast, Attachment A hereto provides an analysis based on the actual parameters of SpaceX's system as modified, and demonstrates that the proposed modification will not result in increased interference to OneWeb's authorized NGSO system. Moreover, the Commission required each system to coordinate with all other NGSOs as a condition on each authorization. Accordingly, OneWeb has presented no plausible basis for the Commission to question the likelihood that the

[21] The calculation is $(3.75/11.3)^2 = .11$.

potential for interference to other NGSO satellite systems would actually be reduced by SpaceX's plan to operate a limited number of Ku-band earth stations with a limited number of first-generation satellites at lower altitude and lower power.

II. THE PROPOSED MODIFICATION WILL ENHANCE THE ORBITAL DEBRIS MITIGATION PROFILE OF SPACEX'S NGSO CONSTELLATION, NOT PRESENT CONCERNS

The principal reason that SpaceX proposed to operate a portion of its system at a lower altitude was to enhance further the already considerable space safety attributes of its constellation.[22] The well-known atmospheric advantage of the 550 km altitude naturally removes objects from orbit, including loose debris, and also improves safety when, in off-nominal events, satellites fail to fully complete their disposal operations. In this case, moving to a lower altitude also provides the additional benefit of increasing the distance between SpaceX's satellites and other proposed large NGSO constellations, including OneWeb – corresponding to a request OneWeb has repeatedly made.[23] Despite all of the positive safety attributes of this modification, OneWeb nonetheless claims that SpaceX's proposed operation at a self-cleaning altitude raises additional orbital debris concerns.

First, OneWeb argues that "the Commission must seek additional information from [SpaceX] regarding the propulsive capabilities and maneuverability of its proposed initial deployment satellites."[24] This argument is curious, given that SpaceX made very clear in the Modification Application that its spacecraft would be fully propulsive and maneuverable. For

---

22 *See* SpaceX Modification at 6-8.

23 *See, e.g.,* Reply Comments of WorldVu Satellites Limited, IBFS File No. SAT-LOA-20161115-00118, at 9 (July 14, 2017) ("OneWeb reiterates its strong belief that the 125 km Safety Buffer Zone is in the public interest and will facilitate a safer orbital environment for all constellations authorized by the Commission pursuant to the current processing round. OneWeb encourages Space Exploration Holdings to consider adjusting the planned altitudes of its constellation.").

24 OneWeb Petition at 17.

example, it states that "SpaceX spacecraft will nominally continue to perform active conjunction avoidance at all stages of flight."[25] Even during the de-orbit phase, "SpaceX satellites will continue to perform conjunction avoidance until the high atmospheric torques from low altitudes cause the vehicle to be uncontrollable."[26] Moreover, "[a]t all times during this descent, including the period during which they will traverse the orbital altitude of the ISS and other NASA assets, the spacecraft will retain sufficient fuel to perform maneuvers."[27] Accordingly, OneWeb's assertion that SpaceX's orbital debris mitigation plan "offers no insights as to the continued viability of [maneuvering] capabilities" is simply inaccurate.[28]

OneWeb's concern in this regard apparently grew out of its misconceptions about the operations of SpaceX's experimental satellites, Microsat 2A and 2B.[29] SpaceX launched these spacecraft in February 2018, and included much of the SpaceX-built technology that will go into the satellites in its constellation, such as its phased-array antennas and its Hall-effect thruster propulsion system. SpaceX originally expected to operate these satellites at approximately 515 km and then raise them to an altitude of 1,125 km for further testing, but chose not to do so. From this, OneWeb leaps to an unsupported conclusion that SpaceX's experimental satellites faced "operational setbacks."[30] To the contrary, SpaceX made a conscious decision to remain at this optimal altitude for further experimentation. The Microsats have now been in orbit for nearly a year, and have been under propulsive control and performing maneuvers as necessary to avoid

---

25 SpaceX Modification, Technical Attachment at 42.

26 *Id.* at 39.

27 *Id.*

28 OneWeb Petition at 18.

29 *See* Call Sign WI2XTA, ELS File No. 0298-EX-CN-2016 (granted Nov. 16, 2017).

30 OneWeb Petition at 14.

orbital debris.[31] Far from facing setbacks, the experimental program has validated SpaceX technology – including the Hall-effect thruster propulsion system and the capabilities of the communications payload. Thus, unlike OneWeb, SpaceX has successfully tested its spacecraft design in advance of initiating deployment of its commercial constellation. In fact, the Commission should take steps to encourage others to test their spacecraft design before full deployment rather than saddle them with additional regulatory burdens as suggested by OneWeb.

OneWeb next argues that the Commission should be "deeply concerned" by the idea of SpaceX operating a portion of its constellation at 550 km.[32] OneWeb notes concern that its own satellites will need to traverse this altitude during its orbit raising phase.[33] Yet OneWeb's satellites would also need to traverse across SpaceX orbits even at their higher currently authorized altitude of 1,150 km. Presumably, OneWeb's operational plan takes into account safe measures for the orbit raise of its satellites through the many constellations up to their proposed 1,200 km operating altitude. Moreover, although OneWeb questions the reliability of SpaceX's de-orbit design, SpaceX will exceed new stricter parameters NASA recently determined for safe operation of large constellations[34] by achieving a 100% success rate of post-mission disposal within 5 years, even assuming worst-case conditions.[35] SpaceX disagrees with OneWeb's frequent refrain that its

---

31 As part of Microsat conjunction avoidance operations, SpaceX has screened thousands of routine conjunction alerts, and operated the thrusters in the rare occasion the spacecraft need to be diverted to a new location.

32 OneWeb Petition at 19.

33 *See id.*

34 *See* J.-C. Liou, *et al.*, *NASA ODPO's Large Constellation Study*, ORBITAL DEBRIS QUARTERLY NEWS, at 4-7 (Sept. 2018) (suggesting that post-mission disposal within five years at a 99% success rate would mitigate the debris concern related to large NGSO constellations), available at https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv22i3.pdf.

35 *See* SpaceX Modification, Technical Attachment at 39-41.

satellites should be given a 125 km "buffer zone,"[36] but given that SpaceX's proposed modification fulfills OneWeb's repeated demand that SpaceX move away from OneWeb's constellation at 1,200 km, one can only wonder whether SpaceX could operate at *any* altitude to OneWeb's satisfaction.

Third, OneWeb clutches at even thinner threads when it asserts that SpaceX's constellation presents a "troubling risk profile" due to the potential for survivable debris.[37] OneWeb does not deny that SpaceX far surpasses the U.S. and international standards for safety of de-orbit operations. Instead, OneWeb argues that the Commission should apply a new and as-yet unquantified standard to SpaceX that would assess potential risks in the aggregate. Such a standard has been applied to no other satellite operator at any orbit – including OneWeb and other applicants in the Ku/Ka-band NGSO processing round. In fact, OneWeb itself has repeatedly refused to make available comparably detailed information on its collision avoidance and orbital debris plans for public scrutiny or Commission review.[38] If a new rule were imposed, it should be considered and adopted in the ongoing *Orbital Debris NPRM* rulemaking and, if adopted, then made applicable to all NGSO system authorizations. It would be inappropriate to apply a novel and unannounced standard to SpaceX uniquely. Indeed, SpaceX's existing authorization is conditioned upon compliance with any future rule.[39]

---

[36] *See, e.g.,* Comments of WorldVu Satellites Limited, IBFS File No. SAT-LOA-20161115-00118, at 11-12 (June. 26, 2017).

[37] OneWeb Petition at 20.

[38] *See, e.g.,* Consolidated Opposition and Reply Comments of OneWeb, IBFS File Nos. SAT-LOI-20170301-00031 and SAT-AMD-20180104-00004, at 23-24 (Aug. 27, 2018) (asking the Commission to rely upon oversight by the U.K. regulator rather than providing orbital debris information); Consolidated Opposition and Reply Comments of OneWeb, IBFS File No. SAT-MOD-20180319-00022, at 22-23 (Aug. 27, 2018) (same).

[39] *See* SpaceX Authorization, ¶ 40r.

OneWeb also argues that the Commission should not accept SpaceX's updated orbital debris showing until after the *Orbital Debris NPRM* proceeding has concluded.[40] But this is inconsistent with Commission precedent. Rather than defer applications pending the completion of a rulemaking proceeding, the Commission routinely grants them subject to any new policies or rules that it may adopt. That is exactly what the Commission did with respect to SpaceX's original application – and OneWeb's as well.[41] The Commission's policy wisely enables satellite operators to proceed with development of their specific systems while more general issues that affect the entire satellite industry are debated and resolved in the larger context of a proceeding to adopt rules for everyone – rules that, once adopted, will be applied to all satellite operators. Any other approach would open the door to mischief by competitors and make the regulatory burden on deploying new services nearly insurmountable. Thus, OneWeb's request for deferral while that larger debate takes place stands Commission precedent on its head, and should be rejected.

Finally, OneWeb cites rumors and unnamed sources as the basis for concern that SpaceX will use the altitudes above the International Space Station ("ISS") as a "testbed" for spacecraft design. As the company planning to fly NASA astronauts to the ISS this year and with numerous successful cargo missions to the ISS already completed, SpaceX welcomes OneWeb's attention to the safety of the ISS and its crew and operations. The future of crewed spaceflight and the safety of astronauts en route to and aboard the space station are SpaceX's top priority, which is why SpaceX continues to collaborate closely with NASA on ISS and crew safety issues, including safe operation for the ISS with the modified SpaceX constellation.

---

[40] *See* OneWeb Petition at 22.

[41] SpaceX Authorization, ¶ 17; OneWeb Authorization, ¶ 12.

OneWeb's criticism of SpaceX's use of rigorous iteration to improve its satellites is particularly surprising given OneWeb's embrace of frequent changes to its own system. In the past year alone, OneWeb has announced plans to increase threefold the size of its constellation to 1,920,[42] then to shrink its initial rollout by 300 satellites,[43] using a testbed of *600 satellites* that operate at what it admits is only 2% of the throughput of its next generation.[44] In contrast, by continuing to proceed deliberately and incrementally, SpaceX has made a single modification that will permit expedited launch of highly capable satellites in the coming months, while OneWeb reduced its initial launch payload by 40% out of concern that its initial satellites will face in-orbit anomalies.[45] Overall, SpaceX's integrated, iterative approach will better serve the public interest by quickly bringing high-speed broadband service to American consumers.

III. THE COMMISSION IS FULLY CAPABLE OF MAKING ITS OWN INITIAL DETERMINATION WITH RESPECT TO SPACEX'S COMPLIANCE WITH EPFD LIMITATIONS

The Commission conditioned SpaceX's authorization on receipt, prior to initiation of service, of a "favorable" or "qualified favorable" finding by the ITU Radiocommunication Bureau regarding its compliance with those EPFD limits.[46] As required by Commission rules, SpaceX

---

[42] *See* Application for Modification of WorldVu Satellites Limited, IBFS File No. SAT-MOD-20180319-00022 (Mar. 19, 2018) (seeking to increase the number of active satellites in its LEO Constellation from 720 to 1,980).

[43] *See* Caleb Henry, *Oneweb Scales Back Baseline Constellation By 300 Satellites*, SPACENEWS (Dec. 13, 2018), *available at* https://spacenews.com/oneweb-scales-back-constellation-by-300-satellites/.

[44] Greg Wyler, Founder and CEO of OneWeb (@greg_wyler), TWITTER (Jan. 23, 2019, 8:38 PM), https://twitter.com/greg_wyler/status/1088294875655782401 ("In phase 1 we launch the satellites needed to achieve global coverage. Currently set at 600 satellites. We then continue to launch up to 900 of this gen1 while we finalize our gen2 design, prepare and validate the supply chains and build the tooling and manufacturing lines… before launching Gen2. The Gen2 satellites will have at least 50x more throughput than Gen1, and likely take us through 1980 satellites.")

[45] *See, e.g.,* Greg Wyler, (@greg_wyler), TWITTER (Jan. 18, 2019, 7:29 AM), https://twitter.com/greg_wyler/status/1086284451087351809 ("Keeping 4 as spares gives us optionality and schedule safety in case of an anomoly [*sic*].").

[46] *See* SpaceX Authorization, ¶ 40n.

has certified that its NGSO constellation, as modified, will comply with the applicable EPFD limits set forth in Article 22 of the ITU Radio Regulations, which have been incorporated by reference into the Commission's rules.[47] However, in light of its expedited deployment schedule and the backlog of EPFD examination showings at the ITU, SpaceX requested a waiver of the condition requiring a favorable ITU determination prior to initiating service. In support of that request, SpaceX included the results of an EPFD analysis using ITU-approved software demonstrating compliance with all applicable EPFD single entry validation limits in the Ku- and Ka-band spectrum covered by its license.[48] SpaceX also provided the data files used for these analyses so that the Commission and any other interested party could independently confirm these technical findings.

Despite all this evidence, OneWeb still frets that SpaceX's waiver request is "based on nothing more than a showing of impatience."[49] Perhaps OneWeb simply overlooked the EPFD compliance showing and underlying data submitted with the application. This analysis was substantially similar to the one SpaceX supplied with its original application – an analysis that the ITU has now confirmed with a favorable finding.[50] SpaceX's sense of urgency reflects its agreement with Chairman Pai that "[i]t really would be a game-changer for rural America if every town in this country were connected."[51]

---

47 *See* 47 C.F.R. § 25.146(a)(2).

48 *See* SpaceX Modification, Technical Attachment, Annexes 1 and 2.

49 OneWeb Petition at 23.

50 *See* EPFD data and EPFD examination results, ITU, https://www.itu.int/ITU-R/go/space-epfd-data.

51 *See* Marguerite Reardon, *FCC Leaders Say We Need A 'National Mission' To Fix Rural Broadband,* CNET (Oct. 24, 2018), *available at* https://www.cnet.com/news/fcc-leaders-say-we-need-a-national-mission-to-fix-rural-broadband/.

As OneWeb recognizes, before the rules were changed in 2017, "the Commission required a 'comprehensive technical showing' demonstrating EPFD compliance by NGSO FSS applicants"[52] under a rule that had been in place since 2000.[53] Thus, it is curious for OneWeb to characterize the ITU's analysis as "the only substantive verification of [SpaceX's] EPFD compliance."[54] As a company that chose to seek a U.S. license for its system, SpaceX is confident that the Commission remains capable of performing its own analysis and reaching its own conclusions about compliance with EPFD requirements, as it had done for over 15 years before this rule change.

SpaceX recognizes that it must comply with the ITU's EPFD limits, has certified that its constellation (as modified) will do so, and has provided the technical inputs for any party to confirm this compliance. SpaceX has no objection to the proposal by SES/O3b that any waiver granted in this proceeding relate only to the timing of the ITU finding, such that SpaceX may proceed at its own risk pending ITU confirmation of a "favorable" or "qualified favorable" finding.[55]

---

[52] OneWeb Petition at 24 (citing 47 C.F.R. § 25.146(a)(2016)).

[53] *See Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range*, 16 FCC Rcd. 4096 (2000).

[54] OneWeb Petition at 26.

[55] *See* SES/O3b Comments at 5.

CONCLUSION

There is no basis for deferring or denying SpaceX's Modification Application. Accordingly, the Commission should grant the Modification Application so that SpaceX can proceed with its plans for expedited deployment of its NGSO constellation.

Respectfully submitted,

SPACE EXPLORATION HOLDINGS, LLC

By: */s/ Patricia Cooper*
Patricia Cooper
Vice President of Satellite Government Affairs
David Goldman, Director, Satellite Policy

SPACE EXPLORATION TECHNOLOGIES CORP.
1155 F Street, NW
Suite 475
Washington, DC 20004
202-649-2700 tel
202-649-2701 fax

William M. Wiltshire
Paul Caritj
HARRIS, WILTSHIRE & GRANNIS LLP
1919 M Street, N.W.
Suite 800
Washington, DC 20036
202-730-1300 tel
202-730-1301 fax

Counsel to SpaceX

February 21, 2019

ATTACHMENT A

DYNAMIC INTERFERENCE ANALYSIS FOR ONEWEB AND O3B NGSO SYSTEMS

In its initial application, SpaceX presented an analysis of the effect of the proposed modification on downlink and uplink interference using the characteristics in the ITU filings of a proposed NGSO system (IK-NGSO-A10K-1) operating in both the Ku- and Ka-bands. The 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 also assumed that the two systems did not implement any interference mitigation strategies.

WorldVu Satellites Limited ("OneWeb") and SES Americom Inc. and O3b Limited ("SES/O3b") have criticized that analysis because it did not include a system involved in the Commission's recent Ku/Ka-band processing round. In order to address this criticism, below we present a dynamic interference analysis to determine whether SpaceX's constellation with the proposed modification would increase interference to the NGSO systems operated by OneWeb (in the Ku-band) and O3b (in the Ka-band). As before, the anlaysis examines both downlink and uplink interference and compares the impact on these victim systems of the original SpaceX constellation and the modified constellation.

For purposes of this dynamic interference assesment, SpaceX makes several worst-case assumptions. First, the earth stations of both the interfering and victim systems are assumed to be collocated. Second, the collocated earth stations are 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 simulation does not consider the effects of atmospheric attenuation.

Most importantly, the analysis assumes that the SpaceX earth station is a gateway rather than a user terminal. This is a worst-case assumption because SpaceX satellites can transmit only one co-frequency, co-polar beam to a user terminal, but can transmit up to four such beams in the Ku-band and up to eight such beams in the Ka-band. In addition, the analysis selects the four or eight interfering SpaceX satellites (depending on opeational frequency band) with smallest off-axis sepration angle from a given victim earth station to communicate with the collocated gateway station at each time step.

The methodology for both dynamic downlink and uplink interference assesment is explained in detail below. As this analysis confirms, because 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, the modification will not increase the potential interference into other NGSO systems.

Downlink:

The analysis simulates downlink interference from the transmitting SpaceX satellites into the O3b and OneWeb NGSO systems' receiving earth stations. Higher gain antenna earth stations

have been chosen from these systems for analysis to ensure high I/N. Consistent with the parameters in their applications, the minimum elevation angles for SES-O3B and OneWeb transmissions are 5° and 45°, respectively. Any SpaceX satellite in view meeting 0° and 10° minimum elevation angle is eligible for analysis with respect to the O3b and OneWeb systems, respectively.[56] For each possible pointing angle from the eligible victim satellite to victim earth station, the following two types of interference are computed and aggregated:

- Mainbeam interference from worst case SpaceX satellites to victim earth station assuming the mainbeam from the interfering satellites are directed to collocated gateway station.
- Sidelobe inteference from the remaining visible interfering satellities to the victim earth station. Sidelobe EIRP from these remaining interfering satellities is assumed to be 30 dB lower on average than their corresponding maximum mainbeam EIRP.

The results of the analysis for a victim earth station of the O3b and OneWeb NGSO systems are set forth in Figures 1 and 2, respectively. In each case, the figure plots a CDF of aggregate I/N levels for the SpaceX constellation as originally proposed and as modified.

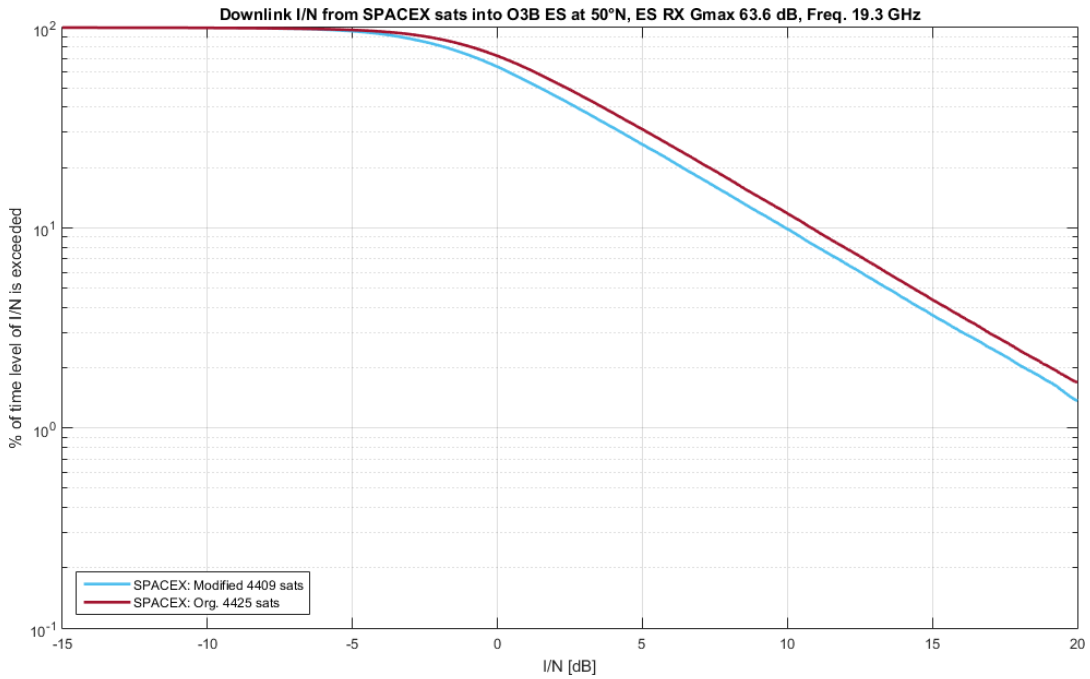

Figure 1. Worst-Case Downlink Comparison for O3b Constellation

[56] Although the O3b and OneWeb systems observe minimum elevation angles of 5 and 45 degrees, respectively, the analysis can consider SpaceX satellites at lower elevation angles (0 and 10 degrees, respectively) for purposes of aggregating sidelobe interference.

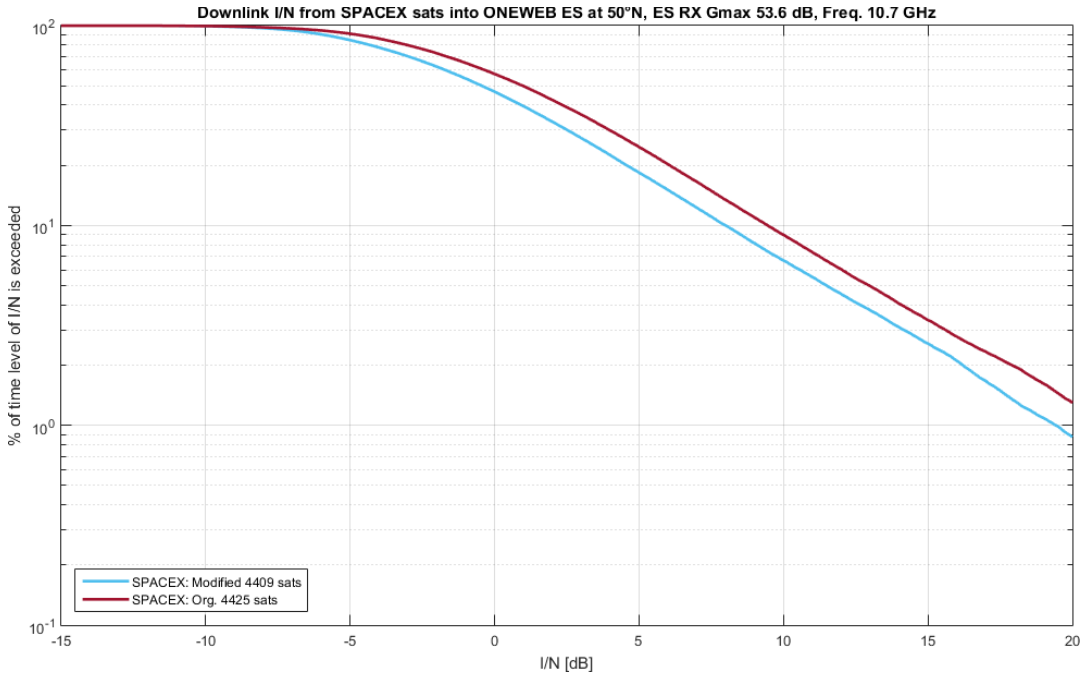

Figure 2. Worst-Case Downlink Comparison for OneWeb Constellation

In the Ku-band, not all earth stations will be gateways. In fact, SpaceX intends to deploy a very small number of Ku-band gateways (communicating with up to four satellites in a frequency) and a very large number of user terminals (communicating with only one satellite in a frequency). Moreover, even for a gateway station, it is highly unlikely that all worst-case satellites with the smallest off-axis sepration angle from victim pointing will transmit at each time step. Hence, the aggrgated I/N represents a worst-case downlink inteference scenario which is certain to be improved in real deployment.

Uplink:

The analysis simulates uplink interference from the transmitting SpaceX earth station into the O3b and OneWeb NGSO systems' receiving satellites. Again, higher gain antenna earth stations have been chosen from the SpaceX system for analysis to ensure high I/N. The O3b and OneWeb earth station can communicate with any satellite in its own system above a 5° and 45° elevation angle, respectively. Similar to the downlink methology, the analysis presents a worst case by selecting SpaceX satellites with the smallest off-axis sepration angle from a given victim satellite for uplink beams from the collocated gateway station at each time step. For each possible pointing angle from the victim earth station to eligible victim satellite, the following two types of interference are computed and aggregated:

- Mainbeam interference from SpaceX gateway earth station to victim satellite assuming the mainbeams from the interfering gateway station are directed to worst case satellites.
- Sidelobe inteference from adjacent earth stations to victim satellite. The anlaysis aggregates contributions from adjacent earth stations located within a square (with the collocated gateway station at the center) with area equal to 100 times the size of a SpaceX

cell. Sidelobe EIRP from adjacent earth stations is assumed to be 30 dB lower on average than their corresponding maximum mainbeam EIRP.

The results of the analysis for victim satellites of the O3b and OneWeb NGSO systems are set forth in Figures 3 and 4, respectively. In each case, the figure plots a CDF of aggregate I/N levels for the SpaceX constellation as originally proposed and as modified.

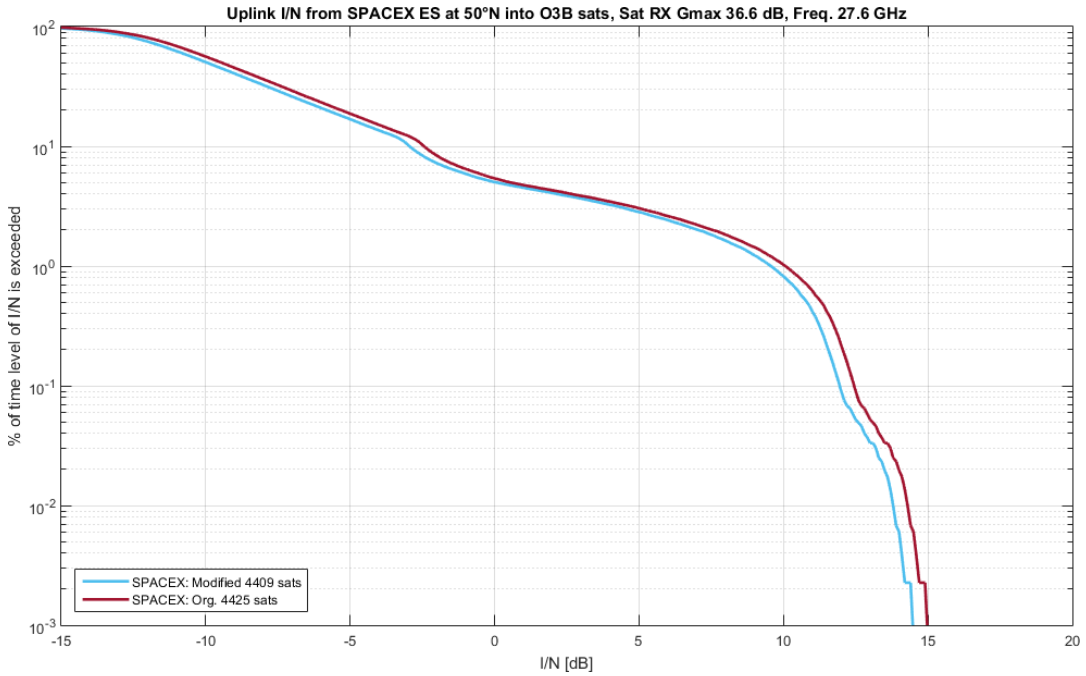

Figure 3. Worst-Case Uplink Comparison for O3b Constellation

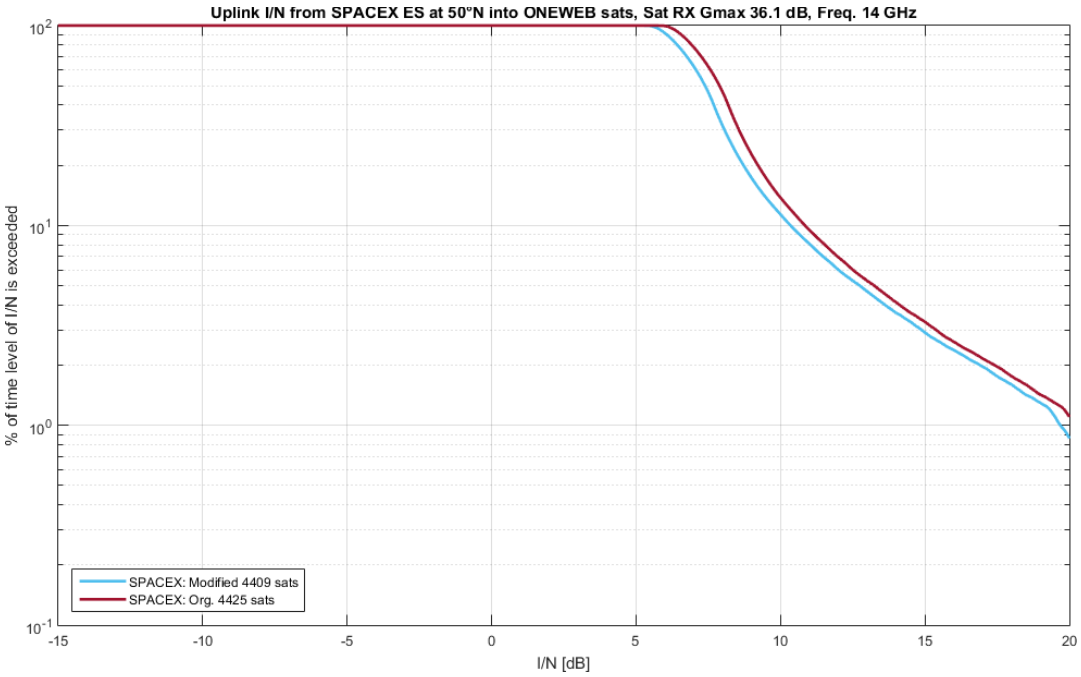

Figure 4. Worst-Case Uplink Comparison for OneWeb Constellation

Again, in a real deployment, it is highly unlikely that the SpaceX earth station will transmit to all worst-case satellites with the smallest off-axis sepration angle from a victim satellite at each time step. Hence, the aggrgated I/N represents a worst-case uplink inteference scenario which is certain to be improved in practice.

ENGINEERING CERTIFICATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this pleading, 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 pleading, 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.

February 21, 2019
Date

CERTIFICATE OF SERVICE

I hereby certify that, on this 21st day of February, 2019, a copy of the foregoing pleading was served via First Class mail upon:

Mariah Dodson Shuman
Head of Regulatory Affairs
WorldVu Satellites Limited
1785 Greensboro Station Place, Tower 3
McLean, VA 22102

Brian Weimer
Douglas Svor
Samuel Swoyer
Sheppard Mullin Richter & Hampton LLP
2099 Pennsylvania Avenue, N.W.
Suite 100
Washington, DC 20006

Suzanne Malloy
Petra A. Vorwig
Noah Cherry
SES Americom, Inc./O3b Limited
1129 20th Street, N.W.
Suite 1000
Washington, DC 20036

Karis A. Hastings
SatCom Law LLC
1317 F Street, N.W.
Suite 400
Washington, DC 20004

/s/ *Samuel D. Sperling*
Samuel D. Sperling