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 and S3018
Application for Modification of Authority for the SpaceX NGSO Satellite System	)	

PETITION TO DENY OR DEFER OF SES AMERICOM, INC. AND O3B LIMITED

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SES Americom, Inc. ("SES Americom") and O3b Limited ("O3b," and collectively, "SES") request that the Commission deny, or at a minimum, defer consideration of, the above-captioned application by Space Explorations Holdings, LLC ("SpaceX") for modification of its authority to launch and operate a Ku/Ka-band non-geostationary satellite orbit ("NGSO") fixed-satellite service ("FSS") system.[1] As discussed below, because the changes proposed in the Application would substantially worsen the NGSO interference environment, adversely affect geostationary orbit ("GSO") networks, and raise space safety concerns, the Commission cannot conclude that grant of the Application would serve the public interest. If it does not reject the Application outright, the Commission must determine that the proposed redesign renders the SpaceX system fundamentally different from what was previously authorized, requiring that the system be treated as newly filed and incorporated into the Ku/Ka-band processing round that closed in May.

INTRODUCTION AND SUMMARY

SES has a strong interest in the Application, as O3b operates a Ka-band NGSO system and SES entities operate GSO networks in both Ku- and Ka-band spectrum. In the Application,

[1] Space Exploration Holdings, LLC, Call Signs S2983 and S3018, File No. SAT-MOD-20200417-00037 (the "Application").

SpaceX proposes major changes to the NGSO system the Commission initially authorized in 2018, which has already been modified twice.[2] SpaceX originally was granted authority for 4,425 satellites at orbital altitudes between 1,110 and 1,325 kilometers,[3] then later asked for and received permission to relocate 1,584 of the satellites to a 550 kilometer altitude.[4] SpaceX now proposes to abandon its initial altitude altogether by relocating the remaining 2,824 satellites in its revised system to altitudes ranging from 540 to 570 kilometers, with a 30-kilometer orbital tolerance.[5]

SpaceX attempts to characterize these serial modifications as a modest evolution of the original system,[6] but the facts tell a different story. Through a daisy chain of adjustments, the SpaceX system authorized by the Commission has morphed into a different constellation altogether, with no material resemblance to the network SpaceX proposed in November of 2016.

Critically, in order to maintain coverage with roughly the same number of satellites operating at a much lower orbit, SpaceX proposes significant system-wide changes to its space and earth station operations that will seriously degrade the interference environment. To compensate for the smaller beam size on the ground that results from the decreased altitude, SpaceX needs to employ a higher scan angle of up to 57 degrees away from nadir in the Ku-band

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[2] *See Space Exploration Holdings, LLC*, Memorandum Opinion, Order and Authorization, 33 FCC Rcd 3391 (2018) ("SpaceX Order"); *Space Exploration Holdings, LLC*, Order and Authorization, 34 FCC Rcd 2526 (IB 2019) ("SpaceX First Modification Order"); *Space Exploration Holdings, LLC*, Order and Authorization, DA 19-1294 (IB rel. Dec. 19, 2019) ("SpaceX Second Modification Order").

[3] SpaceX Order, 33 FCC Rcd at 3392, ¶ 2.

[4] SpaceX First Modification Order, 34 FCC Rcd at 2526, ¶ 2.

[5] Application, Narrative at 3, Attachment A at 3.

[6] *Id.*, Narrative at i.

and up to 66 degrees away from nadir in the Ka-band.[7] Moreover, SpaceX plans to operate its earth stations with a lower minimum elevation angle of 25 degrees for both user beams and gateway beams,[8] compared to 40 degrees in its original filing.[9]

As discussed below, these planned changes to the SpaceX system parameters would create multiple adverse effects on SES's operations. In the NGSO sphere, SpaceX's altered transmission geometries would create new conjunction events with O3b's equatorial satellites over much of the United States, more than quadrupling the time every day during which such events, with the potential for harmful interference to O3b or to SpaceX, would occur. And with the phased array antennas aboard the SpaceX satellites, larger scan angles can create "grating lobes" at a significant angle off the boresight, producing additional harmful interference to O3b earth stations located at distances well outside the target of the SpaceX beam. SpaceX's decision to move its satellites closer to Earth without changing the spacecraft's gain-to-noise temperature

[7] *See id*., Attachment A at 6-7. In comparison, the technical materials for the original SpaceX NGSO filing specified a maximum angle of 40.46 degrees away from nadir for both the Ku-band and Ka-band operations. *See* Space Exploration Holdings, LLC, Call Sign S2983, File No. SAT-LOA-20161115-00118 ("SpaceX 2016 Application"), Attachment A at 5, 14.

[8] Application, Attachment A at 4. SpaceX proposes to use an even lower minimum elevation angle – 5 degrees – for gateway operations inside the polar region with certain satellites. *Id*., Attachment A at 7.

[9] SpaceX 2016 Application, Attachment A at 1 (the proposed "constellation will enable SpaceX to provide full and continuous global coverage, utilizing a minimum elevation angle of 40 degrees"). SpaceX indicated in its November 2018 modification application that it might "periodically use a minimum elevation angle as low as 25 degrees" with the subset of satellites for which it sought a lower orbit altitude in that filing, but emphasized that the elevation angle "will return to 40 degrees as the constellation is deployed more fully." *See* Space Exploration Holdings, LLC, Call Signs S2983 and S3018, File No. SAT-MOD-20181108-00083 ("SpaceX 2918 Modification"), Attachment A at 5, 8. But the instant Application makes clear that SpaceX is now seeking a permanent change to the 25-degree minimum elevation angle, as there is no reference to reverting to a higher elevation angle over time.

("G/T") will also mean that SpaceX will experience a higher magnitude of interference from transmitting O3b earth stations given the lower path loss effects.

Grating lobe emissions would adversely affect earth stations communicating with SES's GSO spacecraft as well, in both Ku-band and Ka-band frequencies. Furthermore, the information SpaceX has supplied casts doubt on the validity of its claims that it will comply with equivalent power flux density ("EPFD") limits designed to protect GSO systems.

Finally, SpaceX's proposal to lower all of its remaining satellites will make physical coordination more difficult for O3b and others planning to deploy satellites near the orbits now sought by SpaceX. Substantial open questions remain regarding the efficacy of the measures SpaceX intends to take to manage space safety matters.

Thus, SpaceX's claims that the changes it proposes "will not have any significant impact on other users of the Ku- and Ka-band spectrum"[10] are directly contradicted by the facts. As SpaceX recognizes, whether a modification presents significant interference problems is a central consideration in whether a modification is eligible for grant.[11] Here, the substantial worsening of the interference environment for NGSO and GSO systems requires the Commission to deny the Application.

At the very least, the breadth of the changes proposed in the Application and the massive increase in interference to O3b require treating the reconfigured SpaceX system as a newly filed request, ineligible for continued inclusion in the Ku/Ka-band NGSO processing round that closed in November of 2016. As SpaceX has previously acknowledged, the Teledesic decision mandates this outcome, specifying that if a modification presents "significant interference

[10] Application, Attachment A at 15.

[11] Application, Narrative at 9 & n.12, *citing* Teledesic *LLC*, 14 FCC Rcd 2261 (IB 1999) ("Teledesic") at 2264, ¶ 5.

problems" the Commission will "treat the modification as a newly filed application and would consider the modification application in a subsequent satellite processing round."[12] Thus, if the Commission does not deny the Application outright, it must address the revised SpaceX network design as part of the more recent processing round that closed in May and impose conditions that require SpaceX to protect incumbent NGSO and GSO operations. SpaceX must also be required to provide additional analysis on grating lobe issues and EPFD compliance and explain more fully how it will effectively implement orbital debris mitigation measures.

I. BECAUSE SPACEX'S PROPOSED CHANGES WOULD ADVERSELY AFFECT THE NGSO INTERFERENCE ENVIRONMENT, GRANT OF THE APPLICATION WOULD BE CONTRARY TO THE PUBLIC INTEREST

The Application does not meet the clear acceptability standards expressed in prior decisions addressing SpaceX modification filings. As SpaceX has recognized, Commission policies specify that a modification application that does not seek access to additional bandwidth will be granted unless authorizing the proposed changes would not serve the public interest.[13] In elaborating on this criterion the International Bureau explained that if "a modification would worsen the interference environment, that would be a strong indication that grant of the modification would not be in the public interest."[14] Determining a modification's effect on the interference environment requires consideration of both whether the changes will cause

[12] *See* SpaceX 2018 Application, Waiver Requests at 2 & n.9, *quoting* Teledesic, 14 FCC Rcd at 2264, ¶ 5.

[13] Application, Narrative at 6 & n.8, *citing* SpaceX First Modification Order, 34 FCC Rcd at 2528, ¶ 7 and 47 C.F.R. § 25.117(d)(2)(ii) and (iv).

[14] SpaceX First Modification Order, 34 FCC Rcd at 2529, ¶ 9.

additional interference to other systems and whether the changes make the applicant more vulnerable to interference from other systems.[15]

The SpaceX Application fails both parts of this test. SpaceX submits an analysis that purports to show that interference to O3b would not increase as a result of the planned system changes,[16] but the facts described below make clear that O3b would experience significant new interference stemming from the revised system configuration. The Application does not address the effects on interference SpaceX would receive at all, and here too the facts show much higher interference levels. These adverse impacts on the overall NGSO interference environment require the Commission to conclude that grant would not serve the public interest.

A. The Modified Geometry of the SpaceX System Would Cause New Conjunction Events with O3b Over the United States

The space station and earth station operating parameters SpaceX proposes would lead to new conjunction events with O3b over a substantial portion of the contiguous United States ("CONUS") where such events would have been impossible before. Under the currently authorized configuration, a SpaceX earth station in CONUS pointing to a space station at 1,150 kilometers with a minimum elevation angle of 40 degrees would almost never have generated an inline event with an earth station communicating with O3b's equatorial fleet at 8,062 kilometers, even if the two companies' earth stations were collocated. Except for in the southernmost tip of Texas or Florida, a SpaceX ground antenna pointed in that manner cannot "see" the equatorial arc occupied by the O3b satellites.

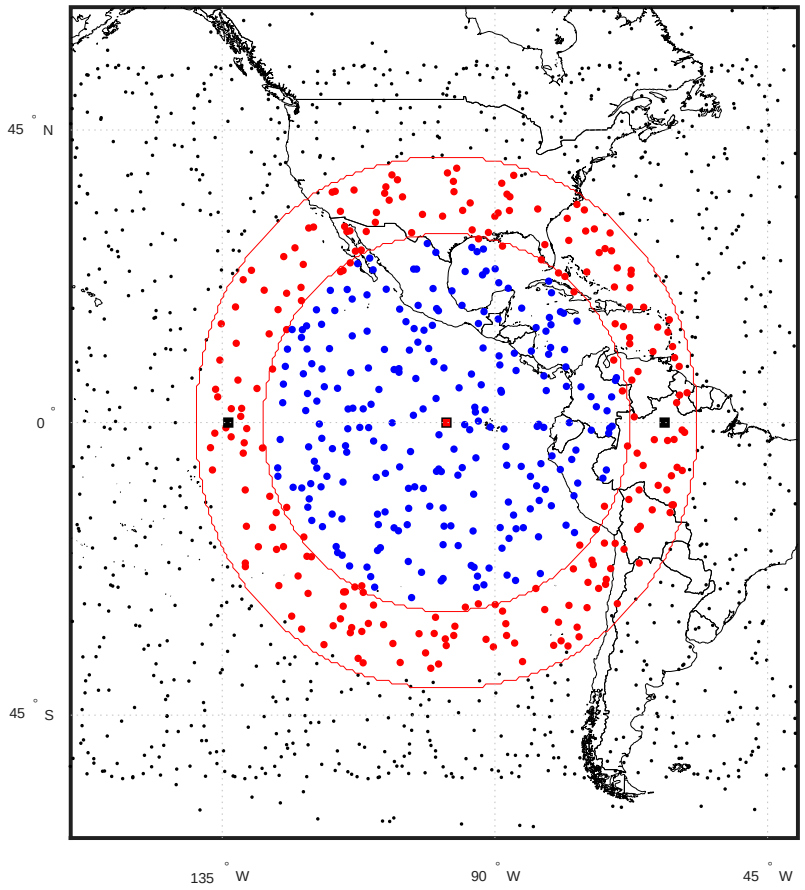
All that would change under the altered characteristics set forth in the Application. The proposed lower elevation angles of SpaceX earth stations pointing at lower altitude satellites

[15] *See id.* at 2530, ¶ 11 and 2531, ¶ 14.

[16] Application, Attachment A, Annex 1 at A1-6, A1-9.

would mean that O3b operations in the majority of CONUS would be subject to conjunction events for the first time.

The following figure provides a snapshot of this effect. An O3b equatorial satellite is shown as a red square in the center of the figure, and the blue dots in the inner ring surrounding the square represent the SpaceX satellites with which conjunction events with the O3b satellite are possible under the current SpaceX network configuration. The red dots in the "donut" between the inner ring and the outer ring show the additional SpaceX satellites capable of creating a conjunction event with O3b if the changes proposed in the Application were implemented. As the O3b satellite moves over the equator, the "donut" will move as well, meaning that any part of CONUS below roughly 41° N.L. will be within the area in which new inline events would be made possible by the SpaceX changes.



These additional conjunction events will create interference concerns for O3b in both the uplink and downlink directions. The attached Technical Annex quantifies the impact on O3b. Specifically, O3b performed a simulation to calculate the duration of inline events with O3b's constellation using the characteristics of the currently authorized SpaceX system and the system as modified by the changes discussed in the Application. The simulation showed that the changes requested in the Application would increase both the number and persistence of inline events with O3b, more than quadrupling the total duration of such events as compared to what would occur with the currently authorized SpaceX system. Specifically, the data show that the O3b constellation is 434% more likely to experience a conjunction event with a SpaceX satellite under the proposed modification.

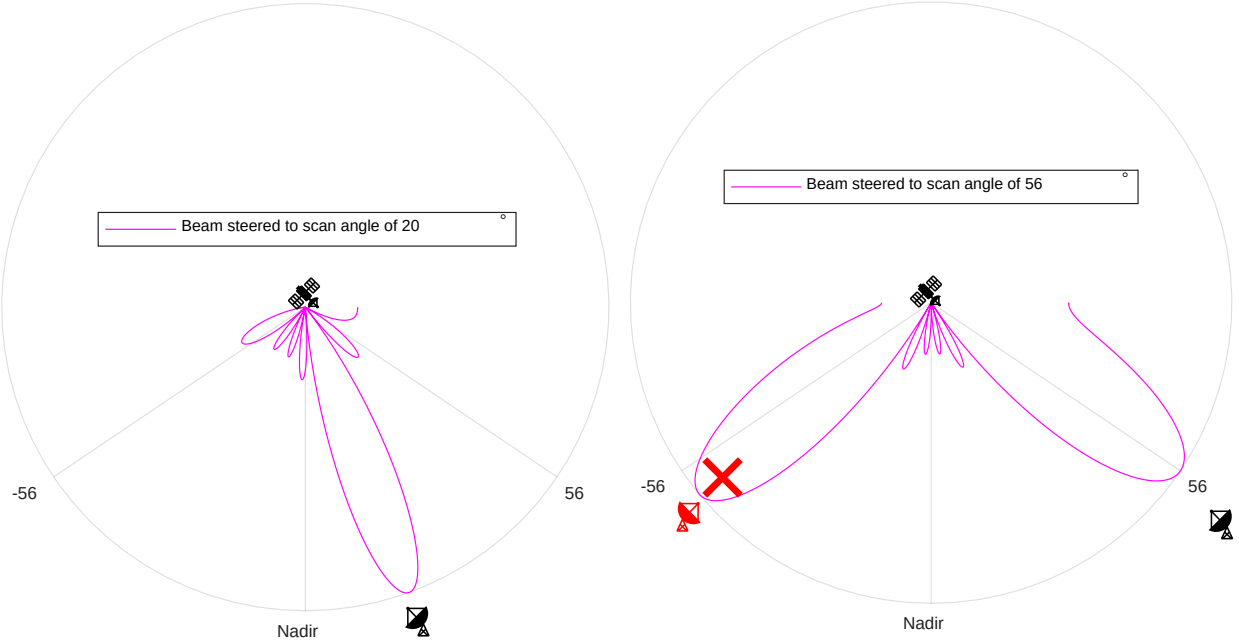
This massive jump in conjunction events directly contradicts SpaceX's claims that the changes it proposes will not harm other NGSO operators and would be consistent with the types of alterations to the SpaceX system that have previously received Commission approval. In allowing SpaceX to lower the altitudes of a portion of its authorized space stations, the International Bureau found that "the number of spatial configurations that have the potential for generating interference between SpaceX and any other NGSO FSS system in the same processing round is expected to remain approximately unchanged," and stated that it considered this factor "to be a fundamental element in assessing whether there would be significant interference problems as a result of granting the proposed modification."[17] Because the revised SpaceX operating characteristics described in the Application would cause a substantially higher number of spatial configurations that would generate interference issues, the Application violates the standards applied in prior decisions and must be denied.

B. The Larger Scan Angles SpaceX Proposes Could Create Grating Lobes That Would Cause Additional Interference to O3b

In addition to the earth station elevation angle and satellite altitude changes that cause the multiplication of conjunction events described above, the Application describes planned alteration of the scan angles employed by the SpaceX satellites. Specifically, in order to operate all of its satellites at a lower altitude but maintain the originally proposed geographic coverage, SpaceX needs to electronically scan its antenna arrays more aggressively to expand their beam coverage. This increased scan angle of the satellites' phased array antennas could produce unintended large side lobes known as grating lobes that pose a significant risk of interference to O3b.

[17] SpaceX First Modification Order, 34 FCC Rcd at 2530, ¶ 11.

As discussed in the attached Technical Annex and depicted in the figures below, an electronically formed and steered beam can have grating lobes that appear unintentionally at far-off angles from boresight but at gain levels comparable to the main lobe. The figure on the left shows a satellite beam pointing at a scan angle of 20 degrees from nadir, which is well formed with no apparent grating lobes landing on the Earth. However, if this same antenna is steered to a scan angle of 56 degrees away from nadir, a second beam can appear at an angle well removed from the desired boresight. The O3b victim earth station shown in red on the figure to the right below may experience interference even though it is located a significant distance from the target SpaceX earth station.



The Application does not discuss the operational impact of the proposed increase in scan angles for the SpaceX satellite antennas or indicate whether SpaceX has taken any steps to evaluate the potential for interfering grating lobes or mitigate their effects. These deficiencies further undermine SpaceX's arguments that its proposed changes will not harm other operators.

C. SpaceX Will Experience Additional Interference from O3b Due to the Changes Proposed in the Application

Two aspects of the changes proposed in the Application would increase the interference O3b's transmissions would cause to SpaceX. First, although the SpaceX satellites would all be deployed much closer to the Earth than previously authorized, the G/T values for the network have changed only modestly, from a peak G/T of 13.7 dB/K in the original SpaceX filing[18] to 11.5 dB/K in the current Application.[19] The G/T describes the satellite receiver's sensitivity to uplink emissions, both wanted and interfering, and this slight decrease in G/T is not commensurate to the change in path loss resulting from the lower altitude, which is roughly 6-8 dB.[20]

The inevitable consequence of SpaceX's decisions is that interference to SpaceX stemming from O3b's transmitting earth stations will be magnified under the system configuration described in the Application. Transmissions originating from O3b's earth stations will be just as strong as they are today, but they will encounter less path loss on the way to the SpaceX satellites due to the substantially lower altitude.[21] As a result, the O3b signal power will be greater when received at the SpaceX satellite than it would if the satellite were further away.

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[18] SpaceX 2016 Application, Schedule S (specifying a G/T at the maximum gain point of 13.7 dB/K in the Ka-band).

[19] Application, Schedule S (specifying a G/T at the maximum gain point of 11.5 dB/K in the Ka-band).

[20] *See* Petition to Defer of SES Americom, Inc. and O3b Limited, Call Signs S2983 and S3018, File No. SAT-MOD-20190830-00087, filed Oct. 15, 2019 at 9-10 n.22 (lowering the altitude of SpaceX's satellites "results in a path loss decrease of 6 to 8 dB").

[21] *See* SpaceX First Modification Order, 34 FCC Rcd at 2531, ¶ 15 (lowering the "operational altitudes of SpaceX's satellites will result in the transmissions from earth stations of other NGSO FSS systems reaching SpaceX's satellites at a higher power level because of less spreading losses between the earth station and the satellites at closer distances than previously proposed").

By reducing orbital altitudes without making its receivers less sensitive, SpaceX has created a situation that will increase the interference it experiences.

Second, the large number of new inline events described above that results from SpaceX's plan to use lower earth station elevation angles will increase the likelihood of O3b interfering with SpaceX just as it increases the interference from SpaceX to O3b. And the duration of these mutual interference events will be the same for both companies as this is a shared problem between the affected parties.

The Application is silent on the issue of interference to SpaceX that would result from the changes it proposes. Of course, there are voluntary actions that SpaceX could take to mitigate these effects. For example, the International Bureau noted in the SpaceX First Modification Order that SpaceX could offset the additional interference resulting from lower satellite altitudes "by keeping the transmit power of its own earth stations at the same level that they are currently authorized to transmit, which would allow the SpaceX transmissions to be received in the presence of stronger signals of other NGSO FSS systems."[22] However, it is unclear whether SpaceX intends to take this step. On the one hand, the Application specifies that the lower spacecraft altitude will allow SpaceX "to decrease the power levels of its transmissions from and to its satellites."[23] On the other hand, in earth station applications filed as recently as last month,[24] SpaceX has continued to seek the same operating parameters including power levels

[22] *See id.*

[23] Application, Narrative at ii. *See also id.* at 10 ("because these satellites will be operating at a lower altitude, they will be able to transmit and receive at lower EIRP levels").

[24] *See, e.g.,* SpaceX Services, Inc., Call Sign File No. E202116, File No. SES-LIC-20200616-00648.

that it requested in prior applications, suggesting that it does not intend to decrease the transmit power of its ground antennas.

In either case, the overall interference environment will be worsened. If SpaceX does lower the power of its earth station transmissions, then its space stations will receive more interference from O3b and other NGSO systems. If SpaceX maintains the same earth station transmission power to avoid receiving additional interference, its transmissions will create greater uplink interference to O3b, as discussed in the Technical Annex.

In the case of the new conjunction events triggered by the lower elevation angles, SpaceX could agree that it would take on the full burden of using space station diversity or other measures to resolve any additional interference it would receive due to the changes proposed in the Application. In reconsidering the SpaceX First Modification Order, the International Bureau declined to impose additional conditions to address increased incidence of inline events, but that was based on the Bureau's acceptance of a dynamic analysis submitted by SpaceX reflecting undefined assumptions that purported to show that the modification reduced the duration and total percentage of time during which a given level of interference would be exceeded.[25] As discussed above, the elevation angle changes accompanying the lowering of satellites proposed in the instant Application increase the number and more than quadruple the duration of inline events between the SpaceX system and the O3b equatorial satellites. As a result, the concerns addressed in the SpaceX Reconsideration Order – that SpaceX's system changes making it more vulnerable to interference would increase the number of situations that require splitting of the available spectrum absent coordination[26] – cannot be ignored here.

[25] *Space Exploration Holdings, LLC*, Memorandum Opinion and Order, DA 20-588 (IB rel. June 4, 2020) ("SpaceX Reconsideration Order") at ¶ 11.

[26] *See id.* at ¶¶ 8-9.

SpaceX has previously been dismissive of objections to its modifications based on the increased interference it would experience,[27] but the Commission has recognized that assessing the effect of proposed changes on the interference environment requires consideration of the interference the applicant would receive as well as the interference it would cause.[28] The justification for such an approach is clear: the Commission cannot permit an applicant to unilaterally make changes to its system that increase its susceptibility to interference and then claim entitlement to protection for its more vulnerable operations.

That is particularly the case in NGSO-to-NGSO sharing, which requires band-splitting if a defined interference threshold is exceeded for either of the systems involved in an inline event.[29] Under these circumstances, SpaceX's decisions that make it more vulnerable to interference can translate directly into depriving other NGSO operators of access to the full available spectrum – a result that cannot be reconciled with the Commission's policies for fair treatment of competing NGSO operators. O3b must not be made to suffer the consequences of SpaceX's own system reconfiguration choices.

The Application completely fails to address these issues. Because the changes SpaceX proposes would make SpaceX's system "more susceptible to interference from other NGSO FSS systems, which would change the operating environment,"[30] grant of the Application would be contrary to Commission policies.

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[27] *See, e.g.*, Opposition of Space Exploration Holdings, LLC and SpaceX Services, Inc., File Nos. SAT-MOD-20181108-00083 *et al*., at 3-4.

[28] SpaceX First Modification Order, 34 FCC Rcd at 2531, ¶ 14.

[29] *See* 47 C.F.R. § 25.261(c).

[30] SpaceX First Modification Order, 34 FCC Rcd at 2531, ¶ 14

D. The Bureau Must Deny or Defer the Application Because the Proposed Changes Will Worsen the NGSO Interference Environment

Thus, the facts contradict SpaceX's claims that its changes will not materially impact other NGSO operators. Instead, the reconfiguration would significantly increase interference to O3b and make SpaceX more vulnerable to interference from O3b and other NGSO operators, leading to the potential for many more cases that could require band-splitting.

According to the International Bureau's previous findings in SpaceX modification proceedings, if "a modification would worsen the interference environment, that would be a strong indication that grant of the modification would not be in the public interest."[31] Consistent with that precedent, the Commission must conclude that this Application is contrary to the public interest and subject to denial on those grounds.

At a minimum, under the precedent established in Teledesic the Commission must determine that the adverse effect on the NGSO interference environment caused by the proposed changes requires that the Application be considered as effectively a re-filing of the SpaceX system proposal that must be incorporated into the Ku/Ka-band NGSO processing round that closed in May. This approach reflects the fact that the system SpaceX now proposes to deploy is fundamentally and materially different than the one for which it originally applied and is necessary to protect the expectations of O3b and other operators that received authority as part of the Ku/Ka-band processing round that closed in November of 2016.

II. HARMS TO GSO OPERATIONS FROM THE CHANGES SOUGHT IN THE APPLICATION PROVIDE A SEPARATE BASIS FOR DENIAL

The operating characteristics discussed in the Application also threaten SES's GSO operations in Ku-band and Ka-band spectrum. First, as discussed above, the phased array

[31] SpaceX First Modification Order, 34 FCC Rcd at 2529, ¶ 9.

antennas on the SpaceX satellites operating with the increased scan angles proposed could generate grating lobes with substantial power at earth station locations far removed from the SpaceX beam's target cell. Ground stations communicating with SES's Ku-band and Ka-band GSO networks could be subject to material interference as a result of these grating beams. Because SpaceX has not provided any analysis of this issue, SES is unable to evaluate the magnitude of the potential interference to its GSO operations.

Second, conflicting information provided by SpaceX calls into question the reliability of its claims regarding compliance with applicable Ka-band EPFD limits in Article 22 of the ITU Radio Regulations for the protection of GSO FSS networks. Specifically, the Application explains that in the Ka-band, "up to eight satellites [transmit] to a gateway location, for a maximum of sixteen co-frequency beams."[32] However, when SpaceX provided additional data SES requested regarding the basis for the EPFD calculations SpaceX supplied with its prior modification, those materials showed that SpaceX used a value of one for the "N_co" parameter that specifies the number of co-frequency satellites transmitting at a given time.

SpaceX does not disclose whether it used an N_co value of eight as appropriate to produce the graphs attached as Annex 2 of the Application's technical showing. If it did not, SpaceX should be required to disclose what value it did use and why.

The prospect of added interference to GSO systems provides an independent basis for denial of the Application. At the very least, the Commission should require SpaceX to provide additional information and analysis regarding how it will mitigate the potential for grating lobes caused by its system reconfiguration to create harmful interference to Ku-band and Ka-band

[32] Application, Attachment A at 8.

GSO earth stations and explain more fully the basis for its assertion of compliance with EPFD limits.

III. THE APPLICATION RAISES SPACE SAFETY ISSUES

Finally, open questions remain regarding how SpaceX will meet space safety standards. SpaceX now proposes to deploy all 4,408 of its planned satellites at nominal altitudes between 540 and 570 kilometers with a tolerance of +/- 30 kilometers.[33] As SpaceX acknowledges, this broad altitude range is already occupied by satellites deployed by other operators,[34] and it is likely to continue to attract more systems. O3b, for example, has requested authority to expand its system by adding satellites at a nominal orbital altitude of 507 kilometers[35] – just three kilometers below the lower end of the span of altitudes sought by SpaceX when taking into account the large tolerance it is requesting. As a result, O3b has a direct interest in SpaceX's ability to conform to collision avoidance and orbital debris mitigation standards.

SpaceX's showing on these matters remains incomplete. The Application indicates that SpaceX has "implemented autonomous conjunction avoidance technology on its spacecraft"[36] but provides no details on the workings of that system. In addressing orbital debris matters relating to the SpaceX 2018 Modification, the Bureau highlighted the fact that SpaceX had "voluntarily assumed responsibility for collision avoidance" with respect to other operators.[37] In this Application, however, SpaceX expressly disavows the idea that it should assume full

[33] *Id*., Attachment A at 3.

[34] *Id*., Attachment A at 23.

[35] *See* O3b Limited, Call Sign S2935, File No. SAT-MOD-20200526-00058, Legal Narrative at 1.

[36] Application, Attachment A at 22.

[37] SpaceX Reconsideration Order at ¶ 20.

collision avoidance responsibility.[38] As a result, the foundation that previously allowed the Bureau to find that permitting SpaceX to lower its satellites' altitude was consistent with Commission debris avoidance policies is absent here. The Commission should not allow SpaceX to evade the consequences of its own decision to introduce a total of more than 4,000 satellites to an orbit with multiple existing and prospective users.

IV. CONCLUSION

Because SpaceX's proposed changes will significantly adversely affect the NGSO interference environment, pose a threat to SES's GSO operations, and create space safety concerns, the Commission should deny the Application. At a minimum, the Commission should defer consideration of the reconfigured SpaceX system to the second Ku/Ka-band processing round and condition any grant to protect O3b and SES operations.

Respectfully submitted,

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July 13, 2020

[38] *See, e.g.*, Application, Legal Narrative at 11 (arguing that SpaceX should not be subject to a condition requiring it to avoid non-propulsive systems).

AFFIDAVIT

1. I am Vice President, Regulatory for O3b Limited.

2. I have reviewed the foregoing Petition to Deny or Defer of SES Americom, Inc. and O3b Limited. All statements made therein are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

By: /s/ Suzanne Malloy

Date: July 13, 2020

CERTIFICATE OF SERVICE

I hereby certify that on this 13 day of July, 2020, I caused to be served a true and correct copy of the foregoing "Petition to Deny or Defer of SES Americom, Inc. and O3b Limited" on the following:

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/s/
Suzanne Malloy

Technical Annex

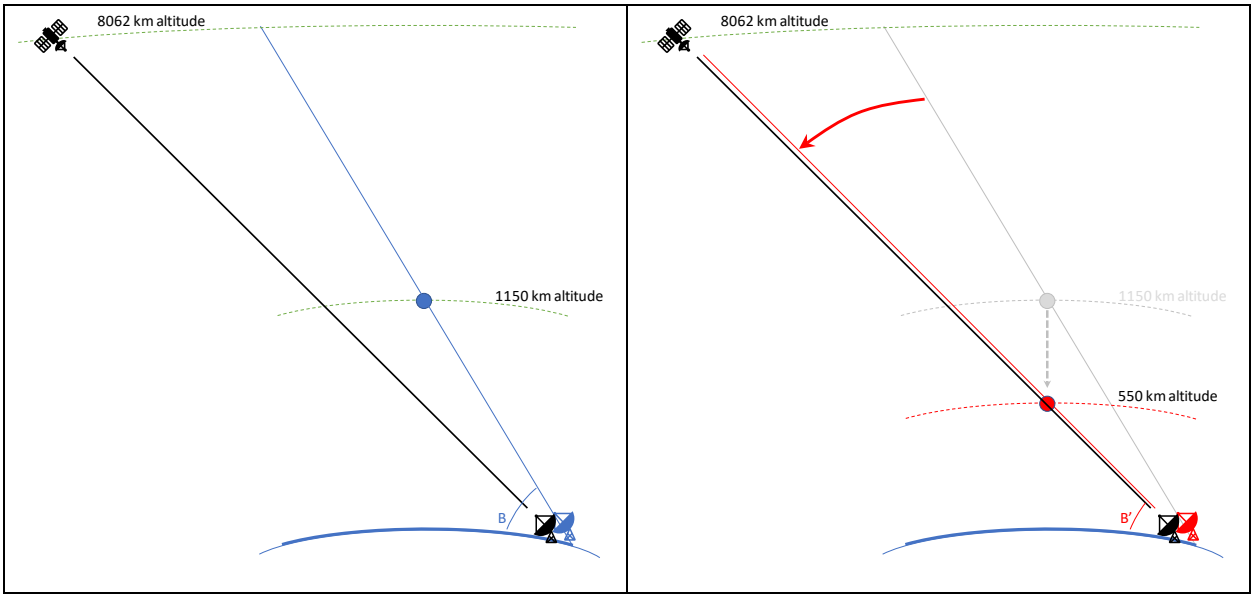
SES has performed a series of analyses to evaluate the potential for changes in the interference environment resulting from SpaceX's Application seeking to fundamentally modify its satellite system design by lowering the orbit of satellites currently authorized for altitudes ranging between 1110 and 1325 km to between 540 and 570 km and making related changes to other operational parameters. The results show that the proposed changes significantly increase the likelihood of interference to the O3b Ka-band NGSO network in both the uplink and downlink directions. SpaceX would also receive greater interference from O3b's operations than if SpaceX maintained its current system design. Moreover, the proposed SpaceX changes would create the potential for additional interference to SES GSO operations in the Ku-band and the Ka-band. These effects are described below.

1. The system-wide changes proposed in the Application, including lowering the minimum elevation angle from 40 degrees to 25 degrees, will substantially worsen the NGSO interference environment

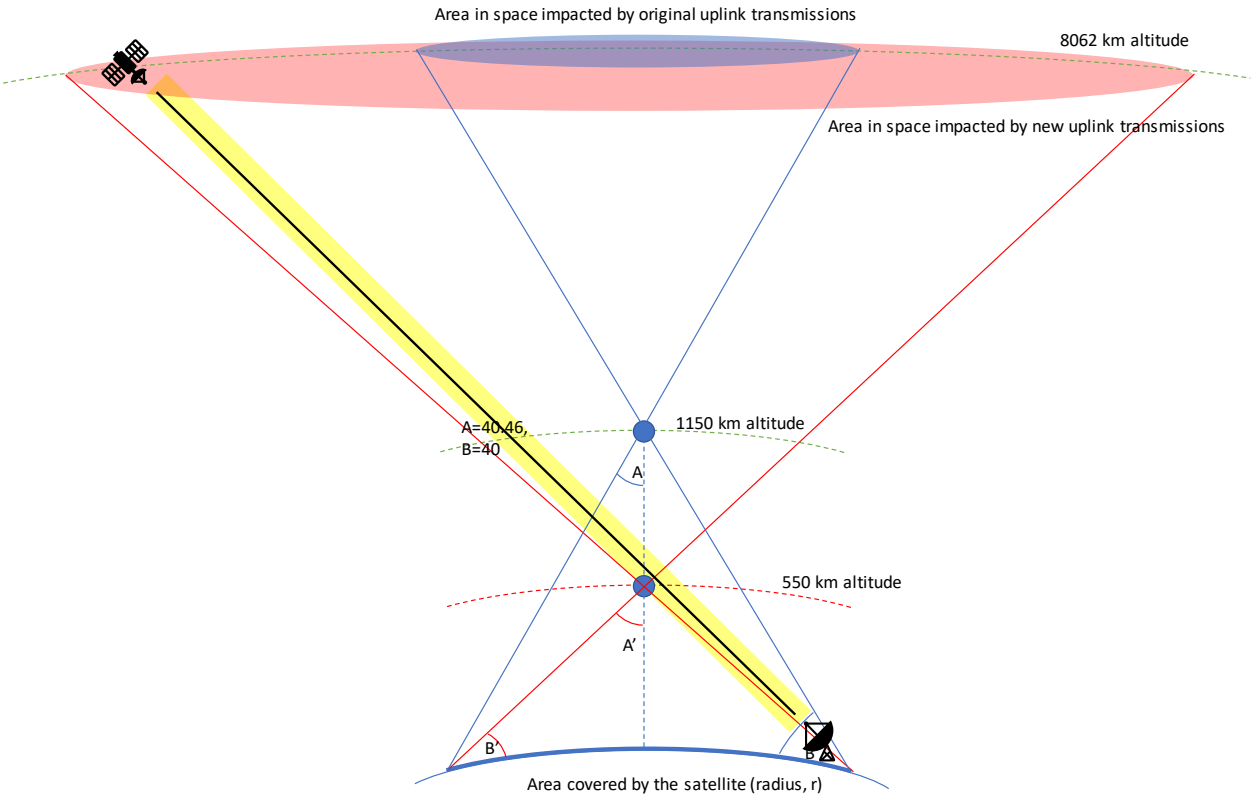
In order to maintain the same coverage area with satellites at a lower altitude, the Application states that the minimum earth station elevation angle will be 25 degrees (Application, Attachment A at 4), rather than the 40-degree minimum elevation angle SpaceX originally specified. SES studied the increased area of possible interference events both in space and on the Earth that results from this change. With a 40-degree elevation angle, inline events between the SpaceX system and the O3b constellation would almost never have occurred over the contiguous United States (CONUS) because the geometry would have allowed conjunction events only for earth stations located in the southernmost regions of CONUS.

The figures below illustrate a SpaceX earth station being served by an original-altitude satellite at 1150 km compared with a proposed-altitude satellite at 550 km. In the figure on the left, the geometry makes it impossible for the SpaceX earth station and satellite pair to have a conjunction event with an O3b satellite at 8062 km serving an earth station collocated with or close to the SpaceX earth station. However, at the lower SpaceX satellite altitude, the geometry changes and produces a conjunction event

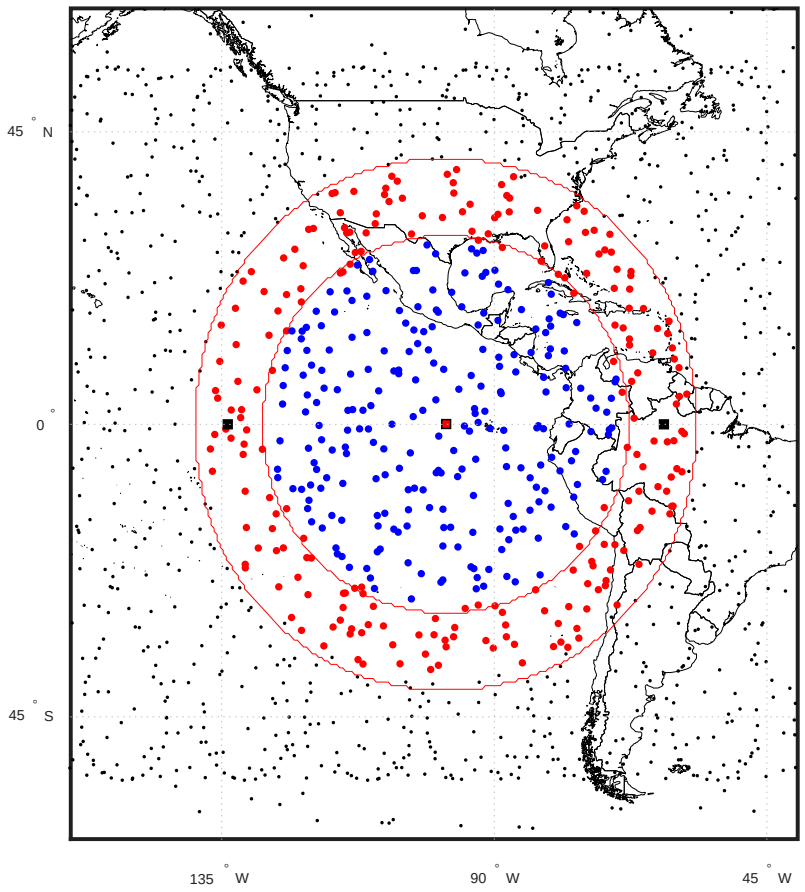
between the SpaceX and O3b satellite-earth station pairs. The effects of the change on the O3b interference environment are discussed below.



Expanding this example to consider all possible geometries, the following graphic illustrates the increased interference area into (and from) O3b satellites and their associated earth stations associated with the lower SpaceX satellite altitude and earth station elevation angle. This two-dimensional graphic is intended to show a three-dimensional issue since the hourglass figures depicted are actually three-dimensional cones. The areas on Earth and in space within which a potential inline event could occur with the currently authorized SpaceX system configuration are outlined in blue, and the areas subject to an inline event with the proposed modified SpaceX configuration are outlined in red. Any O3b satellite that might appear in the red area could experience conjunction events with a SpaceX satellite-earth station pair based on the modified geometry resulting from the changes in the Application, with a potential for interference impact in both the uplink and downlink directions.



SES next maps the area where new conjunction events between SpaceX and O3b could occur due to the changes proposed in the Application. In the figure below, the O3b satellite at 0°N latitude is indicated by a red square, and the two solid red circles represent earth station elevation angles of 40 degrees and 25 degrees. The blue dots within the inner red ring depict SpaceX satellites that could be involved in an inline event with the O3b satellite assuming the minimum elevation angle for SpaceX earth stations is 40 degrees. The red dots between the two rings represent SpaceX satellites that could generate inline events with the O3b satellite under the changed configuration proposed in the Application, with SpaceX using lower satellite altitudes and decreasing the minimum earth station elevation angle to 25 degrees. In this snapshot, the number of "original interfering satellites" (blue) is 210 while the number of "new interfering satellites" (red) is 224 – a 106% increase in possible interference cases for this O3b satellite. Thus, the system configuration changes SpaceX is seeking will produce a 106% greater likelihood of inline events with O3b and a corresponding 106% potential increase in amplitude of the aggregate interference received at the O3b satellites.

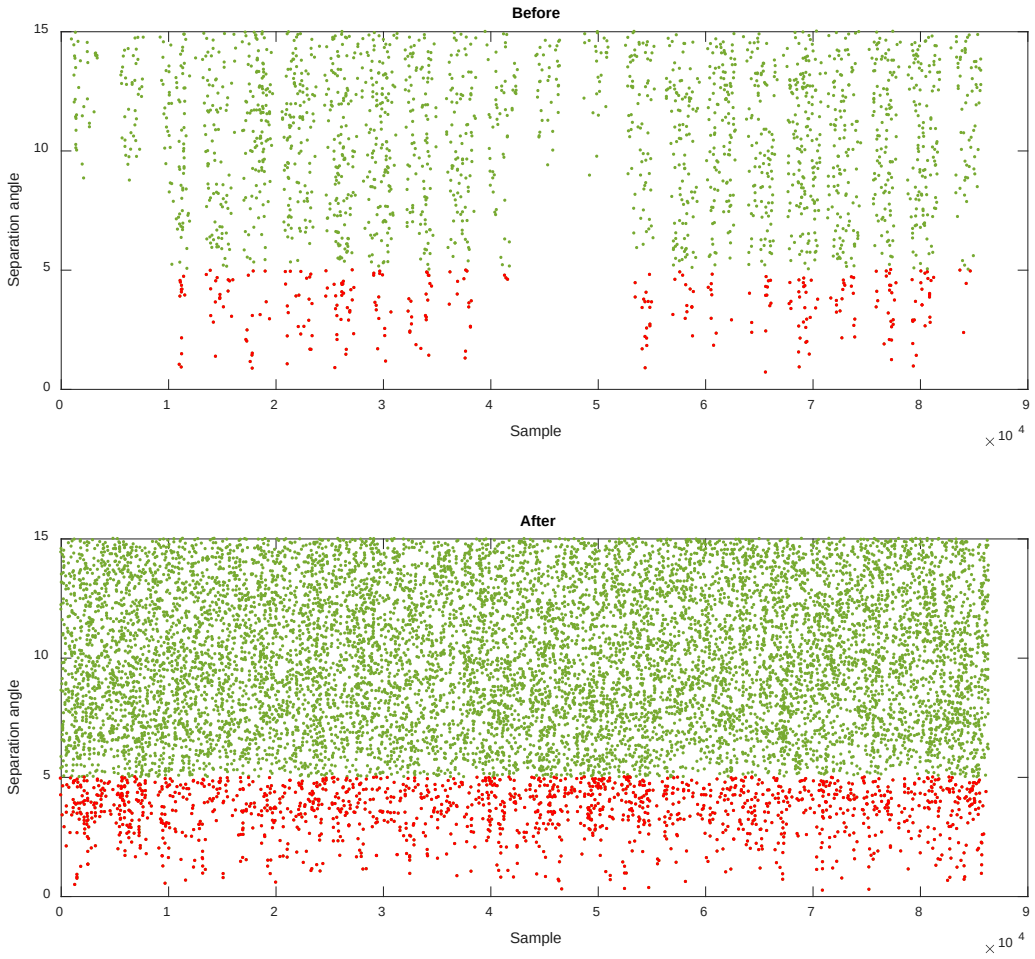


SES performed a simulation comparing the number of conjunction events at an individual O3b earth station that would occur with the current SpaceX configuration (the “Before” case) and with the revised system proposed in the modification (the “After” case). The following two plots illustrate the minimum separation angle from the O3b earth station perspective that exists between any pair of SpaceX and O3b satellites that are visible from this O3b earth station. The results are for a 24-hour simulation of 1 second intervals.

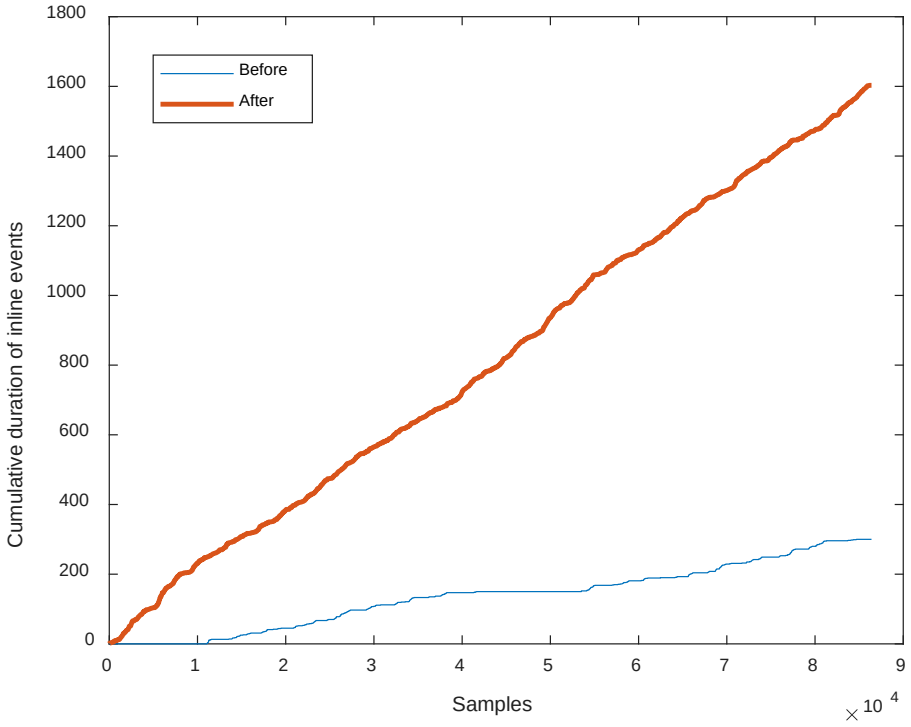
Parameter	Before	After
O3b min elevation angle	10	10
O3b co-frequency satellites	1	1
O3b GSO avoidance angle	6	6
SpaceX constellation	Current	Proposed modification
SpaceX min elevation angle	40	25
SpaceX co-frequency satellites	4	8
SpaceX GSO avoidance angle	22	18
In-line event definition	<= 5 degree of separation	<= 5 degree of separation

At each time step, the number of eligible satellites is determined for each constellation. Eligible satellites are those above the minimum elevation angle for the respective constellation. From this set of satellites, the specified number of co-frequency satellites is randomly selected. For SpaceX four of the eligible satellites are randomly selected for the Before scenario and eight for the After scenario. This reflects the change described in the Application allowing eight rather than four satellites to beam co-frequency transmissions to a SpaceX gateway location. For O3b, the same selection process is followed but only one random satellite is selected from the eligible set. The random selection approach was used to reflect the possibility that any SpaceX or O3b satellite could be communicating with the O3b earth station location at any time. At each time step, the minimum separation angle between any pair of eligible and active SpaceX and O3b satellites was recorded and plotted. Based on the description in the Application, it appears that SpaceX used the same random selection process to perform its interference analyses.

The green points in the figures below represent instances when the minimum separation between a SpaceX and O3b satellite is greater than the 5-degree threshold considered for purposes of this analysis to qualify as a conjunction event. The red points represent instances when the minimum separation angle is less than 5 degrees, signifying a conjunction event.



The figures show that the changes requested in the Application would significantly increase the inline events. In the Before case, the simulation showed that the O3b earth station would be subject to inline events lasting a total of 300 seconds. In the After case, the O3b earth station would be subject to inline events lasting a total of 1603 seconds. This is further illustrated in the following figure depicting the cumulative duration of inline events over the 24-hour sample time for the Before and After cases.

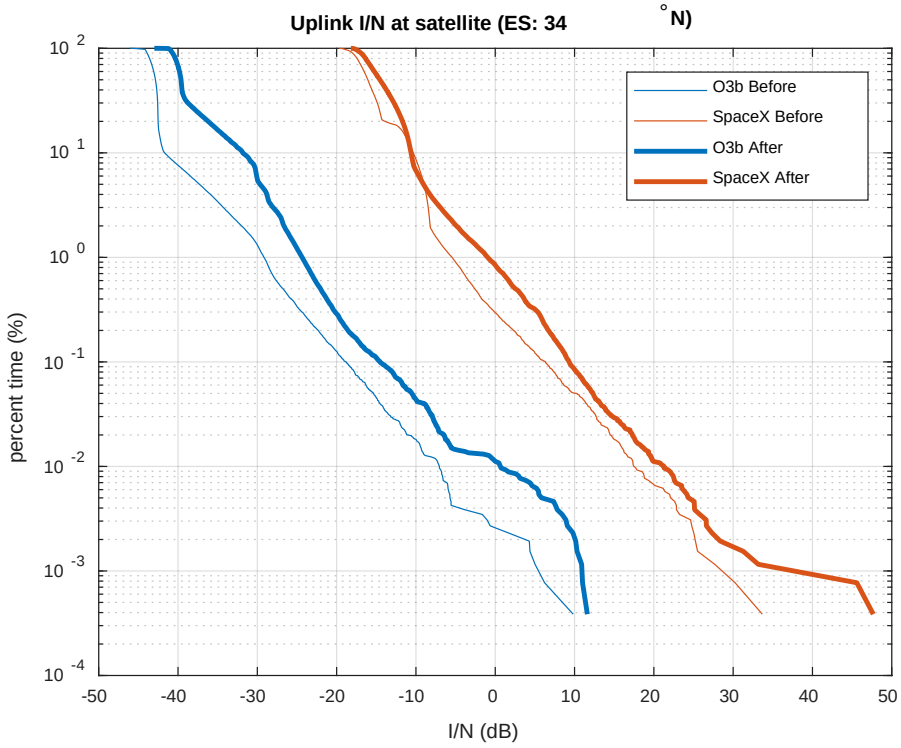


Thus, SpaceX's proposed system modification would increase both the number and persistence of conjunction events experienced by the O3b link, producing a 434% jump in the total duration of such events. As a result, O3b's efforts to avoid interference with SpaceX under the modified configuration would more than quadruple over that required with the existing SpaceX system design.

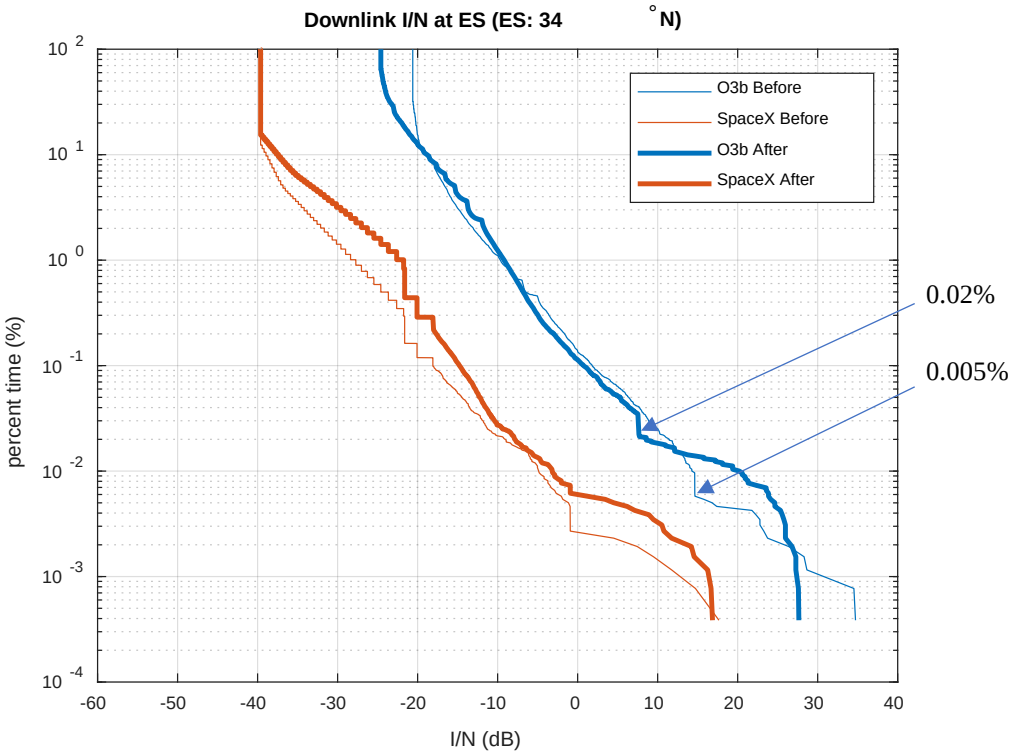
To conclude its analysis, SES performed a simulation that considers the interference-to-noise (I/N) performance of an O3b uplink and downlink for the Before and After cases described above. SES relied on the same inputs used in the prior simulation but employed a longer simulation time of 3 days, with 1-second intervals for the simulation time to collect more data points.

In the uplink direction, the analysis showed a significant harmful impact on O3b. For purposes of its analysis, SES referred to the information available in SpaceX earth station applications on file with the Commission to determine the parameters of the SpaceX uplink emissions. The power levels requested in these recent applications are consistent with those sought in prior SpaceX earth station filings, suggesting that despite statements in the Application about the possibility of using less power to communicate with

satellites at a lower altitude, SpaceX intends to operate its gateway earth stations at the same power levels it has been using to date. The simulation results based on these values show that the changes sought in the Application would cause a significant and persistent increase in interference to the O3b satellites. At the 0 dB I/N point (when SpaceX interference is equal to the O3b system noise), there is a 400% increase in the interference potential. In all cases, the I/N is worse, by significant amounts, for both O3b and SpaceX.



The simulation also showed that the O3b satellite downlink would experience more interference in the short term due to a higher likelihood of main-lobe events created by the proposed modification (changing from 0.005% to 0.02%). Although the probability is still low, this change represents a 300% increase in the likelihood of short-term interference to O3b from the SpaceX operations. This impact is especially meaningful because it represents only the SpaceX contribution to the total interference O3b experiences – multiple other NGSO constellations could also create interference into O3b's operations. The long-term potential for downlink interference to O3b is roughly the same or better in the After case due to SpaceX reducing its peak downlink PFD by approximately 6 dB.

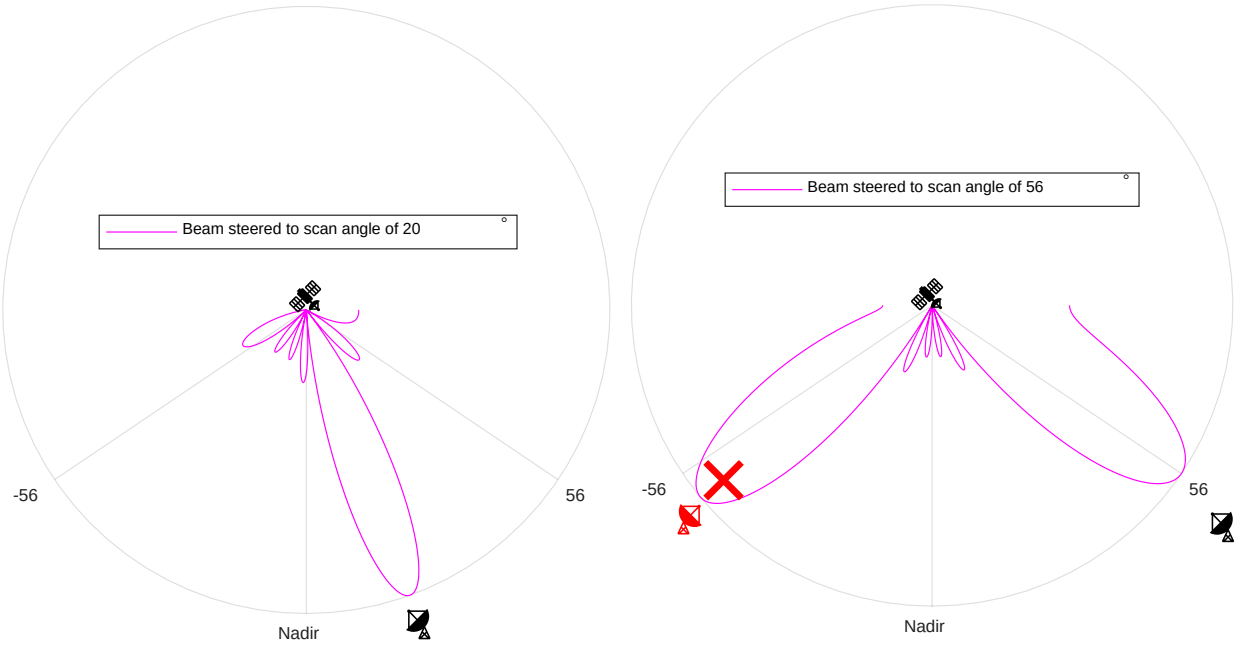


SpaceX earth stations would also be subject to an increase in potential interference from O3b. Specifically, the likelihood that O3b satellite downlinks would cause interference into the main lobe of SpaceX's earth station antennas would increase by approximately 140% (changing from 0.0025% to 0.006%).

2. SES's NGSO and GSO earth stations could both receive additional interference from grating lobes caused by the larger scan angles SpaceX plans to use

In addition to lowering the elevation angle, SpaceX proposes in the Application to use larger scan angles in order to maintain the satellites' total coverage area at the lower altitudes. Increasing the scan angle for satellites that use phased array antennas to electronically form and steer beams can unintentionally create "grating lobes" at a significant angle off the boresight that have gain levels comparable to the main lobe. Such grating lobes are a known phenomenon with active element antennas.

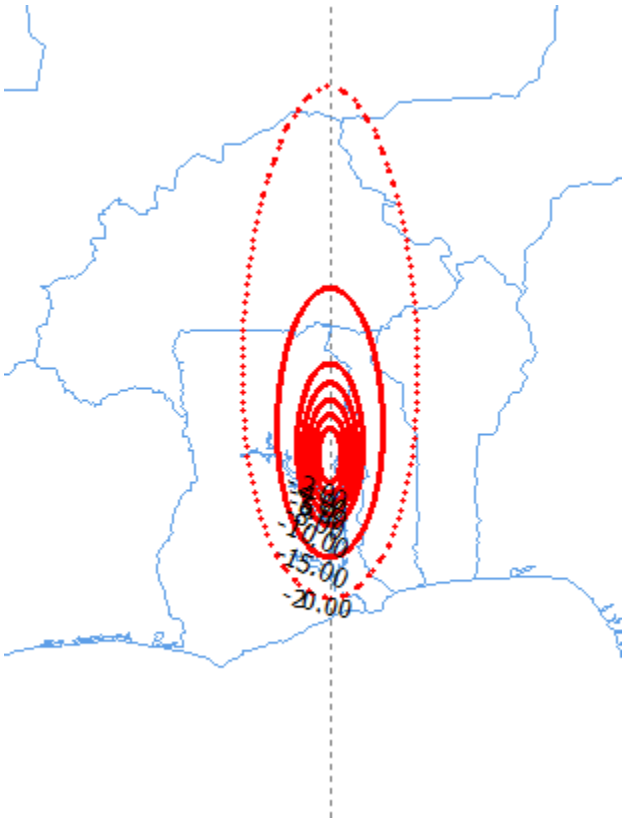
The figures below illustrate this issue. A satellite pointing at a scan angle of 20 degrees from nadir, such as the one shown on the left, generates a well-formed beam with modest sidelobes but no grating lobes that would land on the Earth's surface. At higher scan angles, however, a second beam can appear at an angle significantly offset from the desired boresight, as in the figure on the right. The O3b victim earth station depicted in red on that figure could be subject to interference even though it is located a significant distance from the target SpaceX earth station.



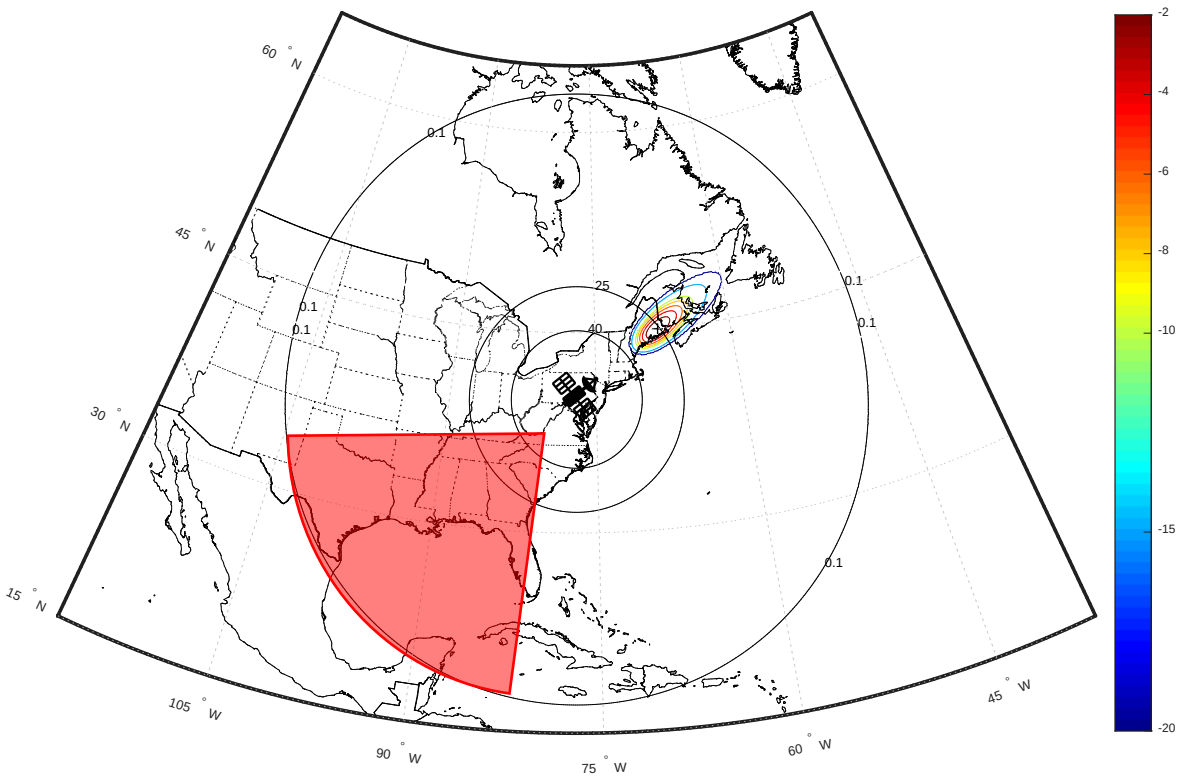
Based on the SpaceX system design description in the Application, SES understands that SpaceX will employ phased array antennas for both its Ka-band and Ku-band operations, creating the possibility of grating lobes that could increase the aggregate interference received at any Ka-band or Ku-band earth station communicating with an SES satellite. If the grating lobe gain is comparable to that of the main lobe, this could also create conjunction events between the grating lobe of the SpaceX system and a link between an O3b space station and earth station pair.

The information provided in the Application does not indicate whether SpaceX has considered the grating lobe issue or taken any steps to mitigate its potential harmful effects. In its Application SpaceX provides

beam coverage information showing data in GIMS format. The figure below illustrates the KA_PHI57 beam diagram supplied by SpaceX.



The SpaceX figure shows the intended beam contours, but the area within the visible range of the space station antenna is much larger. In the illustration below, SES recreated a beam contour based on the SpaceX example shown above but placed it over the United States. The beam is pointed with a 56-degree scan angle away from nadir, consistent with the parameters in the Application, and the figure shows the entire area visible to the satellite.



As originally proposed, the SpaceX design contemplated steering and beamforming within the area shown by the 25-degree elevation angle, with scan angles no greater than ±40 degrees from nadir, allowing for well-formed beams with no grating lobes. With the modifications requested in the Application, to allow the coverage of each SpaceX satellite to remain the same, the scan angles increase up to ±57 degrees from nadir. The larger scan angles substantially increase the possibility of grating lobes arising away from the intended beam target. The most likely area within which these grating lobes would occur is shaded in red in the figure above.

Further information and analysis from SpaceX are required to allow SES and other potentially affected parties to evaluate the magnitude of the resulting interference risk. In particular, SpaceX should provide radiation information for the entire area that could be illuminated by each SpaceX satellite, rather than just depicting the beam characteristics for the intended cell.

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

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

/s/ Zachary Rosenbaum
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July 13, 2020