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-20200417-00037

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

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

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SUMMARY

Given the urgency of bringing broadband to every American no matter where they live, SpaceX is proud to be on the cusp of delivering truly high-speed, low-latency service to customers in the United States and around the world, especially those in underserved and unserved areas including in Polar regions. In just over two years since having received its license, SpaceX has launched many hundreds of satellites for its broadband constellation – many hundreds more satellites than any other non-geostationary orbit ("NGSO") satellite operator authorized in its processing round – and begun to deploy a large-scale ground-based infrastructure. SpaceX operates the satellites currently on-orbit at an altitude of 550 km where the effects of atmospheric drag ensure that orbital debris and any failed satellites de-orbit rapidly. As the Commission has recognized, operating at this low altitude enhances the safety of all systems operating in space. Also, operations at this orbit ensure that SpaceX can offer service that far surpasses the Commission's definition of a low-latency system.

Building on the success of its ongoing deployment and to enhance the already considerable safety attributes of its constellation, SpaceX proposes to relocate those additional satellites currently authorized by the Commission to operate at altitudes above 1,100 km down at the 540-570 km range. Critically, this modification will reduce service latency throughout its constellation without having to request additional spectrum or the deployment of additional satellites. The Commission grants such requests when they do not present significant interference problems and are otherwise consistent with Commission policies. Accordingly, in support of its proposed modification, SpaceX submitted analyses to show that operating at lower altitude will have little to no interference impact on other licensed systems. It has also demonstrated that its modified

system will meet all applicable orbital debris mitigation requirements, including those recently adopted by the Commission that have not yet gone into effect.

Predictably, several parties – mostly competitors whose deployment lags behind that of SpaceX – have filed comments and petitions trying to prevent the proposed modification. As demonstrated herein, commenters raise no genuine issues of space safety or interference concerns, but rather rely on competitive gamesmanship that ultimately hurts the consumer. These comments and petitions fail to raise issues that should prevent the Commission from granting this application and thereby speeding delivery of robust service for consumers.

As the first private company to transport astronauts to the International Space Station ("ISS") and whose very existence depends upon the ability to safely operate in space, ensuring a safe operating environment in space is paramount for SpaceX. The Commission has recognized, and no party in this proceeding denies, that operating satellites at lower altitudes has inherent safety benefits that accrue from the increased atmospheric drag that effectively removes debris (including non-maneuverable satellites) fairly quickly, significantly reducing the risk of collision. SpaceX's proposed modification is designed to capitalize on these safety-enhancing characteristics. Yet despite these well-understood benefits, some parties – whose own systems present much more concerning risk profiles – have resorted to hyperbole in a transparent effort to slow SpaceX's progress. Worse, several non-U.S. operators who themselves consistently refuse to provide detailed debris mitigation plans for their own systems attempt to game the Commission's rules to put U.S.-licensed systems at a competitive disadvantage.

Yet, for all the commenters' exaggeration and game playing, the fact remains that this proposed modification would make SpaceX's system safer in nearly every respect, while helping to close the digital divide in the United States. Even assuming a large avoidance area around each

satellite SpaceX would deploy under its proposed modification, the total amount of space they would occupy is just 0.000065% of the volume of space between the 540 km and 570 km altitudes. Combining this small volume with the maneuverability of its satellites, their predictable orbital tracks, and very precise location information shared with other operators, SpaceX will be able to both manage the spacing of its own satellites and coordinate their operations with other NGSO systems.

Moreover, while SpaceX's new orbits have the potential to overlap with some other systems, the modification clearly removes overlap with others – even with some of those that surprisingly complain about this move. Some operators, including those that have not even been licensed, have gone so far as to try to use this proceeding to claim monopoly rights for themselves over certain altitudes. Yet the Commission has repeatedly rejected these types of anti-competitive attempts by NGSO operators to claim exclusive use of valuable orbital real estate. And while several competitors tried to latch on to the small number of SpaceX satellites that have lost maneuverability, the Commission already addressed this potential, finding that the rapid deorbit and low collision risk even for a non-maneuverable satellite satisfy applicable safety guidelines. In contrast, failed satellites at higher altitudes like those for which SpaceX is currently authorized and that are used by other operators remain in orbit as a risk for decades, centuries, or longer.

Commenters and petitioners also greatly overstate the potential for spectral interference arising from the proposed modification. While improving the safety profile of its system by flying at a lower orbit, SpaceX will also operate at lower power levels, making its uplink and downlink transmissions somewhat more susceptible to interference from other NGSO systems. To address this tension, SpaceX will not object to a condition requiring that it accept any additional

interference from other NGSO systems authorized in the 2016 processing round resulting from this modification compared to its current authorization.

These same power reductions generally work to the benefit of other NGSO operators worried about interference into their own systems. In addition, even accepting interference at the levels of its currently authorized system as discussed above, *interference from other NGSO systems into SpaceX uplinks* without the modification will overwhelm any effect SpaceX's modified operations may have on their respective downlinks. In other words, in the absence of coordination, SpaceX and other NGSO operators will already be subject to the spectrum splitting requirements of Section 25.261 due to interference from other operators into SpaceX's uplinks long before any arguable interference from SpaceX downlinks would trigger that rule. As a result, any impact SpaceX's modified operations might have on other NGSO systems will not increase the amount of time that the parties will have to split common spectrum in the absence of a coordination agreement. Thus, SpaceX's modification will not have a "significant" impact on other NGSO systems.

Any claims raised by geostationary orbit ("GSO") satellite operators are fully addressed by the fact that SpaceX will comply with the applicable equivalent power flux-density ("EPFD") limits that the Commission has adopted to protect GSO systems. Tellingly, no GSO party that weighed in on the proposed modification either accepted SpaceX's repeated offers to supply the data underlying the EPFD analysis submitted with its application or supplied any analyses of their own to support their comments.

Lastly, the Commission should disregard the disjointed and illogical claims raised on behalf of Multichannel Video Distribution and Data Service ("MVDDS") licensees that somehow SpaceX's authorized use of its licensed frequencies could harm their speculation in the 12 GHz

band. Given that these same MVDDS interests have argued for years that *any* NGSO operations in the band would prevent their attempt to expropriate this spectrum, this latest effort to leverage SpaceX's modification verges on the nonsensical. Because the MVDSS licensees' own analysis shows that co-existence with their proposed use is impossible, nothing done in this proceeding could possibly make sharing more difficult. SpaceX has demonstrated that its modified system will comply with all rules imposed to safeguard MVDDS systems as they are currently licensed, following both a fair and a straightforward approach. Nothing about granting SpaceX's proposed modification will change any of the considerations relevant to the MVDDS licensees' desired spectrum grab.

As SpaceX has demonstrated in its application, its proposed modification will improve space safety and speed deployment to consumers without requiring additional satellites or spectrum resources. None of the arguments raised in this proceeding justify deferring or denying the public interest benefits resulting from SpaceX's application. Given the urgent need for high-quality broadband in unserved areas to close the digital divide, the Commission should proceed to review and grant this modification expeditiously so that SpaceX can provide truly low-latency, high-speed broadband to every corner of the United States.

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CONSOLIDATED OPPOSITION TO PETITIONS 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 Petitions filed by Kuiper Systems LLC ("Amazon"), Kepler Communications, Inc. ("Kepler"), SES Americom Inc. and O3b Limited ("SES/O3b"), and Viasat, Inc. ("Viasat") and responds to the Comments filed by AT&T Services, Inc. ("AT&T"), WorldVu Satellites Limited, Debtor-in-Possession ("OneWeb"), and Spire Global, Inc. ("Spire") with respect to the above-referenced application for modification of SpaceX's authorization to launch and operate a non-geostationary orbit ("NGSO") Fixed-Satellite service ("FSS") system.[1] As discussed further below, these parties fail to present any reason to deny or defer this application, and the Commission should grant it expeditiously. A

[1] *See* Petition to Deny and Comments ("Amazon Petition"); Petition to Deny of Kepler Communications Inc. ("Kepler Petition"); Petition to Deny or Defer of SES Americom, Inc. and O3b Limited ("SES/O3b Petition"); Petition to Deny or Defer of Viasat, Inc. ("Viasat Petition"); Comments of AT&T Services, Inc. ("AT&T Comments"); Comments of OneWeb ("OneWeb Comments"); Comments of Spire Global, Inc. ("Spire Comments"). These filings were all submitted in IBFS File No. SAT-MOD-20200417-00037 on July 13, 2020. SpaceX also addresses herein issues raised in three recent ex parte filings. *See* Letter from Charity Weeden to Marlene H. Dortch, IBFS File No. SAT-MOD-20200417-00037 (June 30, 2020) ("Astroscale Ex Parte"); Letter from Vann Bentley and Angie Kronenberg to Marlene H. Dortch, IBFS File No. SAT-MOD-20200417-00037 (July 13, 2020) ("CCIA/INCOMPAS Ex Parte"); Letter from Jeffrey Blum to Marlene H. Dortch, IBFS File No. SAT-MOD-20200417-00037 (July 14, 2020) ("DISH Ex Parte").

prompt review and approval will allow SpaceX to proceed with development and deployment of its NGSO system and extend the benefits of low-latency, high-speed broadband service to customers in rural and other areas of the U.S. – including Polar regions – currently underserved or unserved by other alternatives.

BACKGROUND

SpaceX made a bold proposal in 2016 for an innovative NGSO satellite system designed to provide high-capacity broadband services to customers in America and throughout the world, especially those in rural and other underserved or unserved areas. That system, licensed by the Commission in 2018, was composed of 4,425 satellites operating in Ku- and Ka-band spectrum at altitudes from 1,110 km to 1,325 km.[2] The Commission subsequently granted SpaceX's requests to modify that authorization to relocate 1,584 satellites previously authorized to operate at an altitude of 1,150 km to an altitude of 550 km and to reconfigure those satellites to place coverage and capacity more evenly and rapidly across more of the U.S.[3] The Commission found that these modifications would serve the public interest by improving broadband latency while decreasing the potential for orbital debris and would result in no material change in interference.[4]

SpaceX proceeded rapidly with deployment of its NGSO system after the Commission granted its first modification, launching 538 satellites to date to the 550 km altitude. Based on the success of that ongoing deployment, SpaceX now seeks to operate the remainder of its authorized constellation at lower altitudes as well, ranging from 540 km to 570 km. This proposal takes advantage of the higher atmospheric drag inherent at these lower altitudes that ensures that any

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2 *See Space Exploration Holdings, LLC*, 33 FCC Rcd. 3391, ¶ 11 (2018) ("*Initial Authorization*").

3 *See Space Exploration Holdings, LLC*, 34 FCC Rcd. 2526 (IB 2019) ("*First Modification*"), *on reconsideration*, 35 FCC Rcd. 5649 (IB 2020) ("*Recon Order*"); *Space Exploration Holdings, LLC*, 34 FCC Rcd. 12307 (IB 2019) ("*Second Modification*").

4 *See First Modification*, ¶ 11; *Second Modification*, ¶ 15.

orbital debris will undergo rapid atmospheric re-entry and demise. Critically, this modification does not involve a request for additional spectrum or the deployment of additional satellites, but it will enable SpaceX to speed deployment to polar regions and reduce service latency throughout its constellation.

DISCUSSION

I. THE PROPOSED MODIFICATION WILL ENHANCE THE ORBITAL DEBRIS MITIGATION PROFILE OF SPACEX'S NGSO CONSTELLATION

For SpaceX, ensuring a safe operating environment in space is paramount. Most importantly, NASA has trusted SpaceX to be the first private company in history to deliver astronauts to the International Space Station ("ISS") – a highly complex operation with stringent safety protocols and virtually no margin for error. Being able to safely deliver human life to space is SpaceX's most significant responsibility. But beyond this most sacrosanct mission, keeping space safe is essential for SpaceX's business. SpaceX is planning to launch its vehicles into orbital altitudes at least 25 times this year alone to serve its commercial and government customers. For its satellite customers, SpaceX must safely deliver satellite payloads to their proper orbital altitudes. For other missions, SpaceX must reliably deliver cargo – and now astronauts – to the ISS. SpaceX is privileged to be trusted by NASA and its International Partners with these critical responsibilities.

SpaceX is currently authorized to operate some of its satellites at altitudes above 1,100 km, and now proposes to relocate those satellites to lower altitudes. The Commission and other expert agencies across the U.S. government have recognized the enhanced safety attributes of operating at such lower altitudes. For example, the Commission recently adopted a reliability goal of 0.99

for post-mission disposal of satellites in large NGSO constellations.[5] By relocating its entire constellation to lower altitudes, SpaceX will ensure that its system achieves this goal. Moreover, as summarized in Table 1 below, the modification will significantly enhance the safety of SpaceX's constellation by several measures used in the most recent version of NASA's Debris Assessment Software ("DAS" v.3.1.0).[6]

NGSO System	Altitude [km]	Passive Decay Time [years]	Risk of Collision with Large Debris	Risk of Collision with Small Debris
SpaceX Current	550-1,325	1.1-1,000	0.0101	0.000156
SpaceX Modified	540-570	1.71	0.0000801	0.0000779

Table 1. SpaceX Safety Profile Pre- and Post-Modification

For perspective, Table 2 below shows a top-level debris risk summary comparing the modified SpaceX constellation against other low-Earth orbit ("LEO") NGSO systems using the latest version of DAS. The values shown below use the actual mass and area values provided by Kepler for its satellites.[7] However, other LEO operators have declined to provide this sort of information about their satellites either because they are non-U.S. licensees that claim an exemption from Commission oversight (OneWeb) or have not yet finalized the design of their satellites (Amazon). For these operators, SpaceX has assumed that their satellites will have

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[5] *See Mitigation of Orbital Debris in the New Space Age,* 35 FCC Rcd. 4156, ¶¶ 93-96 and new Section 25.114(d)(14)(vii)(D)(1) (2020) ("*Orbital Debris Update Order*").

[6] Tables 1 and 2 show the calculated values across the entire constellation for (1) passive decay time from operational orbit assuming loss of active post-mission disposal ("PMD") in 2026; (2) risk of full area of one non-maneuverable satellite being impacted by an object >10 cm, averaged over constellation assuming 2026 failure; and (3) risk of reduced area of one satellite being impacted by an object that would prevent active PMD (>1 cm on chassis, >1 mm on cathode, >5.5 mm on fuel tank).

[7] *See* Kepler Application, IBFS File No. SAT-PDR-20161115-00114, Schedule S at 11 (Nov. 15, 2016).

equivalent mass and area values to those deployed by SpaceX, which will likely result in more favorable outcomes for these systems.[8]

NGSO System	Altitude [km]	Passive Decay Time [years]	Risk of Collision with Large Debris	Risk of Collision with Small Debris
SpaceX Modified	540-570	1.71	0.0000801	0.0000779
OneWeb	1,200	100+	0.0157	0.000162
Kepler	500-650	8.4	0.00000237	0.0000006
Amazon (2nd Round)	590-630	5.7	0.000423	0.000138

Table 2. Comparison of LEO System Safety Profiles

In general, there is a high degree of sensitivity to operational altitude. For example, the passive decay time of OneWeb, O3b, and Viasat all far exceed 100 years in comparison to the passive decay time of 1.71 years for the average SpaceX satellite. Indeed, the passive decay times for mid-Earth orbit ("MEO") satellites are so high (greater than 100,000 years) that DAS cannot accurately predict collision risks. For this reason, SpaceX has not included MEO systems (such as O3b and Viasat) in Table 2. This passive decay time drives large differences in various assessments of risk. As shown in Table 2, the modified SpaceX system poses a per-satellite risk that is, on average, orders of magnitude lower than comparable NGSO systems.

Yet, despite these well-understood benefits, some parties have attempted for competitive reasons to portray in sinister terms the effect of lowering the operating altitude of the remaining SpaceX satellites. In addressing a modification to improve the safety of SpaceX's already authorized system, competitors have resorted to fear mongering such as discussing a "powder-keg orbit," "a catastrophic debris cascade," creating a "'Hoberman' sphere," and more over-the-top

[8] SpaceX satellites have a very high area-to-mass ratio, which generally reduces the time required to deorbit and thus decreases the calculated risk of collision.

mischaracterizations.[9] Astonishingly, some of this overheated rhetoric comes from operators that plan to launch hundreds, thousands, or tens of thousands of their own satellites – including satellites that lack any maneuverability to avoid collisions themselves – that involve higher risk levels than SpaceX's modified system.

In assessing these anti-competitive assertions, some additional perspective is in order. For example, considering the total volume of SpaceX's satellites compared to the volume of space in which they will operate confirms that commenters' rhetoric has broken from reality. SpaceX proposes to relocate 2,824 satellites to altitudes from 540 km to 570 km. The volume of space in that range of altitudes is approximately 18.1 billion cubic kilometers.[10] A SpaceX satellite has a volume of approximately .884 m^3, but even assuming a 1 km^3 volume around each satellite to account for an approach close enough that it might trigger a maneuver,[11] the total volume of the relocated SpaceX satellites and the notional bounding spheres around them would be 11,824 km^3. That is just 0.000065% of the volume of space between these two altitudes. Combining this with the maneuverability of its satellites, their predictable orbital tracks, and very precise location capabilities, SpaceX will have little difficulty physically coordinating its system with other NGSO operators, meaning that the practical risk of collision will remain essentially unchanged after modification.

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[9] *See* Kepler Petition at 14; Letter from Jeffrey Blum to Marlene H. Dortch, IBFS File No. SAT-MOD-20200417-00037, at 4 (June 16, 2020). Similarly, Viasat argues that SpaceX's deployment of 10,000 satellites (which will never operate at the same time) will result in "[i]ncreased densification of the Starlink system" that "poses a substantially increased risk of collision with other satellites." Viasat Petition at 10. Astroscale warns that SpaceX's "modified configuration would result in an orbital shell with over 8 times the mass that it has today," Astroscale Ex Parte at 2, while OneWeb foresees SpaceX's constellation becoming "part of a highly congested altitude," OneWeb Comments at 3.

[10] For this calculation, we use 6,378 km as the radius of the Earth (Tim Sharp, "How Big Is Earth," SPACE & ASTRONOMY (Sep. 15, 2017), https://www.space.com/17638-how-big-is-earth html) and the standard formula for volume of a sphere ($4/3\pi r^3$) to determine the volume out to 570 km before subtracting the volume out to 540 km.

[11] *See* Amazon Petition at 10.

Some commenters have expressed concern that operating at lower altitude will reduce the spacing within SpaceX's own constellation, thereby increasing intra-system collision risk, especially in light of the system's ±30 km orbital tolerance.[12] This concern is misplaced. In this regard, the most important variable is the distance at which satellites from differing orbital planes (but the same nominal altitude) approach each other. For nominal operations of the current system, this value is maintained to be no less than approximately 50 km – just under the distance between Washington, D.C. and Baltimore. In addition, even at the lowest proposed altitude (540 km), the average along-track separation between SpaceX satellites in the same orbital plane will be approximately 1,975 km – approximately the distance from Washington, D.C. to Dallas, Texas. SpaceX also maintains a 10 km separation between nominal altitudes for the SpaceX shells[13] – approximately the distance from downtown D.C. to Hyattsville, MD. Thus, while spacing at lower altitude will be somewhat reduced, satellites will still be separated by significant distances in all dimensions of their orbits.

SpaceX has provided more orbital debris information than any other NGSO FSS operator. Ironically, some of the most vociferous commenters on orbital debris issues are companies (like Viasat, O3b, and OneWeb) that have refused to provide much (if any) orbital debris information on their own NGSO systems, a liberty they claim for themselves as non-U.S operators.[14] Indeed, during the recent proceeding to update the Commission's orbital debris rules, Viasat's comments

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12 *See, e.g.,* OneWeb Comments at 4; Viasat Petition at 9-10.

13 Except in unusual cases, SpaceX satellites move in the same pattern during their orbits, such that all orbital shells are at maximum altitude over the same portion of the Earth and at minimum altitude over another portion of the Earth, so that as a practical matter there is relatively little variation from nominal separation between satellites in planes at different nominal altitudes.

14 *See, e.g.,* Petition for Declaratory Ruling, SAT-PDR-20161115-00120, at 20-21 (Nov. 15, 2016); Modification, SAT-MOD-20200526-00058, at 5-6 (May 26, 2020); Application for Modification, SAT-MPL-20200526-00062, at 8-9 (May 26, 2020).

focused on ensuring that its foreign licensed system would continue to escape Commission oversight, and only after that objective appeared to be secure did it suddenly pivot in the last two weeks of the proceeding to espouse collisions risk metrics that would apply to applicants for U.S. NGSO licenses – but not itself.[15] This is precisely the type of gaming that SpaceX warned against in the broader orbital debris proceeding, where SpaceX accurately predicted that non-U.S. operators like these would try to put American systems at a competitive disadvantage.[16] Other operators (like Amazon) have submitted only preliminary information due to the immaturity of their system's design.[17] The Commission should be wary of arguments that would hold SpaceX to a standard that other NGSO operators have avoided.

A. With Reasonable Measures and Cooperation, NGSO Systems Can Operate Safely at Similar Altitudes

Beyond grim rhetoric, some operators also object to potential overlaps between SpaceX's proposed orbital altitudes and their own. But some degree of overlap between operational altitudes is nothing new. Under its current license, SpaceX is authorized to operate its NGSO system at altitudes similar to those authorized for Telesat and OneWeb, in addition to those requested in Viasat's recent NGSO application,[18] resulting in potentially overlapping areas of operation. In fact, before complaining about SpaceX moving to a new altitude, OneWeb worried about SpaceX

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[15] *See, e.g.,* Comments of Viasat, Inc., IB Docket No. 18-313 (Apr. 5, 2019); Letter from John P. Janka to Marlene H. Dortch, IB Docket No. 18-313 (Apr. 10, 2020)

[16] *See, e.g.,* Comments of Space Exploration Technologies Corp., IB Docket No. 18-313, at 8-9 (Apr. 5, 2019).

[17] *See, e.g.,* Letter from Andrew Keisner to Jose P. Albuquerque, IBFS File No. SAT-LOA-20190704-00057, at 5 (Sep. 18, 2019) ("Amazon continues to refine its satellite design with respect to orbital debris mitigation and will provide updated information to the Commission consistent with the Commission's rules. . . . After Amazon has finalized its satellite design, we will provide a DAS analysis to the Commission consistent with the Commission's rules.").

[18] *See* Application, IBFS File No. SAT-MPL-20200526-00056, Exhibit B – Technical Annex at 2 (May 26, 2020) ("Viasat Application").

operating at its current altitude.[19] As SpaceX has previously noted, one wonders whether these competitors would approve of SpaceX operating at any altitude. The fact is, many systems are authorized to operate at overlapping altitudes. The new orbital altitudes that SpaceX proposes to use would simply replace its current set of overlaps with a different one.

As Amazon correctly notes, "FCC rules do not prohibit applicants from seeking overlapping constellations."[20] Thus, in the context of granting SpaceX's request to operate at 550 km, the Commission confirmed that the rules "do not prohibit SpaceX's selection of an orbital regime that is also used by other satellite operators."[21] While the Commission did expect SpaceX to discuss how it would avoid potential collisions in such a case, it found that SpaceX had done so by "stat[ing] that its satellites have propulsion and SpaceX will maintain the ability to maneuver the satellites to avoid collisions."[22] That is still the case, and the conclusion should be the same here. Moreover, the Commission's policy promotes competition. If operators were able to claim exclusive use of productive and safe orbits, they could effectively limit the ability of their competitors to deploy systems and serve consumers.

Amazon's filing exemplifies this point. Before even receiving a license, Amazon has attempted to stifle competitors by claiming orbital real estate for itself. Even assuming Amazon has any basis for claiming such rights before it has its own authorization, Amazon's arguments are off base. Specifically, it claims that the modification would increase the number of daily conjunction events in which SpaceX and Amazon satellites come within 1 km of each other

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19 *See, e.g.,* Letter from Brian D. Weimer to Marlene H. Dortch, IBFS File No. SAT-LOA-20170301-00027, at 3-4 (Nov. 17, 2017).

20 Amazon Petition at 6.

21 *First Modification* ¶ 22.

22 *Id.*

compared to the existing debris catalog.[23] However, to reach that worst-case result, Amazon concedes that it assumed a "a particular orbital configuration"[24] for the SpaceX satellites. Amazon's chosen configuration unrealistically assumes that SpaceX satellites will consistently operate very near the top of their orbital range – 20-22 km above the nominal altitude of the shell. That is not a valid assumption, if only because satellites could be operating above or below the nominal altitude.

More importantly, most SpaceX satellites will operate within much less than 30 kilometers of their nominal altitude most of the time. The 30 km tolerance provides SpaceX the operational leeway to maneuver its satellites as necessary to, for example, avoid another NGSO satellite or a piece of orbital debris or to relocate a satellite within the SpaceX constellation. Except in such cases, SpaceX satellites move in the same pattern during their orbits, such that all orbital shells are at maximum altitude over the same portion of the Earth and at minimum altitude over another portion of the Earth. As a practical matter, there will be relatively little variation from nominal altitude and overlaps involving SpaceX satellites assigned to planes in different altitudes or with other NGSO systems assigned to different altitudes will be rare.

Here again, Amazon's efforts to limit competition require perspective. Focusing on the 1,240 SpaceX satellites that could potentially overlap with 784 proposed Amazon satellites in the region from 581 km to 599 km,[25] the total volume of space at issue is approximately 11 billion cubic kilometers. Assuming a volume of one km in all directions around each SpaceX and Amazon

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[23] *See* Amazon Petition at 10. It is not clear whether the "orbit debris catalog" Amazon used included satellites operated by Kepler and Spire in addition to tracked debris, casting doubt on whether Amazon has selected a reasonable baseline against which to compare the larger number of conjunction events described in Amazon's filing, even setting aside its flawed assumptions.

[24] *See id.* n.28.

[25] *See* Amazon Petition at 5-6. For purposes of this analysis, we consider the orbital range proposed for Amazon's satellites at the nominal 590 km altitude ± 9 km orbital tolerance.

satellite in the region, the two systems combined would take up just 0.000077% of the available space. Given that the satellites of both systems will have propulsion, physical coordination should be achievable – especially given Amazon's previous reliance on coordination to justify its application. Indeed, the Commission has declined to adopt a minimum separation between the operational altitudes of NGSO systems, finding that "these concerns are best addressed in the first instance through inter-operator coordination."[26]

In prior cases, the Commission has rejected calls for creating a buffer zone between NGSO systems. For example, OneWeb sought to exclude Telesat from operating some of its satellites at an altitude that would (considering each system's orbital tolerance) potentially overlap with OneWeb's constellation. The Commission concluded that "these concerns are best addressed in the first instance through inter-operator coordination," and thus declined to impose the requested buffer zone.[27] In addition, the Commission imposed a standard condition requiring that Telesat coordinate its physical operations with space stations of NGSO systems operating at similar orbital altitudes – just as it had required of OneWeb.[28] SpaceX's authorization includes a similar condition.[29] Thus, the Commission has already established how it will handle NGSO systems operating at proximate orbital altitudes, and should take the same approach here as well.

Spire requests that the Commission condition grant of this modification by obligating SpaceX to coordinate physical operations in good faith with other NGSO systems operating in similar orbital altitudes.[30] As noted above, SpaceX is already subject to such a condition, as are

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26 *Orbital Debris Update Order* ¶ 47.

27 *Telesat Canada*, 32 FCC Rcd. 9663, ¶ 12 (2017).

28 *Id.*

29 *See First Modification* ¶ 22.

30 *See* Spire Comments at 2.

all other NGSO operators. Moreover, as Spire requests, SpaceX has made clear that it will not require other systems to assume full responsibility for collision avoidance.[31] SpaceX is fully prepared to work with other operators to craft agreements for coordinated operations that ensure the safety of space for everyone.

Some operators go so far as to demand that the Commission apply special scrutiny to SpaceX's application even as they gloss over altitude overlaps between their own system and others – including SpaceX's. For example, Amazon is well aware that there are several NGSO systems whose operational altitudes will overlap with its own proposed areas of operation.[32] Yet in its application, Amazon said nothing about them, instead stating that "the Kuiper System's lowest orbital shell will be 40 km from the nearest known large proposed NGSO system."[33] Thus, although SpaceX has already provided far more information than Amazon did under analogous circumstances, Amazon once again demands special treatment for itself and extra scrutiny for its competitor. In this case, Amazon asks the Commission to hold SpaceX to a standard far beyond the scrutiny that Amazon's own application could bear.

Similarly, Viasat recently filed an application in the second NGSO FSS processing round that would use a much lower orbital altitude (1,300 km rather than 8,200 km), increase the number of satellites substantially (from 20 to 288), and overlap with SpaceX's currently authorized operations at 1,275 km and 1,325 km (given Viasat's ± 20 km orbital tolerance).[34] Yet Viasat did not provide any technical analysis of the overlap, propose any specific way to resolve potential

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31 *See, e.g.,* Application for Modification, IBFS File No. SAT-MOD-20200417-00037, at 11 (Apr. 17, 2020) ("Modification Application").

32 *See* Amazon Petition at 6 n.24 (citing NGSO constellations of Swarm, Spire, and Planet Labs).

33 Amazon Application, IBFS File No. SAT-LOA-20190704-00057, Technical Appendix at 32 (July 4, 2019) ("Amazon Application").

34 *See* Viasat Application, Exhibit B – Technical Annex at 2.

conjunctions, or reach out to SpaceX to discuss physical coordination. Rather, it implicitly assumed that SpaceX's application to move those satellites would be granted and simply said that if necessary it "will coordinate physical operations of the VIASAT-NGSO satellites with those SpaceX satellites."[35] In its comments in this proceeding, however, Viasat stridently asserts that the potential overlap of orbital altitudes proposed by SpaceX with those of other licensed NGSO systems "requires careful review by the Commission."[36] In other words, Viasat apparently approves of SpaceX's proposal to lower its satellites' operational altitudes when doing so allows Viasat to avoid additional analysis in its own application, even as it argues for unprecedented scrutiny of SpaceX's application on the very same issue. Perhaps Viasat assumes its status as a non-U.S. operator allows it to avoid Commission scrutiny. The Commission should reject such blatantly self-serving arguments.

B. The Proposed Modification Will Easily Satisfy Commission Safety Standards for Collision Risk

Many of the concerns raised by commenters in response to SpaceX's proposal to operate the remainder of its constellation at lower altitudes relate to the risk of collision with other satellites operating, or hoped to be operated, in the 540-570 km region of space. As discussed above, the Commission's rules do not prohibit one NGSO system from selecting an orbital regime that is shared by other NGSO systems.[37] Instead, the Commission requires applicants to include an analysis of the potential risk of collision and a description of what measures the space station operator plans to take to avoid in-orbit collisions.[38] SpaceX provided such information as part of

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[35] *See id.* at 9. This application comes on the heels of Viasat's earlier application that proposed a disposal orbit for its satellites very near the operational orbit proposed by another applicant. *See Viasat, Inc.*, 35 FCC Rcd. 4324, ¶ 30 (2020) ("*Viasat*").

[36] *See* Viasat Petition at 10-11.

[37] *First Modification* ¶ 22.

[38] *See* 47 C.F.R. § 25.114(d)(14)(iii).

its modification application, explaining that its satellites have propulsion and that SpaceX will conduct active maneuvers to avoid collisions with both debris and other spacecraft throughout the life of its satellites, even through the de-orbit phase until the spacecraft enters the atmosphere.[39] These steps far outstrip the efforts of most other operators in the 540-570 km region.

As the Commission has recognized, because SpaceX has invested in advanced propulsion capabilities for its satellites, collision risk is considered to be essentially zero.[40] Moreover, SpaceX has provided analyses of the potential risk of collision, demonstrating that its satellites will present a risk profile that is many times lower than the 0.001 standard recently adopted by the Commission.[41] It has also demonstrated that its satellites will achieve 100% deorbit reliability at the lower altitudes proposed in the modification, exchanging the hundreds of years required for natural orbital decay of a satellite at 1,110-1,325 km for a period of less than five years for a satellite at the 540-570 km altitudes, even considering worst-case assumptions.[42]

As Astroscale recognizes, "better and more precise space situational awareness (SSA) will help to further drive down the full risk of an increase in conjunctions."[43] While such situational awareness may remain a distant goal for some operators, SpaceX has leveraged such techniques for reducing risk from its very earliest deployments. SpaceX not only shares information regarding initial deployment, ephemeris, and planned maneuvers with the 18th Space Control Squadron, but also provides all of its ephemeris data to other NGSO operators via space-track.org and other

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39 *See* Modification Application, Technical Attachment at 21.

40 *See, e.g., First Modification*, ¶ 22.

41 *See* Letter from William M. Wiltshire to Jose P. Albuquerque, IBFS File No. SAT-MOD-20200417-00037 (May 15, 2020); Letter from William M. Wiltshire to Jose P. Albuquerque, IBFS File No. SAT-MOD-20200417-00037 (July 7, 2020); *Orbital Debris Update Order* ¶¶ 33-34.

42 *See* Modification Application, Technical Attachment at 19-20.

43 Astroscale Ex Parte at 5.

public means. SpaceX is also the first operator to optimize the usefulness of this data by supplementing it with co-variance data, which allows other operators to better assess the potential for collision between their own vehicles and SpaceX satellites. As a result, both SpaceX and all other potentially affected operators can make detailed assessments of the potential for collision with a SpaceX satellite and take action as appropriate to eliminate that risk.

Nonetheless, OneWeb and Viasat challenge the sufficiency of these showings as a basis for proceeding with grant of the modification. In particular, they focus on the small number of SpaceX satellites that have lost maneuverability and argue that the Commission must undertake a wholesale reevaluation of the orbital debris implications of SpaceX's proposed modification.[44] However, the Commission "specifically addressed concerns with failed satellites in the *First Modification Order*, and [found] that the conditions placed on SpaceX's operations in that decision are sufficient to protect Kepler and other NGSO systems operating at or near the 550 km orbital altitude."[45] Because "the potential failure of some SpaceX's satellites was contemplated and accounted for in the order granting SpaceX's modification"[46] there is no reason for further consideration of this issue.

Moreover, OneWeb and Viasat are wrong to assume that even these few satellites pose a substantial collision risk. Each of them is in a decaying orbit that is stable, highly predictable, and easily trackable. And, of course, SpaceX has demonstrated that each of these satellites presents a collision risk that is many times lower than the 0.001 standard adopted by the Commission and NASA.

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44 *See, e.g.,* OneWeb Comments at 6-7; Viasat Petition at 20-24.

45 *Recon Order* ¶ 20.

46 *Id.* ¶ 18.

OneWeb critically ascribes these satellite issues to SpaceX's "iterative design" approach.[47] But it is unclear why OneWeb would object to an approach under which improvements in satellite design are rapidly implemented to constantly improve the safety profile of an NGSO satellite system, rather than relying on "design heritage." Indeed, OneWeb's apparent objection to iterative design improvements runs directly contrary to the Commission's recognition that "in some instances, development of the spacecraft is likely to be a rapidly iterative process, involving more in-orbit testing than ground testing," and that in precisely those cases, "lower deployment altitudes may be required in order to achieve a post-mission disposal reliability consistent with the public interest."[48]

Experience demonstrates the wisdom of this approach and confirms that deploying satellites with designs developed many years ago is no guarantee against spacecraft failures. For example, according to the International Bureau Filing System, the Commission has issued SES Americom, Inc. twenty authorizations to launch and operate satellites. Of those satellites, at least one (AMC-9) experienced a serious anomaly that resulted in an uncontrolled drift and the release of several pieces of observable debris.[49] Similarly, Viasat operates three satellites (one of which is a payload on a Hughes spacecraft), and experienced a significant anomaly on the one most recently deployed.[50] SpaceX does not believe that the 33% and 5% anomaly rate experienced by Viasat and SES Americom, respectively, call for any Commission action. To the contrary, all satellite operators have strong incentives to deploy spacecraft that perform as designed throughout

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47 *See* OneWeb Comments at 5.

48 *Orbital Debris Update Order* ¶ 98.

49 *See, e.g.,* "Troubled AMC 9 Satellite Sheds Debris in Populated Orbit, Regains Contact With Ground Control," SPACEFLIGHT 101 (July 3, 2017), https://spaceflight101.com/amc-9-restores-contact-with-ground-sheds-debris/.

50 *See* Caleb Henry, "Viasat preps big insurance claim for Viasat-2 antenna anomaly," SPACE NEWS (May 30, 2018), https://spacenews.com/viasat-preps-big-insurance-claim-for-viasat-2-antenna-anomaly/.

their entire operational lifetime. But under the view expressed by several commenters, such issues would justify subjecting their future applications to a great deal of additional scrutiny. That has not been and should not become the Commission's practice, and the Commission certainly should not single out SpaceX for uniquely unfavorable treatment in this regard.

Finally, Viasat and Astroscale cite an incident in which the European Space Agency ("ESA") performed a maneuver with the Aeolus satellite to avoid one of the first satellites launched by SpaceX. Viasat asserts that this episode calls into question SpaceX's "judgement," whether it had control over the satellite, and "SpaceX's willingness to protect others in a shared space environment,"[51] while Astroscale says that it shows that "each party had differing risk thresholds."[52] But the very articles these parties cite make clear that their arguments are entirely specious – this incident had nothing to do with SpaceX's willingness or ability to control its spacecraft to avoid other operators or differing risk thresholds. Rather, due to an error in an on-call paging system, SpaceX did not learn of ESA's correspondence.[53] Had this error not occurred, SpaceX was both ready and willing to coordinate by sharing details and health information from its state-of-the-art autonomous conjunction avoidance system. After the incident, ESA's Head of Space Safety confirmed that "[n]o one was at fault here," and ESA concluded that "[c]ontact with Starlink early in the process allowed ESA to take conflict-free action later, knowing the second

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51 Viasat Petition at 4.

52 Astroscale Ex Parte at 4.

53 *See* Jonathan O'Callaghan, "SpaceX Declined to Move a Starlink Satellite at Risk of Collision With a European Satellite," FORBES (Sep. 2, 2019), https://www.forbes.com/sites/jonathanocallaghan/2019/09/02/spacex-refused-to-move-a-starlink-satellite-at-risk-of-collision-with-a-european-satellite/#2da9823a1f62; Jeff Foust, "How to better manage space traffic: Aeolus/Starlink encounter shows e-mails and late night phone calls no longer cut it," SPACE NEWS (Nov. 21, 2019), https://spacenews.com/how-to-better-manage-space-traffic-aeolus-starlink-encounter-shows-emails-and-late-night-phone-calls-no-longer-cut-it/.

spacecraft would remain where models expected it to be."[54] Nonetheless, SpaceX has since investigated this issue and upgraded its system for communicating with other satellite operators. It has also continued to upgrade the autonomous conjunction avoidance technology on its spacecraft. If anything, this incident demonstrates SpaceX's ongoing commitment to improving safety procedures.

C. The Commission Should Reject Calls to Apply Standards to SpaceX Inconsistent with Current Rules and That No Other NGSO Operator Has Been Required to Meet

Many commenters propose that the Commission require SpaceX to meet a litany of new standards that not only have never been applied to any other NGSO system, but that, in some cases, the Commission has already rejected. For example, although they may quibble with the precise figures, no one seems to deny that SpaceX's modified constellation would easily satisfy by a substantial margin the Commission's actual rules limiting the probability of collision with a large object.[55] Yet several commenters argue that the Commission should require SpaceX to meet a stringent collision metric based on the aggregate risk across all satellites over the full term of its license.[56] Viasat goes so far as to present a table of expected collisions for constellations of various sizes that is "calculated in the absence of a satellite having effective and reliable maneuverability capabilities over its orbital lifetime" – in other words, Viasat's analysis assumes, without explanation, a wildly unrealistic scenario where each SpaceX satellite loses propulsion capabilities

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[54] The European Space Agency, "ESA spacecraft dodges large constellation," SAFETY & SECURITY (Sep. 3, 2019), https://www.esa.int/Safety_Security/ESA_spacecraft_dodges_large_constellation.

[55] *See* Letter from William M. Wiltshire to Marlene H. Dortch, IBFS File No. SAT-MOD-20200417-00037, at 2 (July 7, 2020) (table showing per-satellite collision risk ranging from 0.000053 to 0.000142); Viasat Petition at 14 (0.0000877 blended probability of collision for a passive SpaceX satellite in operational orbit). Viasat's slightly higher risk calculations can be explained by two inputs. First, Viasat used an outdated area-to-mass ratio of 0.0733 m^2/kg instead of the actual value of 0.0974 m^2/kg. Second, Viasat assumed failure at a period of near-minimum solar activity whereas SpaceX performed a Monte Carlo analysis over a full solar cycle and presented an average value. Both of these factors increase deorbit time and correspondingly increase calculated risk.

[56] *See, e.g.,* Astroscale Ex Parte at 8; OneWeb Comments at 6-7; Viasat Petition at 13; Kepler Petition at 1.

simultaneously.[57] While Viasat seems to believe that as a non-U.S. operator it is exempt from Commission supervision, there is no sign that it will now provide this same information about its own application for a replacement system, with the assumption of 100% failure rate of its satellites. But regardless of the double standard Viasat hopes to apply to competitors, Viasat's arguments merely repeat claims the Commission has already considered when it specifically declined to adopt an aggregate risk metric rather than an aggregate limit in the recent update to its orbital debris mitigation rules.[58] NASA similarly adopted a per-satellite collision metric in its recent update to the U.S. Government Orbital Debris Mitigation Standard Practices.[59]

Here again, parties ask the Commission to hold SpaceX to a standard that their own applications would not satisfy. For example, as described above, Amazon fails to account for SpaceX's conjunction assessment and active collision-avoidance capabilities and asks the Commission to deny SpaceX's application based on the total conjunction risk of the modified SpaceX system, as assessed under Amazon's flawed model. Yet Amazon's own application properly relies on its own collision-avoidance capabilities and compliance with the Commission's per-satellite standard for conjunction risk, noting that "[t]he cumulative lifetime conjunction risk will be held below 0.001 for every satellite, by active conjunction assessment and maneuvering."[60] But now Amazon asserts that its competitor should be given less favorable treatment.

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57 *See* Viasat Petition at 17.

58 *See Orbital Debris Update Order* ¶¶ 36, 155-160. Contrary to Viasat's apparent belief (*see, e.g.,* Viasat Petition at ii, 15), the Commission has *not* proposed a 0.001 aggregate collision standard, though it is investigating a range of options for assessing the public interest implications of large NGSO satellite systems.

59 *See* U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update, at 4, https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.

60 Amazon Application, Technical Appendix at 31.

A few commenters suggest that SpaceX should be required to make a number of additional showings or provide an array of additional information on orbital debris issues.[61] At best, such proposals are appropriate for consideration in the ongoing orbital debris proceeding, where they could be considered for general application to all NGSO operators. But it would not be appropriate to hold SpaceX to a more exacting standard than others – especially at the request of non-U.S. systems that escape Commission review entirely.

II. THE PROPOSED MODIFICATION WILL NOT INCREASE POTENTIAL INTERFERENCE WITH GSO SATELLITES OR OTHER NGSO SYSTEMS

The Commission has recognized that a proposed modification to an NGSO authorization that does not seek additional spectrum should be granted where it "does not present any significant interference problems and is otherwise consistent with Commission policies."[62] In its application, SpaceX provided an analysis that considered the effect of the proposed modification on one Ku-band and three Ka-band NGSO systems to demonstrate that the modification would have no material effect on the interference environment of other NGSO systems.[63] SpaceX also certified that its NGSO constellation, as modified, will comply with the applicable equivalent power flux-density ("EPFD") limits set forth in Article 22 of the ITU Radio Regulations that are designed to protect GSO satellite systems, provided an updated analysis demonstrating that its modified constellation will continue to comply with those limits, and offered to make the underlying data files available to any interested party.[64] It did not, however, provide an analysis of the potential

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61 *See, e.g.,* Viasat Petition at 32-35; OneWeb Comments at 8 n.26; Kepler Petition at 13-14; Astroscale Ex Parte at 5.

62 *See First Modification* ¶ 9 (quoting *Teledesic LLC*, 14 FCC Rcd. 2261, ¶ 5 (IB 1999)).

63 *See* Modification Application, Technical Attachment, Annex 2.

64 *See id.* at 15 and Annex 1.

susceptibility of its own system to interference from other NGSO systems as a result of this modification.

Several parties raised questions about the potential for interference both from and to the SpaceX system as modified. As Viasat, notes, the Commission recently confirmed that a determinative factor in evaluating the interference impact of a proposed modification is "the number of times constellations will be required to reduce spectrum" under the spectrum sharing rules in Section 25.261.[65] Accordingly, SpaceX has used this metric as a key component in evaluating the concerns raised about its proposed operations at lower altitudes.

In addition, SpaceX notes that once again Amazon attempts to claim special rights for itself. While it may be appropriate for the Commission to give some consideration to potential interference to Amazon's planned system in its broader public-interest analysis, Amazon remains an *applicant* for a Commission license in a *later processing round*. It does not hold a license or grant of U.S. market access, much less one granted in the same processing round as SpaceX's application. Thus, Amazon stands on a different footing from other operators in opposing applications that, in its view, would significantly change the interference environment. Because it does not yet hold an authorization there is, indeed, no baseline from which to judge whether a significant change has occurred with respect to Amazon's system. And because it was not considered in the same processing round as SpaceX, Amazon is not entitled to the same interference considerations as are first-round licensees. Moreover, Amazon has repeatedly made clear its conviction that its ability to complete good faith coordination should alleviate any interference concerns.[66] SpaceX addresses Amazon's arguments in the discussion below, but that

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[65] *See Viasat* ¶ 12 (quoted in Viasat Petition at 44).

[66] *See, e.g.,* Amazon Application, Narrative at 14 and Technical Appendix at Annex C; Consolidated Opposition and Response of Kuiper Systems LLC, IBFS File No. SAT-LOA-20190704-00057, at 10, 16-18 (Nov. 13, 2019).

should not be taken as any sort of concession that Amazon is entitled to the same consideration as parties authorized along with SpaceX in the 2016 NGSO processing round.

A. SpaceX Will Accept Increased Interference from Other NGSO Systems that Results from the Modification, But Its Own Operations Will Not Result in a Significant Increase in Interference to Other NGSO Systems

In analyzing past modification proposals, the Commission has assessed the potential for interference with other NGSO systems in four different scenarios: uplink interference to and from SpaceX and downlink interference to and from SpaceX.[67] We discuss each of these scenarios in turn below. In summary, (1) to resolve the concerns raised in this proceeding, SpaceX is willing to accept increased interference from other NGSO systems authorized in the 2016 processing round to its own system on both the uplink and downlink that results from the proposed modification; and (2) concerns about potential interference from SpaceX into other NGSO systems resulting in more spectrum splitting are misplaced, as the uplink interference *from other systems into SpaceX* would have already exceeded the trigger for spectrum splitting well before potential interference from SpaceX becomes an issue under the proposed modification.

1. Interference from Other NGSO Systems into SpaceX Uplinks

Amazon and SES/O3b assert that, while operating at lower altitudes, SpaceX satellites will be more susceptible to uplink interference from earth stations communicating with other NGSO systems.[68] This is because SpaceX satellites will be closer to the transmitting earth stations of other systems and therefore will receive an interfering signal of greater strength. In addition, as discussed in its application, SpaceX has decided to reduce the transmit power of its earth stations

[67] *See, e.g., First Modification* ¶¶ 12-15.

[68] *See* Amazon Petition at 21-22; SES/O3b Petition at 11-12.

communicating with satellites at these lower altitudes.[69] This is consistent with the power levels requested for SpaceX's gateway earth stations, which transmit at levels that are far below the maximum amount authorized under its space station license.

From this, SpaceX concedes that its satellites operating at the lower power and lower altitudes proposed in the modification will be somewhat more susceptible to uplink interference from earth stations communicating with other NGSO systems. In fact, this will necessarily happen for any system wishing to improve its safety profile by lowering its operations to altitudes the Commission has recognized as safer that does not insist on overpowering its uplinks. Despite this tension, SpaceX is willing to accept a condition requiring that it accept any additional interference to its uplinks from other NGSO systems authorized in the 2016 processing round resulting from this modification compared to its current authorization. Appendix A hereto provides an illustration of how the appropriate interference level would be determined based on an analysis of 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.

As shown in Figure 1 below, Kepler provides an extreme case in that the interference its earth stations would cause to SpaceX uplinks exceeds the -12.2 dB I/N trigger for spectrum splitting under Section 25.261 *at all times even with SpaceX satellites operating at the higher altitudes currently assigned.*[70]

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[69] *See, e.g.,* Modification Application at ii ("with its satellites closer to Earth, SpaceX will be able to decrease the power levels of its transmissions from and to its satellites").

[70] This figure is for earth stations located at 35° N latitude, but the result is similar for the 80°, 85°, and 90° latitudes presented in Kepler's analysis. It also reflects the use of Kepler's least interfering type of earth station.

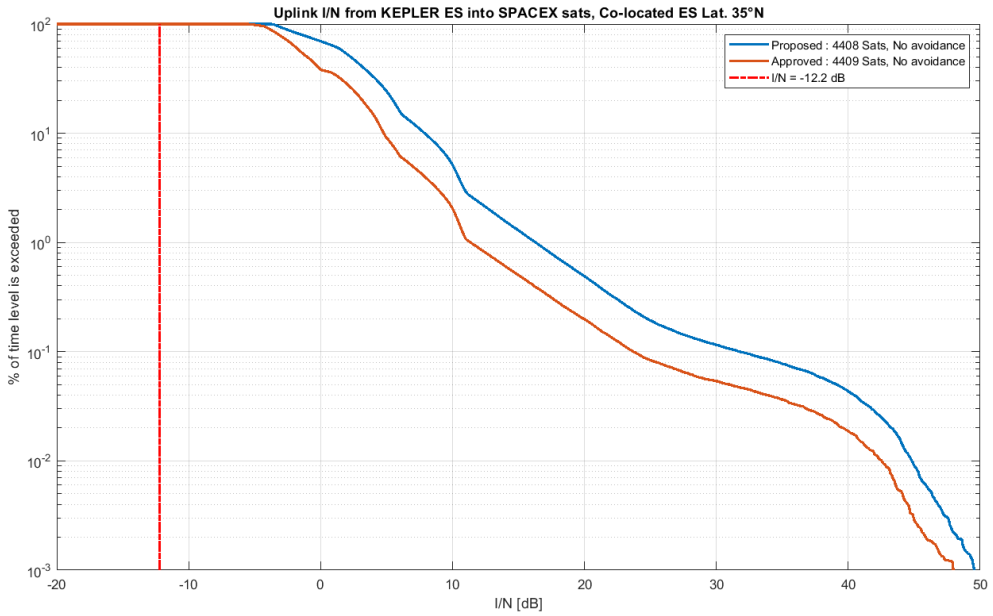

Figure 1. Example of Uplink Interference from Kepler Into SpaceX

Indeed, Kepler's interference exceeds approximately -4 dB I/N 100% of the time both before and after the modification, even when assessing its least-interfering type of earth station. As a result, even under SpaceX's existing authorization, these two systems will have to split their shared spectrum at all times in the absence of a coordination agreement. As discussed in Appendix A, this effectively renders moot any other potential effects SpaceX's modified operations might have on Kepler's system.

OneWeb provides a more typical case. SpaceX performed an I/N CDF analysis incorporating worst-case assumptions and using the parameters for the 3.5 meter antenna provided in OneWeb's earth station application. The analysis of uplink interference to SpaceX shows that OneWeb would exceed the -12.2 dB spectrum splitting trigger approximately 8% of the time when interacting with SpaceX's constellation as currently authorized. In order to maintain that 8% in-line event level with its modified system, SpaceX would accept an I/N of -9.6 dB as its trigger for spectrum splitting on the uplinks affected by this modification. On the downlink, the analysis confirms that there is no material increase in interference from SpaceX into OneWeb as a result of

the modification, as any action taken to address the uplink interference to SpaceX would also decrease the downlink I/N for OneWeb below the spectrum splitting trigger.

2. Interference from Other NGSO Systems into SpaceX Downlinks

With respect to downlinks from its satellites, SpaceX will transmit at lower power in light of its satellites' lower altitudes. In the Ku-band, it will nonetheless maintain the same PFD level on the surface of the Earth from lower altitude as it would from the currently authorized higher altitude.[71] Thus, as the Commission found in a prior modification, "[t]here should be no change to the interference environment" because the level of desired signal received by a SpaceX earth station "will be the same, as the level of the signal transmitted from a SpaceX satellite at lower altitude will be reduced only to the amount that compensates for the shorter transmit path."[72] As a result, SpaceX Ku-band downlinks will be no more susceptible to interference from other NGSO systems as a result of the modification, so no corrective action is required.

As OneWeb notes, SpaceX proposes to reduce the PFD levels for its Ka-band downlinks by 7 dB.[73] This could make these transmissions to gateways more susceptible to interference.[74] Accordingly, as with uplinks, SpaceX is willing to accept a condition requiring that it accept any additional interference in its Ka-band downlinks from other NGSO systems authorized in the 2016 processing round resulting from this modification compared to its current authorization.

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71 *See* Modification Application, Technical Attachment at 11; Application, IBFS File No. SAT-MOD-20181108-00083, Technical Attachment at 12 (Nov. 8, 2018) ("SpaceX First Mod Application").

72 *First Modification* ¶ 14.

73 *See* OneWeb Comments at 16. OneWeb incorrectly assumes a reduction of 10 dB; while that is the correct value for a single polarization, SpaceX will use both polarizations resulting in an increase of 3 dB. Accordingly, the downlink PFD will decrease from -116.3 dBW/m^2/MHz to -123.3 dBW/m^2/MHz. *See* Modification Application, Technical Attachment at 10; SpaceX First Mod Application, Technical Attachment at 11.

74 *See also* Amazon Petition at 21-23.

3. Interference from SpaceX Uplinks into Other NGSO Systems

Here again, operating satellites at lower altitude will enable SpaceX to use lower power uplinks from its earth stations to communicate with them. In a previous modification, the Commission noted that the only limitation on SpaceX's existing authorization imposed on uplink transmissions was compliance with the applicable $EPFD_{up}$ limits and that "the decision that no other limits on earth station transmissions are necessary was recently reaffirmed by the Commission."[75] SpaceX has taken a more sharing-friendly approach by applying for gateway earth stations that operate at lower power levels in anticipation of communications with SpaceX satellites in the 540-570 km altitude.[76] Were it forced to operate at its currently authorized altitudes, it would instead need to use the higher power levels authorized in its existing space station license. As a result, the uplink interference environment would be better for other NGSO systems as a result of the modification.

Kepler asserts that the modified SpaceX constellation would impose a significant increase in interference on its system, arguing that its system is especially sensitive to these changes because of its low elevation angles (10° minimum) and focus on high-inclination orbits serving polar regions.[77] However, as discussed above, this analysis is made irrelevant by the fact that the interference that Kepler will cause to SpaceX uplinks will require spectrum splitting at all times in the absence of a coordination agreement. Because Kepler will have such a dramatic impact on

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75 *First Modification* ¶ 13.

76 This may answer OneWeb's question about uplink power levels assumed in SpaceX's analysis (OneWeb Comments at 15), with operations under its existing authorization up to the $EPFD_{up}$ limits and operations at lower altitudes consistent with the parameters of its gateway earth station applications.

77 *See* Kepler Petition at 7-11. Kepler asserts that it performed a dynamic, time-varying interference analysis using all the same general assumptions SpaceX did for its analysis, yet it also refers to "the increase in EIRP" as a factor that explains the outcome of that analysis. *Id.* at 7. To the contrary, SpaceX proposes to decrease the EIRP of its earth stations communicating with satellites operating at lower altitude.

SpaceX's uplinks, any arguable increase in the number or duration of inline events on Kepler's uplinks cannot increase the amount of time Section 25.261's spectrum splitting rules will apply.

4. Interference from SpaceX Downlinks into Other NGSO Systems

Several parties raise concerns about the potential for SpaceX's modified operations to increase interference experienced by the downlinks of other NGSO systems, but these arguments fall flat. SES/O3b argues that the lower elevation angles SpaceX proposes "would increase the number of situations that require splitting of the available spectrum absent consent."[78] Amazon and OneWeb make a similar argument, concluding that the modification would increase the number and duration of in-line events (even though their graphs of downlink interference before and after the modification show only modest differences in the probability of interference at any given I/N value).[79] Kepler argues that its operations in high latitudes are particularly susceptible to interference from SpaceX's modified operations, while Viasat asserts that it is difficult to tell the precise effects of the modification from the figures provided by SpaceX and requests that SpaceX provide a table with the probability that it will cause interference exceeding the 6% $\Delta T/T$ threshold.[80]

These assertions fail to consider the larger question that is critical in assessing changes to the interference environment: whether the proposed modification would increase the number of in-line events during which two NGSO operators would be required to split a spectrum band under Section 25.261 in the absence of a coordination agreement.[81] Making this determination requires

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[78] SES/O3b Petition at 13. SES/O3b also claims that the modification would increase the number of in-line events. *See id.* at 6-8.

[79] *See* OneWeb Comments at 10-14; Amazon Petition at 15-20. *Compare* Amazon Petition at 25 (Figure 12); OneWeb Comments at 13-14 (Figures A and B).

[80] *See* Kepler Petition at 7-11; Viasat Petition at 44-46.

[81] *See Viasat* ¶ 12.

more than just looking at the effect on downlinks in isolation. To the contrary, the analysis must look at all four scenarios discussed in this section to see whether a change in any one is material. Here, as demonstrated in Appendix A, *existing interference from other NGSO systems into SpaceX uplinks* (even at the levels experienced at its currently assigned orbital altitudes) will overwhelm any effect SpaceX's modified operations may have on their respective downlinks.[82]

As shown in Appendix A and summarized in Table 3 below, the percentage of time during which interference to SpaceX uplinks would exceed the -12.2 dB trigger for spectrum splitting is far greater for Amazon, Kepler, and O3b than the percentage of time during which interference from SpaceX's modified downlinks would exceed this level.

NGSO System	Interference Into SpaceX Uplinks (at current altitudes)	Interference From SpaceX Downlinks (at proposed altitudes)
Amazon	100%	50%
Kepler	100%	3%
O3b	88%	3%
OneWeb	8%	1%

Table 3. Probability of Exceeding -12.2 dB I/N Trigger

Indeed, each currently authorized SpaceX satellite would already experience an in-line event due to uplink interference from at least one Amazon earth station for 100% of its time on orbit, and the same is true for Kepler as well. O3b is only slightly better, at 88% – and as demonstrated in Appendix A its claim of increased in-line events appears not to have accounted for the 18 degree GSO avoidance angle observed by the SpaceX system which will continue to prevent such in-line

[82] SpaceX raised the issue of uplink interference and proposed limits on uplink power levels in the orbital debris mitigation proceeding. While the Commission "recognize[d] the potential utility of SpaceX's proposal," it decided that it would be premature to adopt such limits. *Updates to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, 32 FCC Rcd. 7809, ¶ 55 (2017) ("*NGSO Update Order*").

events with O3b's equatorial NGSO system. For these three systems, the modification will cause no material change to the number or duration of in-line events because their own uplinks will exceed the trigger long before any effect on their downlinks would do so. While the uplink interference from OneWeb does not totally overwhelm any effect on downlink interference in the same way it does for these other three NGSO operators, Appendix A demonstrates that steps taken to avoid splitting spectrum on the uplink would reduce I/N on the OneWeb downlink to levels below the -12.2 dB trigger.

As a result, while SpaceX has always believed there would be no "significant" change in interference to the downlinks of other operators in any event, any impact SpaceX's modified operations might have on other NGSO systems' downlinks will not increase the amount of time that the parties will have to split common spectrum in the absence of a coordination agreement.

Finally, Amazon points to the fact that SpaceX has doubled the number of active satellites communicating with each gateway earth station as a potential cause for increased interference.[83] OneWeb makes a similar claim, as well as the slightly contrary argument that SpaceX will need to deploy more gateways in order to service its satellites at lower altitudes.[84] In fact, by allowing more satellites to communicate with each gateway site, SpaceX will decrease the number of such sites its system needs to use. Moreover, neither commenter explains exactly why this change in operations would result in an increase in interference – especially given that SpaceX will reduce the EIRP of its transmissions by 3 dB to account for the fact that twice as many satellite beams may be downlinking to a site at once.

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[83] *See* Amazon Petition at 20-21.

[84] *See* OneWeb Comments at 9-11.

B. SpaceX's Compliance with Applicable EPFD Limits Will Ensure that GSO Satellites Do Not Experience Harmful Interference

As required by Commission rules, SpaceX 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.[85] That is sufficient under the Commission's rules. Nonetheless, SpaceX went above and beyond the Commission's requirements by submitting the results of an EPFD analysis using ITU-approved software implemented in full compliance with ITU methodology to confirm that its system would operate within all applicable EPFD single entry validation limits in the Ku- and Ka-band spectrum covered by its license.[86] As the Commission has recognized, "[a]ny NGSO FSS system operating in compliance with these limits is considered as having fulfilled its obligation under Article 22 of the ITU Radio Regulations not to cause unacceptable interference to any GSO network."[87] SpaceX also made the data files used for these analyses available to any interested party upon request so that they could independently confirm these technical findings.

Despite all this evidence, DISH claims that the proposed modification threatens the Direct Broadcast Satellite ("DBS") service and that SpaceX "continues to stonewall interested stakeholders and refuses to provide the technical analysis and information requested to date."[88] Notably, DISH has never asked for the data offered by SpaceX, and thus has never actually done any of its own technical analysis. Rather, DISH quibbles with a single assumption included in SpaceX's EPFD analysis based on the fact that two other NGSO operators took a different

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85 *See* Modification Application, Technical Attachment at 15; 47 C.F.R. § 25.146(a)(2).

86 *See* Modification Application, Technical Attachment, Annex 2.

87 *NGSO Update Order* ¶ 32.

88 DISH Ex Parte at 2.

approach.[89] Yet the ITU has evaluated previous network filings for the SpaceX constellation and concluded that SpaceX complies with the EPFD limits designed to protect DBS systems, issuing a favorable finding based on the inputs supplied by SpaceX.[90] Thus, the expert agency that developed and oversees these EPFD calculations has both implicitly endorsed the methodology used by SpaceX and found that SpaceX would comply with the rules adopted for the benefit of DBS systems. DISH not only seeks to dictate the use of its own preferred methodology, but asks the Commission to second-guess the ITU in doing so,[91] directly contrary to the approach the Commission decided to take in updating its rules for NGSO systems.[92] The Commission should reject these arguments.

AT&T, DISH's DBS competitor, also raises concerns about protection of its DBS operations. Under SpaceX's current authorization, the Commission has waived the requirement that SpaceX receive a favorable or "qualified favorable" finding from the ITU with respect to its compliance with applicable EPFD limits *prior to* commencing operations, imposing instead the obligation to receive such a finding from the ITU at some point and adjust its operations as necessary to satisfy ITU requirements.[93] This condition essentially enables SpaceX to proceed only at its own risk while continuing to ensure that SpaceX's constellation will ultimately have been shown to protect DBS operations.

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89 *See id.* at 2-3.

90 *See* International Telecommunication Union, "EPFD Data and EPFD Examination Results," SPACE SERVICES, https://www.itu.int/en/ITU-R/space/Pages/epfdData.aspx (STEAM-1 and STEAM-2B networks).

91 DISH Ex Parte at 4.

92 *See NGSO Update Order* ¶ 41 ("We do not believe that such review is warranted to reduce the likelihood that an incorrect submission is made to the ITU.").

93 *See Second Modification* ¶¶ 10, 19n.

Nonetheless, while making no attempt to analyze the data SpaceX has made available, AT&T would like the Commission to withdraw that waiver and require SpaceX to defer deployment under a modified authorization until after the ITU has issued its determination.[94] This would significantly delay SpaceX's deployment of most of its system, including the portions that provide coverage to polar regions that are woefully underserved by terrestrial broadband alternatives. As the Commission found in rejecting calls to await EPFD analysis of a prior modification proposed by SpaceX, "there is no legal requirement that third parties evaluate the sufficiency of EPFD data inputs prior to deployment of an NGSO system, and, more importantly, this delay would unfairly prejudice SpaceX's timely implementation of its new system."[95] Moreover, AT&T's additional request for a condition requiring SpaceX to protect DBS incumbents against *any* increase in interference, no matter how small, is flatly inconsistent with the international accord holding that operating within the EPFD limits provides sufficient protection to GSO systems.[96] Like Dish, AT&T inappropriately asks the Commission to second-guess internationally agreed interference-protection standards. The Commission should decline to do so.

For its part, SES/O3b raises the possibility that the increased scan angles proposed by SpaceX could result in grating lobes that would direct Ka-band energy in unexpected directions and potentially affect earth stations communicating with GSO satellites.[97] However, this is not a phenomenon associated with the phased array antennas used on SpaceX satellites, which have

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94 *See* AT&T Comments at 4-6.

95 *Second Modification* ¶ 11.

96 *See* AT&T Comments at 6. AT&T also asks that the Commission consider the potential implications for aggregate EPFD in light of applications filed in the second NGSO processing round. *See id.* at 6-7. SpaceX is already subject to a condition requiring cooperation with other NGSO operators to jointly comply with applicable limits on aggregate EPFD. *See Second Modification* ¶ 19o.

97 *See* SES/O3b Petition at 15-16.

been specifically designed with sufficiently small spacing between antenna elements to operate at the highest frequency and largest scan angle proposed herein without producing grating lobes. SES/O3b also raises a question based on the EPFD data provided in connection with SpaceX's *last* modification.[98] Given that SES/O3b has failed to request (much less analyze) the data SpaceX has made available with respect to this application, the Commission should reject its speculative concern.

Lastly, Viasat claims that the Commission should closely examine SpaceX's EPFD showing based on an unrelated request for special temporary authority ("STA") and alleged concerns over satellite payload testing.[99] Viasat ignores the fact that SpaceX has performed such testing pursuant to STAs for over a year without complaint from any party, including Viasat. Viasat also raises questions as to how the various ITU filings made on SpaceX's behalf fit into its EPFD analysis.[100] SpaceX has conducted its EPFD analysis based on procedures and software approved by the ITU. It has every incentive to ensure that this analysis has been performed properly because if the ITU were to determine for any reason that SpaceX's system would exceed the applicable EPFD limits, SpaceX would have to revise its operations to come into compliance with those limits. Although SpaceX has provided Viasat the EPFD data files, Viasat presents no analysis in support of its claims and no cogent basis for subjecting SpaceX's analysis to even greater scrutiny than it is already under.

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98 *See id.* at 16. Although SpaceX has requested an STA under which it might exceed the EPFD limits during very brief intermittent periods for a few days after each launch, it has not made such a request in this proceeding.

99 *See* Viasat Petition at 39-40.

100 *See id.* at 40-44.

III. GRANTING THE PROPOSED MODIFICATION WILL HAVE NO EFFECT ON MVDDS SYSTEMS, NOW OR IN THE FUTURE

In 2016, the MVDDS 5G Coalition filed a petition for rulemaking that proposed to stifle FSS consumers' ability to use the 12.2-12.7 GHz band so that Multichannel Video Distribution and Data Service ("MVDDS") operators could be given mobile rights.[101] On behalf of MVDDS interests, CCIA/INCOMPAS assert that "[i]f the Commission grants the modifications requested in the SpaceX application, the potential 5G uses for the 12 GHz band may never occur."[102] They do not, however, explain the basis for that assertion. In particular, they do not explain how granting SpaceX a modification to operate in spectrum it is already authorized to use consistent with the co-primary FSS allocation in the U.S. Table of Frequency Allocations would change conditions in the 12 GHz band in any material way. Nor do they seem to recognize that other NGSO FSS operators, including OneWeb, Kepler, Space Norway, Karousel, and Theia, are also authorized to provide service in this band.

Simply put, there is no plausible explanation for CCIA/INCOMPAS's assertion. As recently as December 2019, members of the MVDDS 5G Coalition conceded that "concurrent sharing of spectrum between co-primary 5G and NGSO FSS operations is not viable in the 12 GHz Band."[103] An earlier MVDDS sharing study similarly concluded that "MVDDS licensees *cannot* deploy two-way 5G services in the 12.2-12.7 GHz band without overwhelming NGSO FSS operations even under the current rules, notwithstanding new 5G deployment architectures and newly available high-resolution ground-obstacle data."[104] Not surprisingly, there is no proposal

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[101] *See* MVDDS 5G Coalition Petition for Rulemaking to Permit MVDDS Use of the 12.2-12.7 GHz Band for Two-Way Mobile Broadband Service, RM-11768 (Apr. 26, 2016) ("2016 Petition").

[102] CCIA/INCOMPAS Ex Parte at 2.

[103] Letter from Alison Minea to Marlene H. Dortch, RM-11768, at 3 (Dec. 2, 2019).

[104] Comments of the MVDDS 5G Coalition, RM-11768, Attachment I at 2 (June 8, 2016) (emphasis in original).

for MVDDS sharing the band with NGSO FSS,[105] and thus any changes that even arguably would make sharing more difficult are completely irrelevant. Accordingly, the modification proposed by SpaceX is immaterial to the MVDDS 5G Coalition's efforts to uproot NGSO FSS systems from the band.

To be clear, CCIA/INCOMPAS do not allege that SpaceX's proposed modification will harm licensed MVDDS operations – nor could they. SpaceX has demonstrated that its system as modified will continue to comply with all rules imposed to safeguard MVDDS systems – operating at least 15 dB below the applicable PFD limit.[106] Instead, CCIA/INCOMPAS seem to be concerned not about the rights that MVDDS operators actually have – i.e., rights to operate low-power fixed links in shared spectrum – but rather about the high-power mobile rights they hope the government will give them for free at the expense of other licensees in the band. As detailed in the record of the 2016 Petition, there are many good reasons not to grant MVDDS licensees the windfall they request. But the simple fact is that nothing about granting SpaceX's proposed modification will change any of the relevant considerations.

IV. THE COMMISSION SHOULD GRANT AUTHORITY FOR INITIAL OPERATIONS AFTER ORBITAL INJECTION OF SPACEX SATELLITES

As part of the proposed modification, SpaceX requested that the Commission include authority for communications with SpaceX satellites during transition phases before and after reaching authorized orbital positions. This would include authority to perform TT&C functions during orbit-raising and de-orbit maneuvers,[107] as well as authority for testing of the Ku- and Ka-band communications payloads during the orbit-raising process, which would be conducted on a

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[105] The 2016 Petition proposes that the allocation under which consumers would receive NGSO FSS services in the 12 GHz band be either eliminated entirely or relegated from co-primary to secondary. *See* 2016 Petition at 23.

[106] *See, e.g.*, Modification Application, Technical Attachment at 11-12 (demonstrating compliance with PFD limits).

[107] Such TT&C functions are authorized by rule for GSO satellite systems. *See* 47 C.F.R. §§ 25.282, 25.283.

non-protected, non-harmful interference basis. Granting the requested authority as part of the space station license would replace the current practice under which SpaceX must file – and the Commission must process – an ongoing stream of applications for special temporary authority to cover operations as satellites are raised into and de-orbited out of the constellation.

While it did not actually oppose this request, Viasat asserts that SpaceX has made no showing that it can conduct these operations on a non-interference basis.[108] As SpaceX discussed in its application, it has conducted such operations on a non-interference basis pursuant to numerous STAs over the last year without complaint from any other licensed spectrum user.[109] The fact that Viasat was apparently unaware of these activities confirms that SpaceX can and does conduct them on a non-interference basis. Incorporating this authority into SpaceX's license would serve the public interest by relieving the Commission of the burden of processing STA applications for the foreseeable future without affecting the operations of any other licensee.

[108] *See* Viasat Petition at 39-40.

[109] Modification Application at 4 n.7.

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/ David Goldman*
David Goldman, Director, Satellite Policy

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

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

July 27, 2020

APPENDIX A

DYNAMIC INTERFERENCE ANALYSES FOR ONEWEB, KEPLER, AMAZON, AND O3B

Some parties have raised concerns about the recent application by Space Exploration Holdings, LLC ("SpaceX") to modify its existing system authorization, which would lower the orbits of all satellites in the SpaceX system to altitudes ranging from 540 km to 570 km. They present analyses that purport to show that SpaceX's requested modification would degrade the interference environment by changing "the frequency and character of in-line events."[1]

To evaluate these claims, SpaceX conducted dynamic interference analyses with respect to each of these operators using publicly available system parameters and, when relevant parameters were not available, conservative assumptions. The analyses considered the dynamic, time-varying interference, with results expressed as cumulative distribution functions ("CDFs") of the interference-to-noise ratio ("I/N"). The I/N CDFs were derived from time-domain simulations of the NGSO systems under consideration 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 besides their respective stated geostationary orbit ("GSO") avoidance angles and, where applicable, spectrum splitting or other coordination measures necessary to mitigate in-line interference events. While these results demonstrate some increase in SpaceX's susceptibility to uplink interference, they confirm that other operators will not experience any significant change in their interference environment, and no increase in the frequency of in-line events.

I. OneWeb

SpaceX performed simulations to assess interference between the OneWeb and SpaceX NGSO systems, including both OneWeb's interference to SpaceX's uplinks and SpaceX's interference to OneWeb's downlinks, before and after the proposed modification. This analysis made the worst-case assumption that both systems' earth stations would be co-located and considered an earth station at a latitude of 41.5 degrees – the latitude used in OneWeb's own analysis. For the downlink analysis we assume the 3.5 meter antenna described in OneWeb's earth station filings. Consistent with the parameters in its application and existing authorization, SpaceX satellites simulated under the existing authorization observed a 40 degree minimum elevation angle, while those simulated under the proposed modification observed a 25 degree minimum elevation angle.

The results of the analysis for a victim SpaceX satellite and victim OneWeb earth station, for uplink and downlink interference simulations respectively, are set forth in Figures I-A and I-B. In each case, the figure plots a CDF of aggregate I/N levels for the SpaceX constellation as currently authorized and as modified.

[1] Kepler Petition at 7.

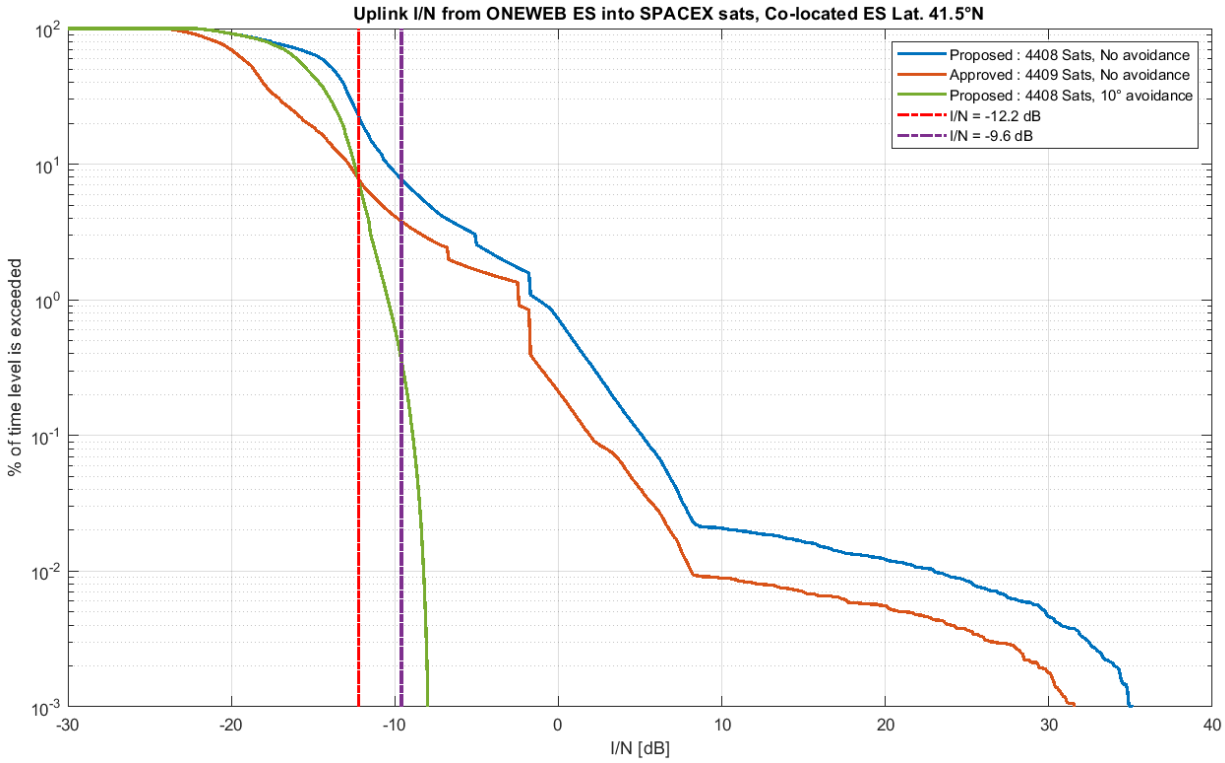

Figure I-A — Uplink Interference from OneWeb to SpaceX

The uplink interference results depicted in Figure I-A indicate an increase in interference to SpaceX's uplinks as a result of the proposed modification. However, they also reveal that uplink interference would be common without the modification. Considering uplink interference, a currently authorized SpaceX satellite would already experience an in-line event (i.e., I/N ≥ 12.2 dB) with a OneWeb earth station approximately 8% of the time. As stated in this filing, although the proposed modification causes an increase in interference to SpaceX's uplinks, SpaceX is willing to accept this additional interference. For example, in this case, the point at which the curve for the currently authorized system crosses -12.2 dB I/N is at the same point on the vertical axis as the point at which the curve for the modified constellation crosses -9.6 dB. Accordingly, we will assume an in-line event trigger of I/N = -9.6 dB for OneWeb's interference into SpaceX uplinks, thus maintaining the same 8% probability of interference to SpaceX uplinks as modified, without additional protections.

Despite SpaceX's accepting additional interference, frequent spectrum splitting or other coordination measures will still be required. For purposes of illustration, we assume here that a 10 degree avoidance angle is implemented, such that the spectrum is split whenever the angular separation becomes less than 10 degrees. This would ensure that interference (the green curve in plot above) remains at a more reasonable—but still not acceptable—level.

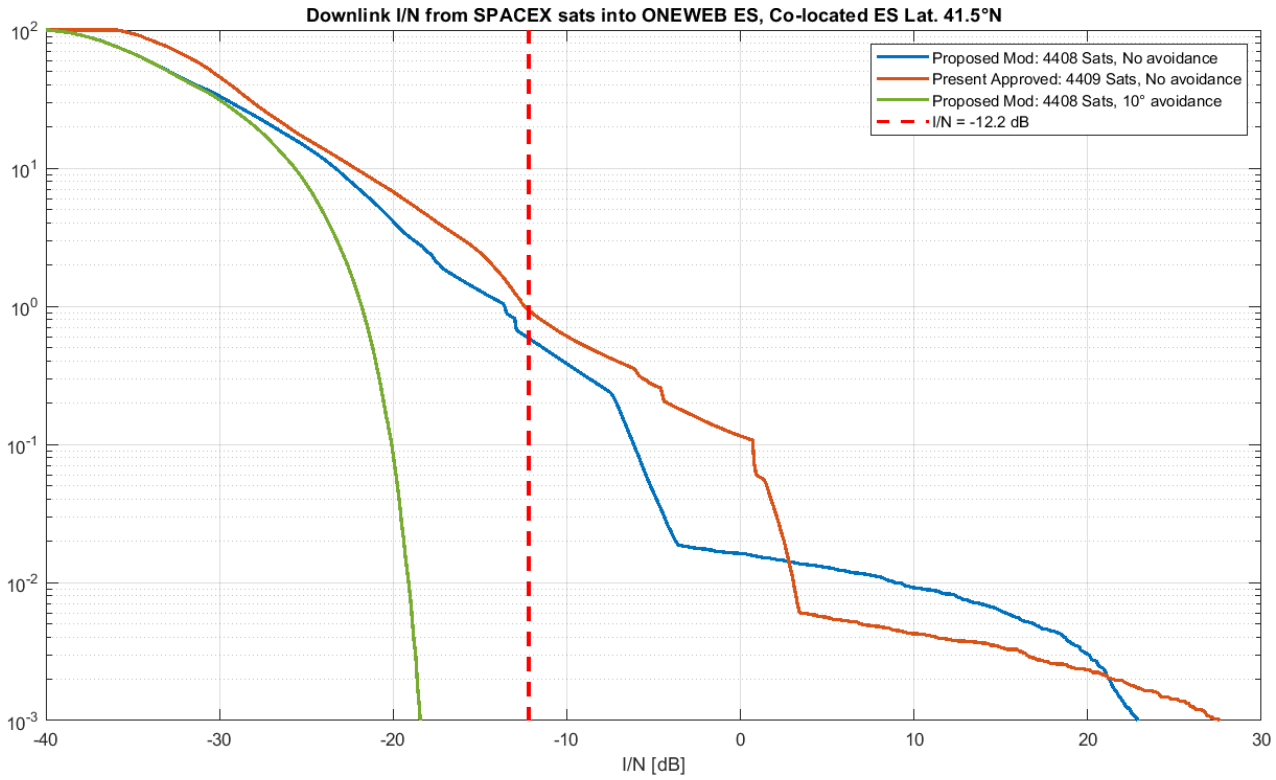

Figure I-B — Downlink Interference from SpaceX to OneWeb

In the case of downlink interference into a OneWeb earth station from a SpaceX satellite, illustrated above in Figure I-B, the results confirm that there is no material increase in interference, which remains well below -12.2 dB I/N in all cases where spectrum splitting has not already occurred due to interference to SpaceX uplinks (i.e., where separation is greater than 10 degrees).

II. Kepler

SpaceX also performed simulations to assess interference between the Kepler and SpaceX systems. This analysis made the worst-case assumption that earth stations would be co-located and considers earth stations at latitudes of 35, 80, 85, and 90 degrees. To ensure a conservative result, we have assumed a Kepler transmit antenna pattern described by ITU-R Rec. S.1428 which would tend to minimize the interference to SpaceX's uplinks. Consistent with the parameters in its application and existing authorization, SpaceX satellites simulated under the existing authorization observed a 40 degree minimum elevation angle, while those simulated under the proposed modification observed a 25 degree minimum elevation angle.

The results of the analysis for uplink interference from Kepler earth stations at various latitudes to a victim SpaceX satellite are set forth in Figures II-A through II-D. The figure plots a CDF of aggregate I/N levels for the SpaceX constellation as currently authorized and as modified.

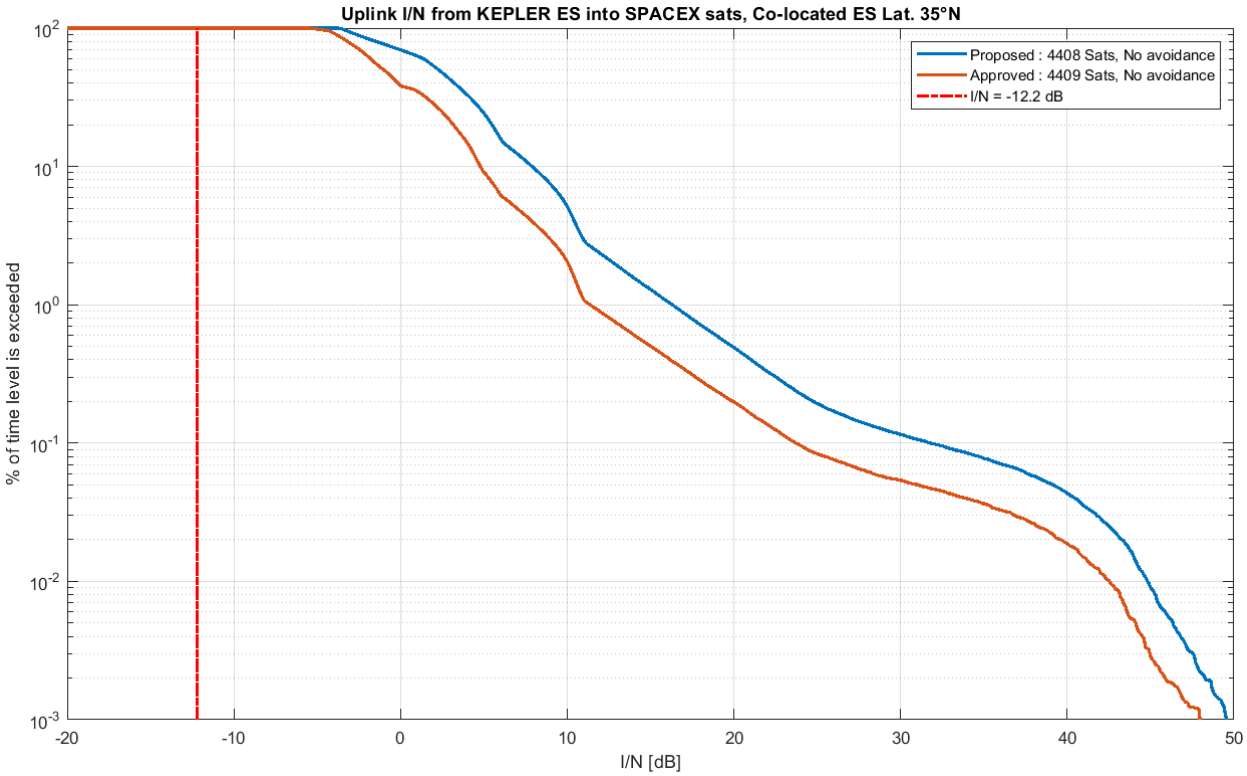

Figure II-A — Uplink Interference from Kepler to SpaceX, Co-located at latitude 35°N

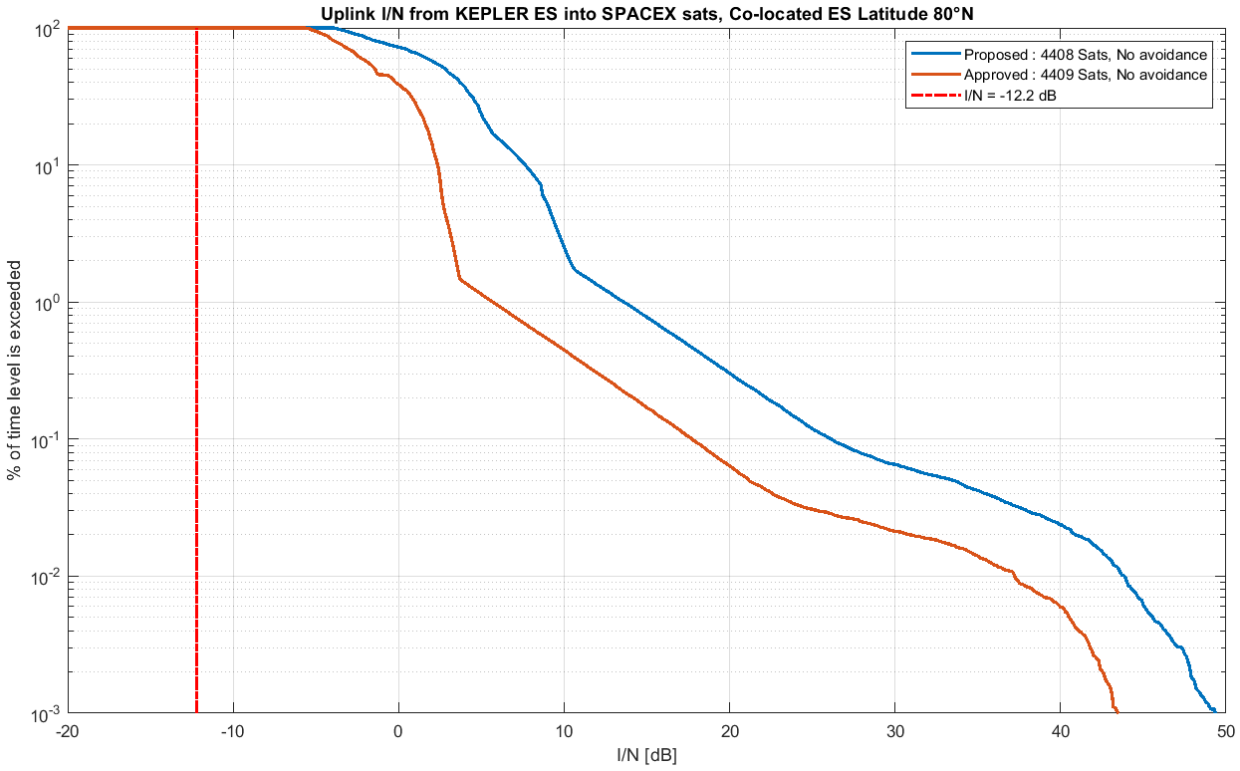

Figure II-B — Uplink Interference from Kepler to SpaceX, Co-located at latitude 80°N

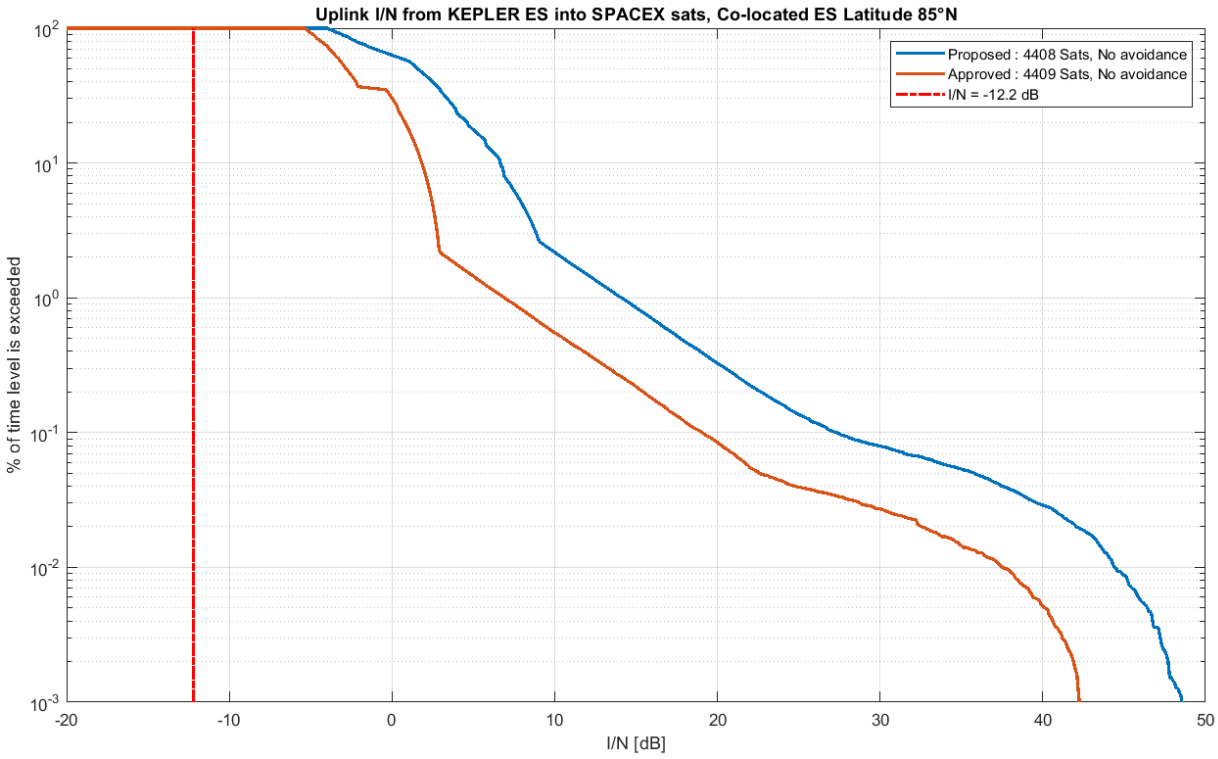

Figure II-C — Uplink Interference from Kepler to SpaceX, Co-located at latitude 85°N

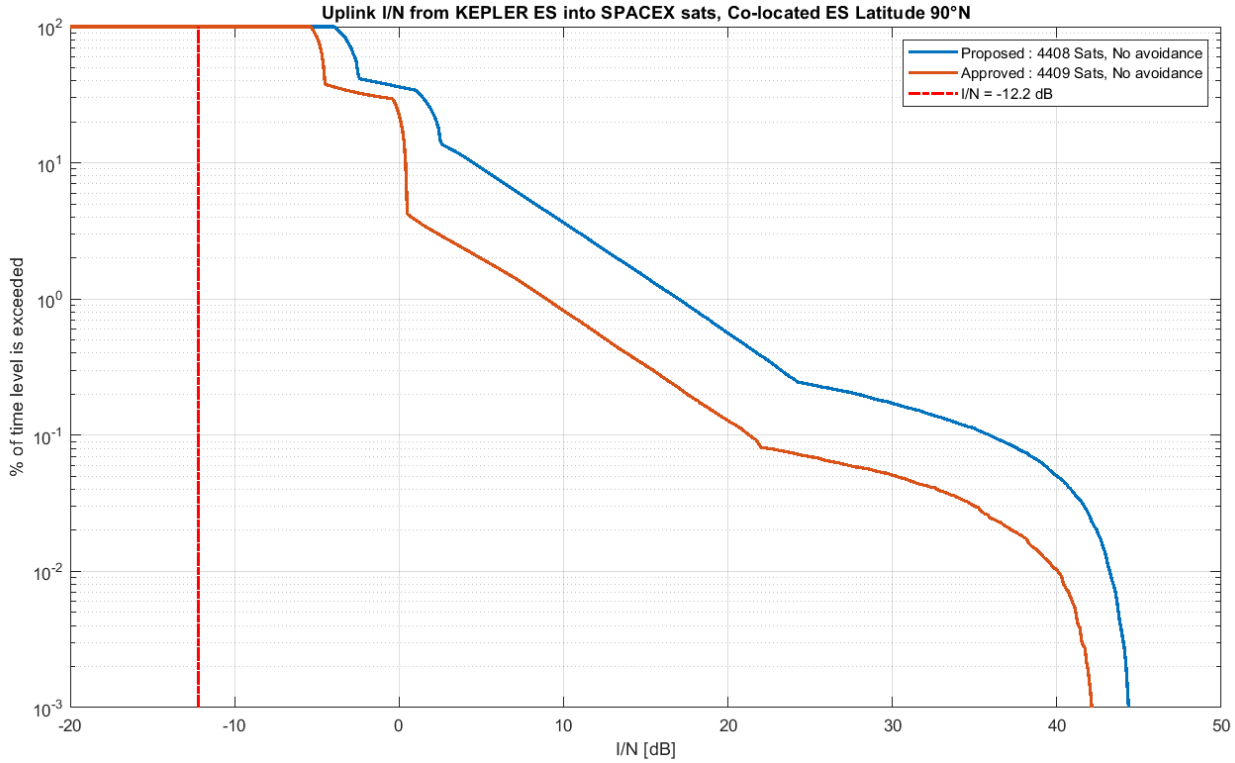

Figure II-D — Uplink Interference from Kepler to SpaceX, Co-located at latitude 90°N

The uplink interference results depicted in these figures indicate a theoretical increase in interference to SpaceX's uplinks as a result of the proposed modification. However, they also reveal that uplink interference is already pervasive in the absence of the modification. Each currently authorized SpaceX satellite would already experience an in-line event with at least one Kepler earth station for 100% of its time on orbit. Notably, this analysis assumes uplink transmissions from the smallest user terminal described in Kepler's filings, with an EIRP of -13.27 dBW/Hz. Uplink interference would be even more severe from larger Kepler earth station antennas.

To provide additional context regarding the pervasiveness of Kepler interference to SpaceX uplinks even with no modification, SpaceX supplemented the dynamic analysis above with the static analysis for SpaceX satellites at 1,110 km provided in Table II-A. These results document the interference caused by Kepler earth stations with antennas of varying diameters to SpaceX satellites with currently authorized parameters both at zenith with respect to that earth station and at maximum slant, under the best case assumption that the gain of Kepler's earths station antenna towards the SpaceX satellite is the minimum possible based on the appropriate earth station antenna pattern (-9 dBi for 0.65-1.03m antennas and -12 dBi for the 2.4m antenna). Even under these conditions, the results demonstrate that each SpaceX satellite will experience interference from Kepler uplinks far above the 6% ΔT/T in-line event trigger at all times.

Kepler ES Diameter [m]	ES Tx Gain [dBi]	ES EIRP density [dBW/Hz]	Lowest possible UL ΔT/T at SpaceX satellite	
			at zenith	at slant
0.65	37.7	-13.27	158.7%	59.8%
0.85	40.7	-10.27	158.7%	59.8%
0.98	41.2	-9.77	158.7%	59.8%
1.03	41.6	-9.37	158.7%	59.8%
2.4	47.4	3.42	397.8%	149.8%
2.4	47.4	8.37	1243.6%	468.2%

Table II-A — Static Analysis of Kepler Uplink Interference to SpaceX Satellites

These results demonstrate that any potential increase in the frequency of in-line events or increased interference levels to Kepler's downlinks described in Kepler's filing is entirely theoretical. In practice, Kepler earth stations' uplink interference to SpaceX will trigger in-line events requiring band splitting at all times and would do so both with and without the proposed modification. Thus, the modification has no material effect on the frequency or duration of such spectrum splitting with respect to Kepler's downlinks.

III. Amazon

Although Amazon's system was not authorized in the 2016 processing round, SpaceX also performed simulations similar to its analysis of interference involving Kepler to assess interference between the SpaceX and Amazon systems, considering an earth station at 35 degrees latitude. However, our analysis differs from the one presented by Amazon in that, unlike Amazon, we do not assume co-location of SpaceX and Amazon gateways. Given the fairly limited number of

gateways to be deployed by each operator, this situation is too implausible to support a reasonable interference analysis and, in any event, could readily be avoided by both operators. Instead, we assumed colocation of an Amazon user terminal with a SpaceX gateway, a far more reasonable scenario. Consistent with the parameters in its application and existing authorization, SpaceX satellites simulated under the existing authorization observed a 40 degree minimum elevation angle, while those simulated under the proposed modification observed a 25 degree minimum elevation angle. Amazon earth station parameters are assumed to be consistent with those filed with the ITU.

The results of the analysis for uplink interference to a victim SpaceX satellite are set forth in Figure III-A. The figure plots a CDF of aggregate I/N levels for the SpaceX constellation as currently authorized and as modified.

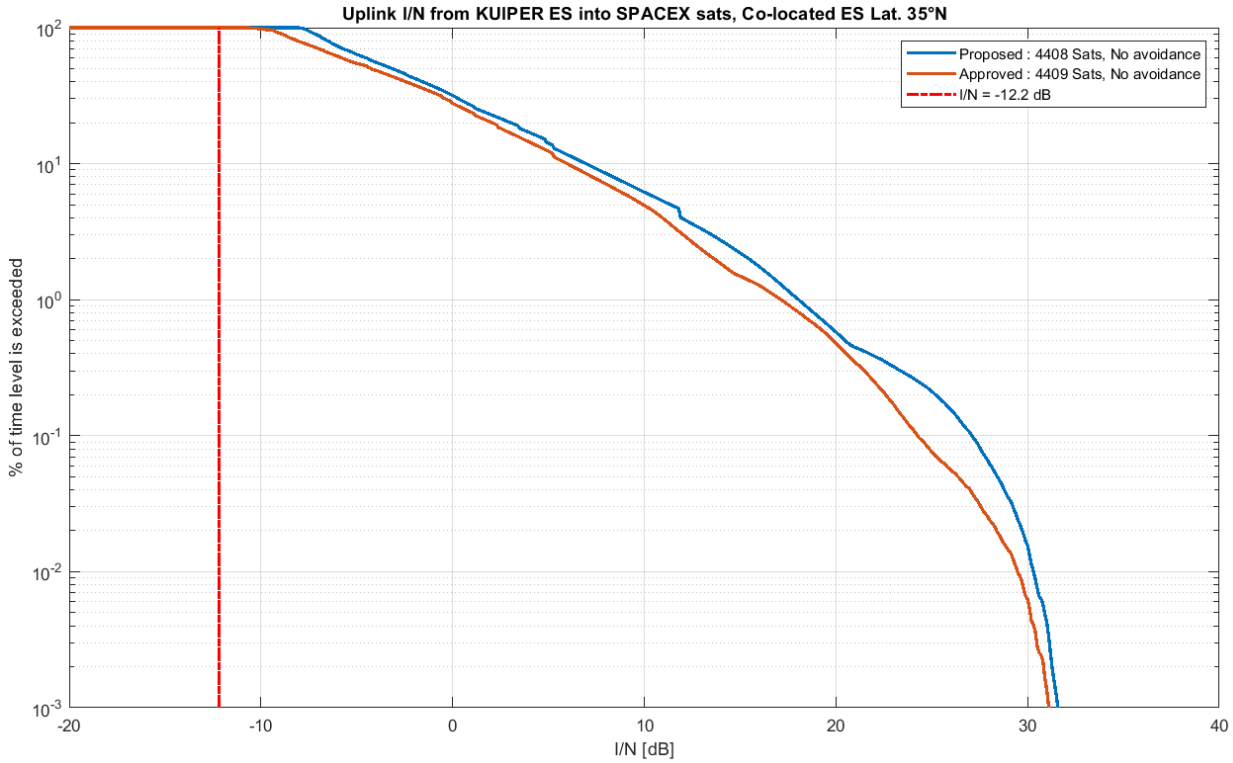

Figure III-A—Uplink Interference from Amazon to SpaceX

These results demonstrate that the proposed SpaceX modification will have a negligible effect on Amazon's interference to SpaceX uplinks, with only a modest increase at extremely high I/N levels, well above where spectrum splitting would have already been necessary.

However, these results also indicate that uplink interference from Amazon to SpaceX will trigger in-line events requiring band splitting or other measures 100% of the time, both before and after the proposed modification. Therefore, as with Kepler, any potential increase in interference from SpaceX to Amazon downlinks is entirely theoretical. In each case, an Amazon earth station will experience an in-line event with a SpaceX satellite due to its interference to SpaceX uplinks

long before it would experience any material interference to the Amazon downlink. Thus, the proposed modification has no material effect on the frequency or duration of spectrum splitting with respect to Amazon downlinks.

IV. O3b

O3b's filing raised concerns that the lower-altitude operations proposed in the modification would increase the probability of in-line events between SpaceX and O3b's equatorial satellites. However, O3b's analysis appears not to have accounted for the 18 degree GSO avoidance angle observed by the SpaceX system which will continue to prevent these in-line events.

Figures IV-A and IV-B below depict the results of SpaceX's simulations accounting for this avoidance angle. Possible SpaceX beam positions are illustrated by the areas either bounded by the solid black line, or on the far side of the topmost black line from the GSO arc, which is marked in red. The simulations assumed earth stations at 30 and 40 degrees latitude, the latitudes bounding the area of concern described in O3b's filing.

These results illustrate that the 18-degree GSO avoidance angle will preclude virtually any connection between a SpaceX earth station at these latitudes and SpaceX satellites that could have resulted in an in-line geometry with an equatorial O3b satellite. As depicted in Figure IV-A, such a link is only theoretically possible in an extremely small region that will likely allow too brief a connection to be practically used. Moreover, our analysis identified such a region only at 30 degrees. This area becomes even smaller as latitudes increase and has virtually disappeared by 40 degrees latitude.

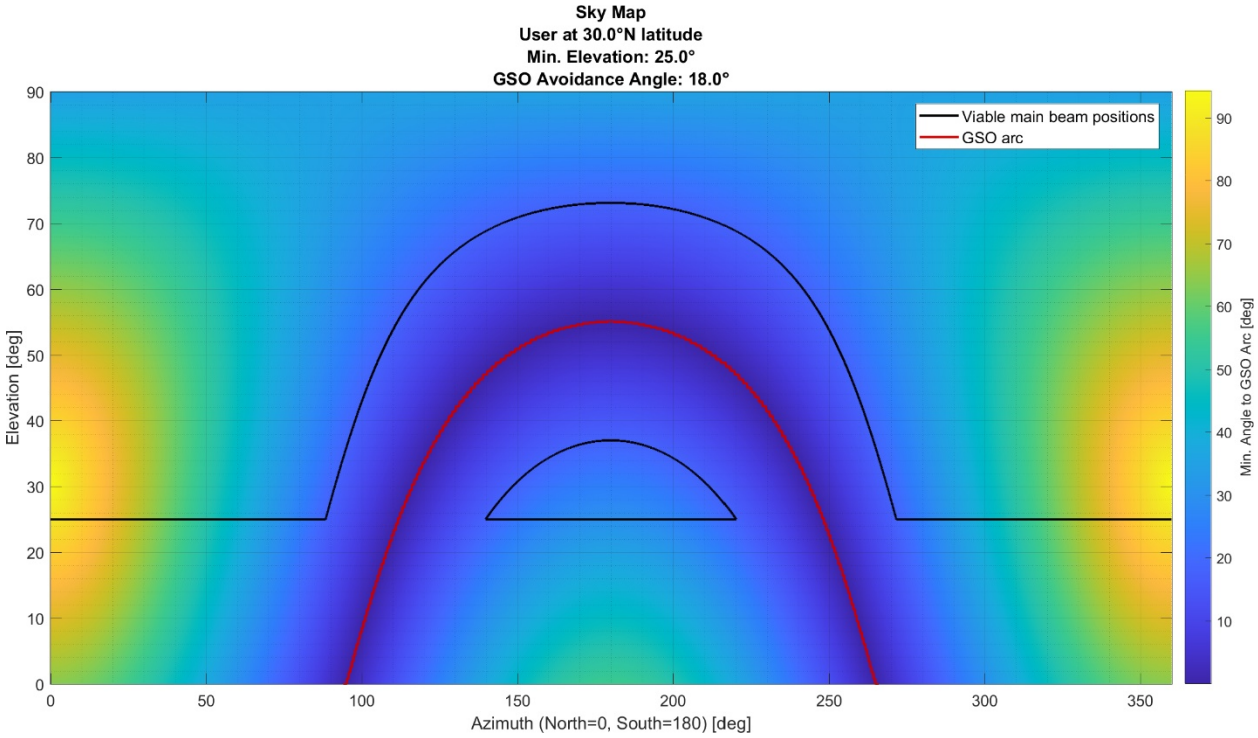

Figure IV-A—Viable SpaceX beam positions relative to GSO arc at 30 degrees latitude.

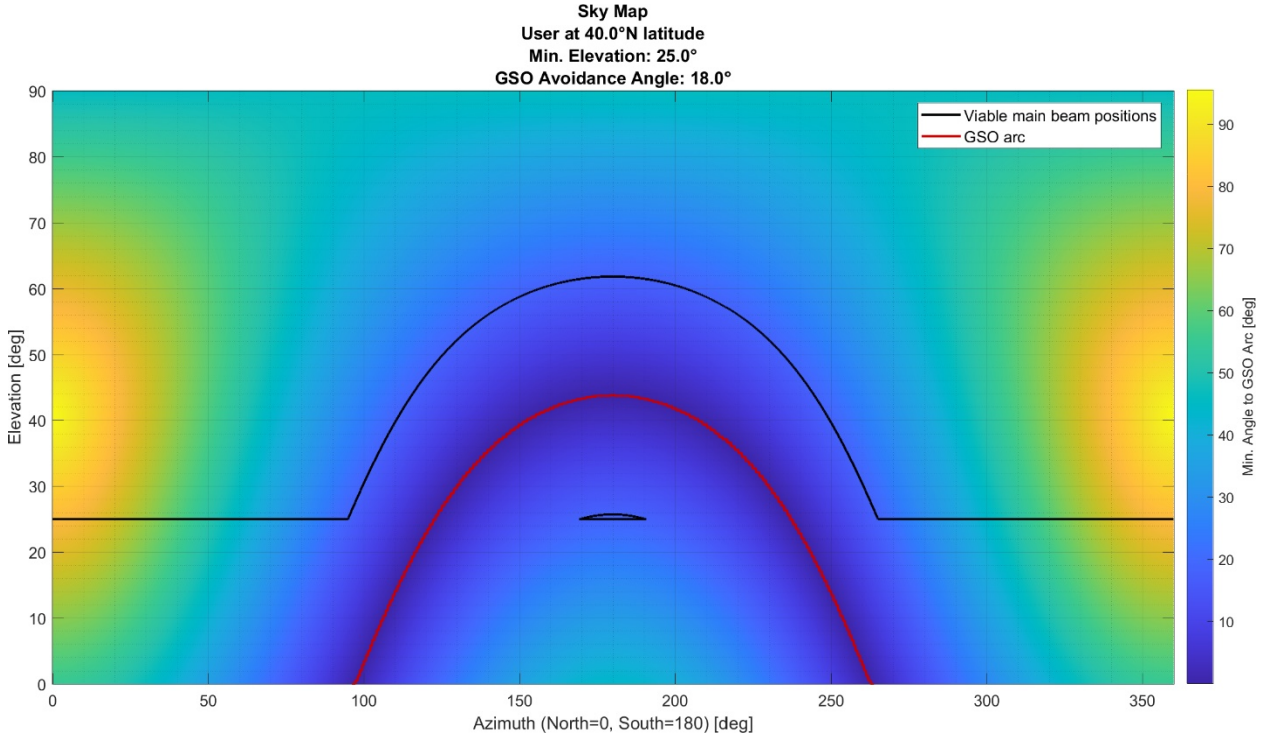

Figure IV-B— Viable SpaceX beam positions relative to GSO arc at 40 degrees latitude.

In addition to these results, SpaceX evaluated the prevalence of uplink interference from O3b to SpaceX satellites to determine the baseline frequency of in-line events. The results of these simulations are provided in Figure IV-C below.

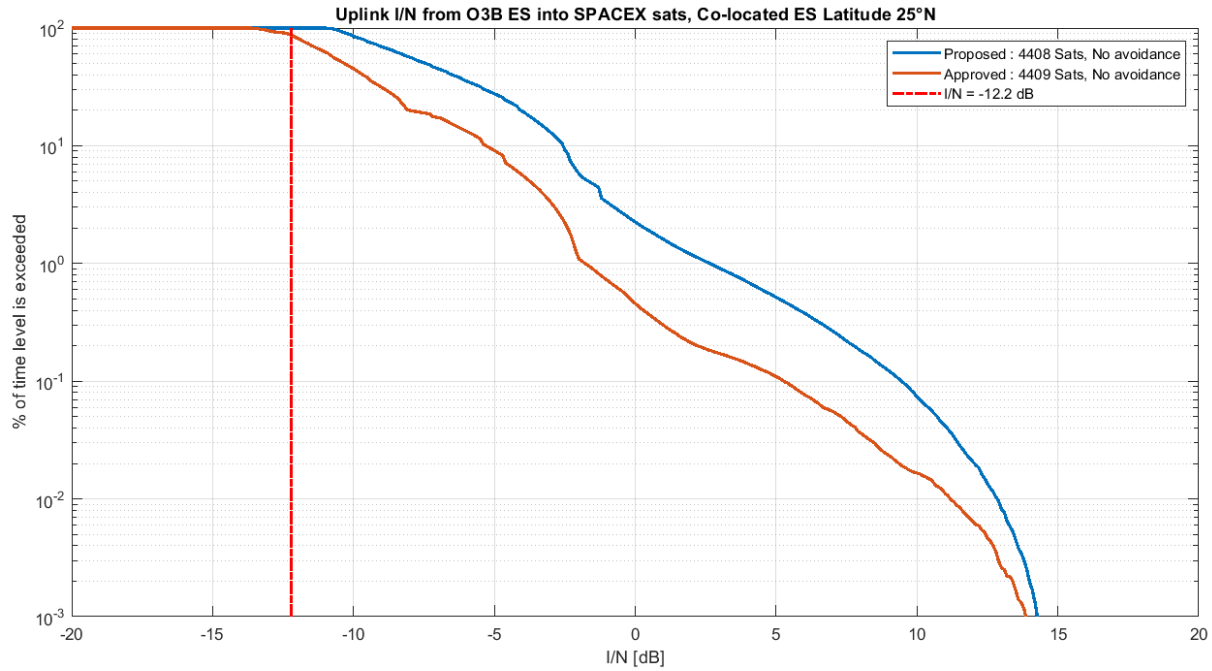

Figure IV-C—Uplink Interference from O3b to SpaceX

These results indicate that O3b's interference to SpaceX uplinks as currently authorized will trigger in-line events requiring spectrum splitting or other measures 88% of the time. Thus, as with Amazon and Kepler, any theoretical increase in interference caused by SpaceX's proposed modification is immaterial. O3b's interference to SpaceX, both with and without the proposed modification, would already have triggered an in-line event well before any theoretical interference by SpaceX to O3b would actually affect the O3b system by increasing the frequency or duration of spectrum splitting in the absence of coordination.

ENGINEERING CERTIFICATION

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

/s/ *Mihai Albulet*

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

July 27, 2020
Date

CERTIFICATE OF SERVICE

I hereby certify that, on this 27th day of July, 2020, a copy of the foregoing pleading was served via First Class mail upon:

Julie N. Zoller
Andrew Keisner
Mariah Dodson Shuman
Kuiper Systems LLC
410 Terry Avenue N
Seattle, WA 98109

Nickolas G. Spina
Kepler Communications, Inc.
196 Spadina Avenue
Suite 400
Toronto, ON Canada M5T2C2

Ruth Pritchard-Kelly
WorldVu Satellites Limited
1785 Greensboro Station Place, Tower 3
McLean, VA 22102

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

Suzanne Malloy
Petra A. Vorwig
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

John P. Janka
Amy R. Mehlman
Viasat, Inc.
901 K Street, N.W., Suite 400
Washington, DC 20001

Christopher Murphy
Viasat, Inc.
6155 El Camino Real
Carlsbad, CA 92009

Vann Bentley
Computer and Communications Industry Association
25 Massachusetts Avenue, N.W.
Suite 300C
Washington, DC 20001

Angie Kronenberg
INCOMPAS
1100 G Street, N.W.,
Suite 800
Washington, DC 20005

Jessica B. Lyons
Michael P. Goggin
Gary L. Phillips
David L. Lawson
AT&T Services, Inc.
1120 20th Street N.W., Suite 1000
Washington, DC 20036

Ananda Martin
Spire Global, Inc.
8000 Towers Crescent Drive
Suite 1225
Vienna, VA 22182

Jeffrey Blum
DISH Network L.L.C.
1110 Vermont Avenue, N.W.
Suite 450
Washington DC 20005

Charity Weeden
Astroscale U.S. Inc.
1401 Lawrence Street
Suite 1600
Denver, CO 80202

Henry Goldberg
Joseph A. Godles
Goldberg, Godles, Wiener & Wright LLP
1025 Connecticut Avenue, N.W.
Suite 1000
Washington, DC 20036

/s/ *Hailey Stewart*
Hailey Stewart