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

REPLY OF VIASAT, INC. IN SUPPORT OF ITS PETITION TO DENY OR DEFER

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SUMMARY

This Reply of Viasat focuses on (i) the issues and analyses in its Petition to Deny or Defer that SpaceX simply ignored in its Opposition, (ii) collision risk probabilities regarding failed (and failing) Starlink satellites that demonstrably affect space safety, and (iii) SpaceX's attempt to deflect attention from that critical collision risk issue. This Reply also addresses SpaceX's failure to provide all relevant information, the risk of harmful interference presented by the modification application, and certain unsubstantiated assertions about public interest matters.

Notably, SpaceX does not respond to the evidence of its satellite failure rates and how they materially increase the collision risk of the Starlink system, including the obvious point that Starlink satellites that cannot reliably maneuver cannot avoid the types of collisions that produce large amounts of orbital debris that can take many decades to re-enter the atmosphere.

SpaceX ignores Viasat's showings (based on SpaceX's own data) that its experiential failure rate:

- Alters the collision risk analysis underlying its prior grants of authority.
- Materially varies from SpaceX's prior assurances to the Commission about the reliability of its satellites.
- Is getting *worse* over time, and not better.

Nor does SpaceX contest that:

- SpaceX intentionally designed the Starlink satellites with only those safety mechanisms that were "easy" to implement—in explicit contrast with reliability methods, processes, and forms of redundancy applied to other SpaceX programs (*e.g.,* Cargo Dragon) that SpaceX touts as a bellwether of quality.
- SpaceX uses this approach because it intends to launch so many (unreliable) satellites that individual failures have, from SpaceX's own perspective, tolerable (*i.e.,* immaterial) consequences on system functionality.
- SpaceX understands that other methods, processes, and forms of redundancy that could improve reliability exist, but has simply decided not to use them.

- SpaceX's design practice directly conflicts with the Commission's stated objective of avoiding the "tragedy of the commons" that would result from individual operators neglecting space safety in order to maximize their own short-term financial gains.

Moreover, SpaceX's story keeps changing. In fact, it is impossible for the Commission or interested parties to assess fully the impact of SpaceX's modification application when SpaceX (i) keeps changing the factual and analytical bases for its positions, (ii) relies upon best-case scenarios that materially misrepresent collision risk, and (iii) refuses to disclose its underlying assumptions to allow others to validate *anything SpaceX has asserted—whether as to space safety or as to RF interference*. This pattern continues in SpaceX's Opposition.

A theme running through the SpaceX Opposition is that its failure rates do not matter because Starlink satellites will operate at altitudes such that "any failed satellites *and orbital debris* will de-orbit rapidly." Science does not support this claim. In fact, SpaceX's focus on the passive deorbit time of its *intact satellites* ignores the long-term effects of the *orbital debris* produced by even a single collision involving one of its failed satellites and another space object. The orbital debris cloud from such a collision would pollute a wide range of orbital altitudes, and take much, much longer to passively deorbit. *In fact, it would take decades, or even more than a century, for the effects of those collisions to clear out of the LEO orbits used by a wide range of other satellite systems.*

This is but one example of the myriad risks presented by SpaceX's admitted "system-level" fault tolerance that relies on launching more satellites to address its failures. As Viasat previously explained, this approach effectively results in polluting space, and produces a negative externality that adversely affects others—a "tragedy of the commons" that Commission policy seeks to avoid.

Given (i) the significant failure rates that SpaceX has already experienced, and (ii) that even a single failed SpaceX satellite involved in a collision could produce many hundreds of orbital debris objects with orbital lifetimes of up to 100 (or even more) years:

- The Commission should closely examine the significant issues presented by SpaceX's approach to the commercialization of space and require SpaceX to address on the record the nature and root causes of the Starlink failures.
- The Commission should not accept SpaceX's vague assurances of "iterative improvements" as a solution to SpaceX's failure to honor its commitment to design and construct highly-reliable satellites.
- The Commission should expressly address the large LEO constellation reliability issue that both it and NASA recognized years ago, and provide guidance on what it considers to be a sufficiently-high level of satellite reliability.

Indeed, unless the Commission does so, a logical conclusion for SpaceX and the industry to draw would be that iterating to satellite designs that improve economics but degrade reliability is acceptable, and that operators can rely entirely on the eventual passive deorbit from LEO of both failed satellites and the new orbital debris they generate when they collide.

To assist in resolving these critical collision risk issues, Viasat urges the Commission to require that SpaceX, on the record: (i) fully address the unresolved questions about its satellite failures; (ii) make regular periodic (*e.g.*, weekly) disclosures regarding the status of its fleet; and (iii) provide updated predictions of the reliability of its remaining in-orbit fleet based on root cause analyses and all failures to date.

SpaceX has not sufficiently addressed Viasat's showings on the potential for SpaceX's modified system to substantially increase interference. SpaceX tacitly admits that its own analysis demonstrated that its modification would increase interference to other NGSO systems, and also makes claims that are flatly contradicted by technical information underlying that modification application. Moreover, SpaceX fails to address concerns about its certification to protect GSO networks from interference, and how it is utilizing its Norwegian ITU filing.

Consistent with its precedent, the Commission should examine these issues fully and consider SpaceX's modification application in the March 2020 Processing Round.

Finally, SpaceX's claim that authorizing it to operate at ~550 km somehow *ensures* the provision of service that far surpasses the "Commission's definition of a low-latency system" is both *unsupported and unsupportable*. Free-space propagation is but a small element of the overall latency to be expected on a LEO broadband system, particularly one like SpaceX's that uses on-board processing. There is no basis to conclude that SpaceX can achieve latency well below 100 ms for 95% of the time in the busiest hour.

At bottom, SpaceX's modification application presents the Commission with a choice that goes to the heart of its policies on space safety and large LEO constellations:

- Require that SpaceX fulfill the commitment in its initial Starlink application—design and manufacture satellites with a sufficiently-high high level of reliability that they can be maneuvered to avoid debris-generating collisions over their 5-year design life; *or*
- Allow SpaceX to continue its current course, and signal to the entire industry (and the world) that operators may launch large LEO constellations without ensuring that their satellites can be maneuvered reliably, on the hope that failed and non-maneuverable satellites will deorbit and enter the Earth's atmosphere before they cause collisions.

The right policy choice should be apparent. Many different LEO systems need to share outer space, and unreliable satellites create collision risks that (i) imperil the orbits they share (as well as orbits above and below) and (ii) increase the likelihood of a Kessler syndrome—"a space-asset destructive chain reaction" that would put a tragic end to the New Space Age for well beyond our lifetime. If the Commission provides clear guidance about the importance of satellite reliability and space safety, the market will positively respond by fostering the mass-production of innovative, low-cost, and reliable satellites and satellite components.

The Commission must address this precedent-setting issue before many hundreds (or even thousands) more LEO satellites are launched to form large constellations. Waiting until the resolution of the pending *Mitigation of Orbital Debris in the New Space Age* proceeding would be too late.

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REPLY OF VIASAT, INC. IN SUPPORT OF ITS PETITION TO DENY OR DEFER

Viasat, Inc. ("Viasat") submits this Reply in Support of its Petition to Deny or Defer[1] the above-referenced modification application of Space Exploration Holdings, LLC ("SpaceX"). SpaceX submitted a consolidated Opposition that conflates the arguments and analyses presented by Viasat and numerous other petitioners and commenters. This Reply focuses on SpaceX's response to the myriad of concerns that *Viasat* raised, including (i) the issues and analyses that SpaceX ignored, (ii) collision probabilities regarding failed (and failing) Starlink satellites, and (iii) SpaceX's attempt to deflect attention from that collision risk. This Reply also addresses SpaceX's failure to provide all relevant information, the risk of harmful interference presented by the modification application, and certain unsubstantiated assertions about public interest matters.

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[1] Petition to Deny or Defer of Viasat, Inc., IBFS File No. SAT-MOD-20200417-00037 (filed July 13, 2020) ("*Viasat Petition*").

I. SPACEX'S FAILURE RATES AND PROPOSED SYSTEM MODIFICATION SUBSTANTIALLY INCREASE THE RISK OF COLLISIONS

A. SpaceX Does Not Respond to Key Showings Regarding its Failure Rates and the Associated Collision Risks

SpaceX has not responded to the evidence of its satellite failure rates and how they materially increase the collision risk presented by its modified system design. As Viasat's Petition explains:

- The nature of the modified Starlink constellation design (densified orbits overlapping many other LEO systems), coupled with the experiential failures of Starlink satellites (loss or degradation of maneuverability at far above the level expected), warrants a fresh assessment of the risk to safe space.[2]

- The proposed modification would increase the probability of collision risks within the SpaceX constellation, with other constellations, and with orbital debris in general.[3]

- SpaceX satellites that cannot reliably maneuver cannot avoid collisions—events that produce large amounts of additional, passive orbital debris that increase collision risk,[4] and can take decades, or more than a century, to re-enter the atmosphere.

- SpaceX's experiential failure rates:
    - Alter the collision risk analysis underlying its prior grant—including the absolute level of failures and the associated implications for collision probabilities.[5]
    - Represent new information, such that no further assumptions about collision risk are warranted simply because Starlink satellites include maneuverability capabilities.[6]
    - Raise material questions about the reliability of the satellites that SpaceX is launching.[7]

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2 *See id.* at 6-8. In light of the serious concerns and substantive analysis in Viasat's Petition regarding collision risk and safe space, SpaceX's claim that no party has "raise[d] genuine issues of space safety" regarding Starlink is absurd. *See* Consolidated Opposition to Petitions and Response to Comments of Space Explorations Holdings, LLC, IBFS File No. SAT-MOD-20200417-00037, at ii (filed July 27, 2020) ("*SpaceX Opposition*").

3 *See Viasat Petition*, at 9-11.

4 *See id.* at 18-19.

5 *See id.* at 22-25.

6 *See id.* at 19.

7 *See id.* at 25-26.

- Materially vary from SpaceX's prior assurances about the reliability of its satellites in its initial applications.[8]
- Lead to an expectation of hundreds, if not thousands, of defunct SpaceX satellites in orbit—uncontrollable objects presenting collision risks.[9]

- SpaceX's orbital debris analysis does not assess all relevant risks.[10]

- Avoiding space pollution in the first instance by deploying satellites that have a designed and proven high level of reliability is the best way to mitigate the risk of collisions that (i) fragment satellites, (ii) create large debris clouds, (iii) threaten the safe and reliable operation of other satellites, and (iv) increase the likelihood of a Kessler syndrome.[11]

Notably, SpaceX does not contest, and simply ignores, numerous evidence-backed showings in Viasat's Petition, including:

- Viasat's assessment of the failure rates of Starlink maneuverability capabilities, based on SpaceX's own data.[12]

- The observation that SpaceX's failure rate is getting *worse* over time, and not better.[13]

- SpaceX has not met its commitments to the Commission in its prior Starlink applications.[14]

- SpaceX intentionally designed the Starlink satellites with only those safety mechanisms that were "easy" to implement—in explicit contrast with reliability methods, processes, and forms of redundancy applied to other SpaceX programs (*e.g.,* Cargo Dragon) that SpaceX touts as a bellwether of quality.[15]

- SpaceX uses this approach because it intends to launch so many (unreliable) satellites that individual failures have, from SpaceX's own perspective, tolerable (*i.e.,* immaterial) consequences on system functionality.[16]

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8 *See id.* at 26-37.

9 *See id.* at 15-16.

10 *See id.* at 11-18.

11 *See id.* at 3-4, 7, 17, 36.

12 *See id.* at 21-22.

13 *See id.* at 21-22, 26-29.

14 *See id.* at 29-32.

15 *See id.* at 31.

16 *See id.* at 30-31.

- Both NASA and the Commission recognized the importance of high levels of design and fabrication reliability for "*large constellations such as the one proposed by SpaceX,*" considering *"the unprecedented number of satellites proposed by SpaceX."*[17]

- SpaceX understands there are other methods, processes, and forms of redundancy that could improve reliability, but has simply decided not to use them.[18]

- SpaceX's design practice directly conflicts with the Commission's stated objective of avoiding the "tragedy of the commons" that would result from individual operators neglecting space safety in order to maximize their own short-term financial gains,[19] even when they are capable of designing and manufacturing sufficiently-reliable satellites and provide assurances they will do so in applications to the Commission.

Moreover, and as discussed below, were the Commission to sanction SpaceX's approach to commercializing space (expressly or implicitly), it effectively would signal that SpaceX (and the industry as a whole) may prioritize *virtually any low level* of satellite reliability for the sake of commercial expediency, and may make iterative changes to satellite designs to achieve that priority goal—all at the expense of space safety. Encouraging the deployment of satellites with low levels of reliability (and creating the associated risks of collisions and resulting debris clouds) would increase the likelihood of a Kessler syndrome—"a space-asset destructive chain reaction"[20] that would put a tragic end to the New Space Age for well beyond our lifetime.

B. Material Unresolved Issues Remain About Collision Risk and Starlink Satellites

Viasat's Petition provided a table comparing (i) the DAS 3.1.0 calculated values for the probability of large object collision that SpaceX provided in its July 7 letter with (ii) the values

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17 *See id.* at 2 (citations omitted) (emphasis supplied).

18 *See id.* at 31.

19 *See id.* at 35-37.

20 Thompson, R., "A Space Debris Primer," in *Crosslink* (Aerospace Corporation, Fall 2015), p.26.

Viasat computed.[21] Viasat emphasized that the values it computed were *at least* a factor of two larger than those provided by SpaceX, and that SpaceX had not provided all of the inputs underlying its analysis.[22] SpaceX did not directly address that discrepancy or omission in its Opposition. Instead, SpaceX provided a new satellite area-to-mass ratio of 0.0974 m^2/kg in a footnote,[23] assumed all failures occur in 2026 (as opposed to using the 2020 start year that Viasat used based on the *actual* current deployment of the Starlink fleet[24]), and also used a new definition of its own making.

For this Reply, Viasat used DAS 3.1.0 to recompute the values in its Petition and used the newly-stated SpaceX area-to-mass ratio and the latest solar flux tables provided by NASA. Table 1 shows the results. Notably, Viasat's revised DAS 3.1.0 values exceed, *by a factor of about 3,* the SpaceX-calculated values for its *self-defined* "Risk of Collision with Large Debris."

Altitude (km)	SpaceX Calculation	Revised Viasat DAS 3.1.0 Calculation
540	0.000069	0.000264
560	0.000139	0.000460
570	0.000138	0.000393

Table 1: Comparison of Viasat and SpaceX Large Object Collision Risk Calculations

The discrepancies between Viasat's calculations and SpaceX's calculations shown in Table 1 above easily are reconciled. When comparing pre- and post-modification "Risk of Collision with Large Debris," *SpaceX has made up its own metric, rather than use DAS 3.1.0's*

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21 *See Viasat Petition*, at 12, Table 1.

22 *See id.* at 12.

23 *See SpaceX Opposition*, at 18, n.55. Contrary to what SpaceX claims, Viasat did not use an "outdated area-to-mass ratio" instead of "the actual value." Rather, Viasat used the very same value that SpaceX certified in the modification application was unchanged. *See infra* at 7-8.

24 *See Viasat Petition,* at 12 & n.35.

Requirement 4.5-1 Probability of Collision with Large Object assessment.[25] Specifically, SpaceX computes the "risk of full area of one non-maneuverable satellite being impacted by an object > 10 cm, averaged over constellation *assuming 2026 failure*."[26] Had SpaceX instead used the standard DAS 3.1.0 assessment for its proposed modified system, and a start date of 2020, it would have been apparent that the constellation average, per satellite, probability of collision with a large object (> 10 cm) is 0.000316,[27] or *four times* the value SpaceX labels as "risk of collision with large debris" in its Table 1.

Similarly concerning is the calculation SpaceX provides in its Opposition for the risk of collision with large debris objects for a single satellite in its currently-authorized system at altitudes of 550-1,325 km. SpaceX calculates this single-satellite risk as 0.0101, or *one-in-one-hundred*.[28] As noted above, SpaceX defines this value as the "risk of full area of one non-maneuverable satellite being impacted by an object > 10 cm, averaged over constellation assuming 2026 failure."[29] In its previous filings,[30] SpaceX assured the Commission that its system would comply with the *one-in-one-thousand* (or 0.001) single-satellite probability specified in NASA Standard 8719.14 Requirement 4.5-1, specifically:

> For each spacecraft and launch vehicle orbital stage in or passing through LEO, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft

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25 *See SpaceX Opposition*, at 4, Table 1.

26 *Id.* at 4, n.6 (emphasis supplied).

27 Weighted average of all proposed shells, including 550 km.

28 *SpaceX Opposition*, at 4, Table 1.

29 *Id.* at 4, n.6.

30 *See* Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20161115-00118 (filed Nov. 15, 2016), Attachment A, at 67; Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20170726-00110 (filed July 26, 2017), Attachment A, at 42; Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20181108-00083 (filed Nov. 8, 2018), Attachment A, at 48. In each case, SpaceX provided a graphic showing compliance with NS 8719.14 Requirement 4.5-1.

and orbital stage, *the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001*.[31]

Now SpaceX appears to say that under its currently-authorized system, risk of a large object collision is *over ten times lar*ger than previously reported. This is yet another in a series of SpaceX assurances in its applications that have not matched the reality of system implementation. As detailed in Viasat's Petition, and in light of this history, there is no basis for making licensing decisions on the types of unsubstantiated assertions made in the modification application. Moreover, compelling reasons exist to examine the prior assurances on which SpaceX's existing authority is based.[32]

As to further discrepancies in SpaceX filings before the Commission, the collision risk and passive orbit decay value in Table 1 of SpaceX's Opposition are based on a sudden and unexplained change to the technical information otherwise underlying its modification application. SpaceX's modification application is based on the following certification: "SpaceX certifies that all other information provided in its Ku/Ka-band applications, as modified, remains unchanged."[33] That certification specifically references both its 2017 application,[34] and Section 25.117(c), which provides: "Only those items that change need to be specified, provided that the applicant certifies that the remaining information has not changed."[35] However, as noted above, in its Opposition, SpaceX suddenly changed a key input parameter for its orbital debris analysis.

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[31] NASA Technical Standard, "Process for Limiting Orbital Debris," NASA-STD-8719.14B (Apr. 25, 2019), at 36 (emphasis supplied).

[32] *Viasat Petition,* at 26-37.

[33] Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20200417-00037 (filed Apr. 17, 2020) ("Application"), Narrative, at 1 (footnote omitted).

[34] *See id.* at 1, n.1 (citing Space Exploration Holdings, LLC, AIBFS File No. SAT-LOA-20170726-00110 (filed July 26, 2017)).

[35] 47 C.F.R. § 25.117(c).

Viasat's analysis in its Petition was based on the area-to-mass ratio that SpaceX provided in that very same 2017 application[36]—a value that SpaceX did not identify as changing in the modification application.

Needless to say, it is impossible for the Commission or interested parties to assess fully the impact of SpaceX's modification application when (i) SpaceX keeps moving the proverbial football, and (ii) SpaceX does not timely disclose the underlying assumptions in its analyses that would allow the Commission or third parties to validate *anything SpaceX has asserted—whether as to space safety or as to RF interference*.[37]

In this respect, neither the Commission nor Viasat is able to evaluate SpaceX's claimed risk of collision with small debris objects[38] because SpaceX failed to provide the input parameters required for the Commission and other interested parties to run the DAS 3.1.0 Requirement 4.5-2 Probability of Damage from Small Debris assessment. The Commission should require SpaceX to make available these input parameters and all other input parameters underlying SpaceX's assertions regarding space safety and RF interference.

Although SpaceX quibbles with whether other operators have provided adequate collision risk analyses,[39] as evidenced by the "creative" new approach in its Opposition, and SpaceX's prior deficient collision risk showings in this proceeding,[40] it should be clear that SpaceX is the one obscuring the facts.

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36 As Viasat explained: "For its calculation, Viasat used the 0.0733 m2/kg area to mass ratio value that SpaceX provided in an earlier application[.]" *Viasat Petition,* at 12 (citing Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20170726-00110, Attachment A, at 30 (filed July 26, 2017)).

37 *See e.g.*, *Viasat Petition*, at 12.

38 *See SpaceX Opposition*, at 4-5, Tables 1 & 2.

39 *See SpaceX Opposition*, at 4.

40 *See Viasat Petition*, at 11-12.

C. SpaceX Materially Understates the Time for Failed SpaceX Satellites, and the Orbital Debris They Create, to Re-enter the Atmosphere

A theme running through the SpaceX Opposition is that its failure rates do not matter because (i) Starlink satellites will operate at an altitude such that "the effects of atmospheric drag ensure that *orbital debris* and any failed satellites de-orbit rapidly,"[41] and (ii) the "higher atmospheric drag inherent at [540-570 km altitudes] ensures that *any orbital debris* will undergo rapid atmospheric re-entry and demise."[42] This is a reference to what SpaceX otherwise describes as "passive decay time." As detailed below, science does not support these claims, and Viasat does not accept SpaceX's mischaracterization of the record or the relevant law.[43] Moreover, as discussed below, SpaceX's focus on the passive decay time of its satellites is a red herring. The collision risk probability created by failed Starlink satellites is the real issue, because the large amounts of *new orbital debris resulting from collisions will take much longer to passively decay than an intact Starlink satellite*.

In its Petition,[44] Viasat noted Figure A.11-1 (Demise Time at Various Altitudes) in the modification application, which clearly shows that, at the highest proposed nominal altitude of 570 km under the 11-year solar cycle, and under *current* atmospheric conditions, passive decay time is about 5 years (slightly less for a failure involving the propulsion system, slightly more for a failure of the attitude control system that sends the satellite tumbling).[45]

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41 *SpaceX Opposition*, at i (emphasis supplied).

42 *Id.* at 2-3 (emphasis supplied).

43 *See id.* at ii ("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.").

44 *Viasat Petition,* at 25.

45 Application, Attachment A, at 19-20, Figure A.11-1 & n.26.

SpaceX's Opposition ignores its own prior statements about current atmospheric conditions and instead pivots to a best-case analysis considering expected conditions in six years (2026), which materially misrepresents the collision risk associated with its failed satellites. Moreover, SpaceX's Opposition ignores how long the orbital debris clouds resulting from collisions with its failed satellites would continue to pollute a wide range of orbital altitudes.

1. SpaceX misrepresents the passive decay times for failed Starlink satellites

Table 1 of SpaceX's Opposition compares the passive decay time of its satellites assuming a loss of maneuverability after a failure, on a pre- and post-modification basis, based on expected atmospheric conditions in 2026.

As an initial matter, and as noted above, SpaceX's Table 1 is based on an unexplained change to the technical information otherwise underlying its modification application; namely a change in the physical characteristics that SpaceX otherwise provided in its 2017 application and certified as remaining accurate in its April 2020 modification application.[46] As a result, the collision risk analysis in Viasat's Petition was based on the area-to-mass ratio that SpaceX provided in that very same 2017 application[47]—a value that SpaceX did not change in the modification application.

Even accepting this new value, SpaceX grossly misrepresents the collision risks associated with satellites with lost or degraded maneuverability by calculating the expected deorbit for its satellites during the most favorable single year in the current solar cycle (2026), when the Sun is predicted to be most active and have the greatest effect on the atmosphere, and

46 Application, Narrative, at 1 & n.1 (citing SpaceX Exploration Holdings, LLC, IBFS File No. SAT-LOA-20170726-00110 (filed July 26, 2017)).

47 As Viasat explained: "For its calculation, Viasat used the 0.0733 m2/kg area to mass ratio value that SpaceX provided in an earlier application[.]" *Viasat Petition,* at 12 (citing Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20170726-00110, Attachment A, at 30 (filed July 26, 2017)).

thus on passive deorbit of a satellite.[48] To state the obvious, all 10,000 of SpaceX's satellites launched over the 2019-2034 license term will not deorbit in 2026. SpaceX has not evaluated the varying passive decay times resulting from the 11-year solar cycle, nor has it provided a representative analysis for the ~10,000 satellites it expects to launch over its 15-year license term.

If calculated in 2020 (and for 2031 when similar solar minimum conditions can be expected) the decay time ranges from 3.2 to 3.9 years, depending on orbital shell, with an average of 3.5 years. If SpaceX's proposed ±30 km altitude tolerance is included, the top of the range increases to 4.6 years for a 2020 failure. If a satellite is tumbling, it increases the top of the range to 6.1 years. SpaceX has chosen to provide only the most optimistic value possible, instead of a range of values that would be useful to the Commission in evaluating the collision risk presented by the modification application.

2. SpaceX does not address the passive decay times for debris created by collisions of Starlink satellites

SpaceX also has ignored the long-term effects of even a single collision involving one of its failed satellites and another space object. As Viasat explained in its Petition, such a collision could create a large debris cloud extending hundreds of kilometers, polluting other orbits, endangering other satellites, and disrupting vital communications services, both near- and long-term.[49] These are material risks that the Commission itself has recognized in commencing its

48 A nearly periodic 11-year change occurs in the Sun's activity, which has a corresponding effect on the density of the Earth's atmosphere, which, in turn, affects passive deorbit time for a given satellite design. That is, when the Sun is most active, the "drag" of the atmosphere is greatest and passive deorbit times decrease. When the Sun is least active, the drag is the lowest, and passive deorbit times increase. SpaceX presented its results based on one year over the next 11 when the Sun is expected to be most active. All 10,000 of its satellites obviously will not fail and deorbit in the same year.

49 *See Viasat Petition,* at iii, 3, 7, 17, 36.

proceeding on the risks associated with large LEO constellations, and entitled *Mitigation of Orbital Debris in the New Space Age.*[50]

By way of example, if only two of the 10,000 satellites SpaceX expects to deploy over 15 years were to collide, we could expect a debris cloud similar to that of the 2009 collision between Iridium 33 and Cosmos 2251. The following figure shows that debris cloud as of a few days ago, 11 years after the event. There are still 1,380 trackable debris objects (typically > 10 cm) in orbit with apogees up to 1,656 km—orbital debris that have spread over 800 km above the orbits of the satellites involved in the original collision.

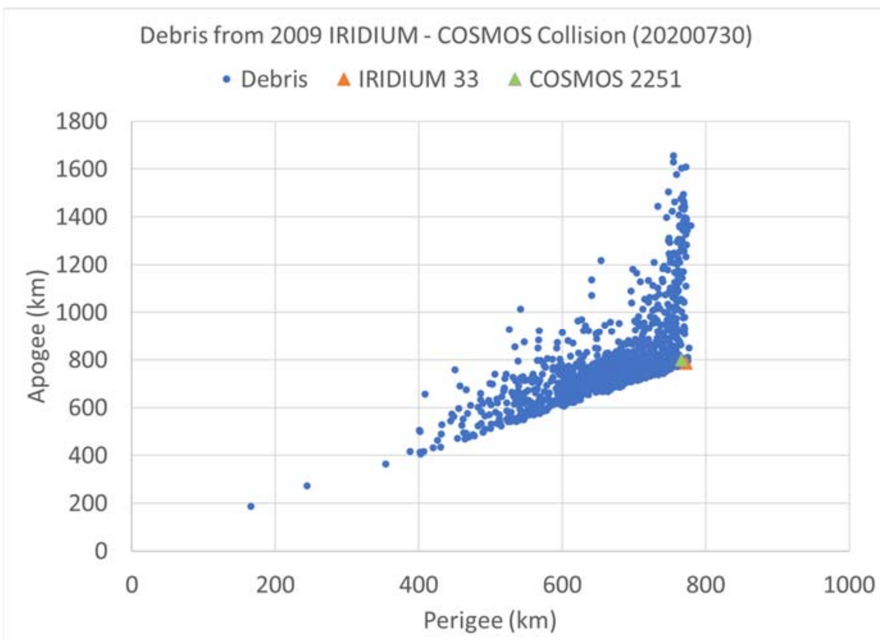

Figure 1: Debris Field 11 Years After Collision of Two LEO Satellites

While SpaceX has designed its satellites for a specific area-to-mass ratio that can be factored into predicted passive decay times, the size and area-to-mass ratios of debris objects

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50 *Mitigation of Orbital Debris in the New Space Age*, Notice of Proposed Rulemaking, 33 FCC Rcd 11352 (2018), at ¶ 89 (emphasis supplied).

resulting from collisions cannot be pre-determined with the same certainty. However, illustrative calculations can be made on currently-available data. A typical area-to-mass ratio for a debris object is 0.01 m^2/kg, and a 10 cm aluminum debris object would have a mass of about 1 kg. Such an object impacting a satellite (SpaceX's or another's) at a relative velocity of 10 km/s (a velocity not unusual for LEO objects) would have collision energy equivalent to 12 kg of TNT, sufficient to fragment that satellite and create new debris objects. Using debris with a 0.01 m^2/kg area-to-mass ratio and a collision at 550 km perigee (representative of the lower level of SpaceX's proposed orbit shells), the following table shows illustrative passive decay times for orbital debris existing at various apogees following collisions involving a SpaceX satellite in 2020 and in 2026.

Apogee (km)	2020	2026
550	13.7 years	9.6 years
650	17.8 years	17.8 years
750	28.6 years	26.7 years
850	42.9 years	41.7 years
950	59.9 years	55.2 years
1050	79.7 years	75.4 years
1150	96.5 years	96.3 years
1250	> 100 years	> 100 years
1350	> 100 years	> 100 years

Table 2: Passive Decay Times for Orbital Debris in Various LEO Orbits

The illustrative passive decay times for the debris resulting from collisions of failed SpaceX orbits speak for themselves. This is but one example of the myriad risks presented by SpaceX's admitted "system-level" fault tolerance that relies on launching more satellites to address failures, and deorbiting the disposable satellites. As Viasat previously explained, this approach effectively results in polluting space, and produces a negative externality that adversely affects others—a tragedy of the commons.[51]

Given (i) the significant failure rates that SpaceX has already experienced, and (ii) that even a single failed SpaceX satellite involved in a large object collision could produce hundreds of orbital debris objects with orbital lifetimes of up to 100 (or even more) years, three things should be apparent:

- The Commission should closely examine the significant issues presented by SpaceX's approach to the commercialization of space and require SpaceX to address on the record the nature and root causes of the Starlink failures;
- The Commission should not accept SpaceX's vague assurances of "iterative improvements" as a solution to SpaceX's failure to honor its commitment to design and construct satellites with high levels of reliability; and
- The Commission should address the large LEO constellation reliability issue that both it and NASA recognized needed to be addressed years ago,[52] and provide guidance on what it considers to be a sufficiently-high level of satellite reliability.

Indeed, unless the Commission does so, a logical conclusion for SpaceX and the industry to draw would be that iterating to satellite designs that improve economics but degrade reliability is acceptable, and that operators can rely entirely on the eventual passive decay from LEO orbit of failed satellites and the new orbital debris that they generate when they collide.

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51 *See Viasat Petition,* at 37. Contrary to SpaceX's claim that it has "strong incentives to deploy spacecraft that perform as designed throughout their entire operational lifetime," *SpaceX Opposition*, at 16-17, Viasat has explained—and SpaceX does not deny—that SpaceX has evidenced a "dispose and replace" approach to satellite deployment, and declining launch costs and economies of scale have *eliminated* SpaceX's incentives to achieve safe-space operations, *see Viasat Petition*, at 29-31, 35-37.

52 Letter from Anne E. Sweet, NASA, to Marlene H. Dortch, Secretary, FCC, IBFS File No. SAT-LOA-20161115-00118, at 1-2 (filed June 26, 2017) ("For large constellations such as the one proposed by SpaceX, NASA notes that the reliability of the design and fabrication of the spacecraft . . . [is] of particular interest from the perspective of keeping the orbital environment safe. . . . [A] design and fabrication reliability on the order of 0.999 or better per spacecraft may be prudent to mitigate the risk of malfunction in a 4,000+ spacecraft constellation."); *Space Exploration Holdings, LLC, Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System*, Memorandum Opinion, Order, and Authorization, 33 FCC Rcd 3391 (2018), at ¶ 15 ("*SpaceX Initial Authorization*") ("[W]e agree with NASA that the unprecedented number of satellites proposed by SpaceX and the other NGSO FSS systems in this processing round will necessitate a further assessment of the appropriate reliability standards of these spacecraft.") (citation omitted).

It bears emphasis that these risks to safe space discussed above affect all satellite operators—not just SpaceX. In addition to the LEO systems that would operate in the orbits affected by SpaceX's failures and the debris from resulting collisions, these risks affect any operator whose satellites would have to transit through the orbits affected by SpaceX to get to their own orbital altitudes, and then transit through them back again to enter the Earth's atmosphere during end-of-life disposal.

D. Material and Unexpected Starlink Satellite Failures Remain Unexplained

Viasat's Petition raises many material questions about the nature and causes of the Starlink failures. SpaceX has refused to assess the following types of questions that go to the heart of the collision risk presented by the proposed Starlink modification and that also may affect the RF interference environment:[53]

- Has SpaceX determined the root causes of its satellite failures?
- If the failures were the result of a design or software flaw, what steps has SpaceX taken to address that issue in subsequent satellite production or software updates?
- Did non-space-rated components cause SpaceX's failures, and if so, what expectation existed that those components would be reliable in space, and are those same components still being used?
- Is there redundancy designed into the system(s) that also failed?
- Does SpaceX have any analysis, accelerated life testing results, sample tests, or any other way to assess reliability other than in-orbit failures?
- How is the Starlink system designed to respond in circumstances that affect the ability to command collision avoidance maneuvers, such as when a satellite loses power, and when contact is lost with a satellite?
- Does an automatic initiation of disposal occur when communications with a satellite otherwise cease or become limited?
- Is there a possible failure mode under which the payload on the Starlink satellites continue to transmit to gateways or user terminals after a critical failure, and, if not what makes that occurrence impossible?
- How reliable is the command link connectivity with the Starlink satellites?

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53 *See Viasat Petition*, at 24-26, 31-32.

- To the extent the satellites are to be maneuvered autonomously, how reliable is the integrity of the database used and the security of the associated network?
- Why has SpaceX experienced failure rates 2x to 3x the level that it assured the Commission were "unlikely" and that its satellites would be "nowhere near"?
- What is the overall failure rate of its satellites, including those that failed at injection orbit? This is a relevant question because infant mortality (*i.e.*, early failure) is often a predictor of future failures.

Faced with a lack of further information from SpaceX, Viasat elaborates below on the issues presented by SpaceX's failure disclosures and provides a further analysis about Starlink failures.

1. SpaceX does not contest key assertions about Starlink failures

SpaceX's May 15, 2020 and June 23, 2020 reports to the Commission[54] are concerning because of (i) the level of disclosed failures relative to SpaceX's prior representations of how the Starlink system would function in its initial application, (ii) the increasing failure rate between those two reports, and (iii) the absolute level of failures and the associated implications for collision probabilities.[55] As Viasat noted in its Petition, if the Starlink satellites continue to fail at 1.9% per 5 months once above injection orbit, then the failure rate per satellite over its 5-year lifetime would be 22.8%,[56] and even this rate would be optimistic because it does not account for matters such as "wear out" failures that can be expected later in design life. The more Starlink satellites that fail before the end of their 5-year design life, the higher the likelihood that SpaceX will exceed the 10,000 satellites that it currently estimates launching over its 15-year license term.

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[54] Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Division, FCC IBFS File No. SAT-MOD-20200417-00037, at 4-5 (filed May 15, 2020) ("*May 15 Letter*"); Letter from William M. Wiltshire, Counsel to SpaceX, to Marlene H. Dortch, Secretary, FCC, at 1 (filed June 23, 2020) ("*2020 Annual Report*").

[55] *See Viasat Petition*, at 15-18, 22-25, 26-29.

[56] *Id.* at 15.

SpaceX does not contest Viasat's assessment of Starlink failure rates, that the failure rate is getting worse (not better), or that SpaceX intentionally designed its satellites with only the "easy" mechanisms to maintain control—in explicit contrast with reliability methods, processes, redundancy, etc., applied to other SpaceX programs (*e.g.*, Cargo Dragon). SpaceX does not contest the observation that in the case of Starlink, SpaceX is taking an approach that diverges from the high level of reliability it delivers to NASA—a different approach under which it intends to launch so many (unreliable) satellites that individual failures have, from SpaceX's own perspective, tolerable consequences on system functionality (*i.e.,* do not matter). It is clear that SpaceX understands there are other methods, processes, and redundancies that could improve reliability, but that it simply has decided not to employ them for Starlink.

Nor does SpaceX contest the assertion that its design practice is in direct conflict with the Commission's stated objective of avoiding the "tragedy of the commons" that would result from individual operators neglecting space safety in order to maximize their own short term financial gains.

Particularly in light of these considerations, including increased numbers of failures in the short time interval between SpaceX's two disclosures, the Commission should require that SpaceX, on the record: (i) address the questions above; (ii) make regular periodic (*e.g.*, weekly) disclosures regarding the status of its fleet; and (iii) provide updated predictions of the reliability of its remaining in-orbit fleet based on root cause analyses and all failures to date. Such disclosures should include the precise identification of each satellite (*e.g.*, NORAD catalog number), precise definition of the potential classifications of satellites still in orbit as well as the classification of each and the dates/reason for any changes in classification (*e.g.*, nominal, loss of maneuverability, degraded functional performance, "failed," etc.), along with the complete criteria used for each classification.

2. Independent analysis of the Starlink fleet suggests that failure rates are even higher than reported.

It is difficult for the Commission, or other interested parties, to assess the existing state of the SpaceX constellation without access to telemetry data. However, given the substantial negative impact on shared access to space of the extremely large number of satellites proposed for the Starlink constellation, and the precedent-setting nature of the current situation, Viasat and others are regularly analyzing satellite tracking data to form estimates. Viasat's approach to determining if a satellite orbit is decaying is by using a downward trend in the semi-major axis below the lower orbit tolerance. Viasat cannot determine why a specific orbital track would exhibit these characteristics and recognizes that it is possible that some of these satellites may still be capable of collision avoidance maneuvers. Regardless, Viasat believes these observations reinforce the need for greater disclosures by SpaceX—including the information recommended above. These observations, if correct, suggest that Starlink satellite reliability is deteriorating even further.

Using the Space-Track dataset from July 17, 2020, Viasat identified 16 apparent Starlink v1.0 satellite failures. The following histogram shows the distribution of failures with respect to days post-launch. Because more than one-half of the satellites in the dataset had been in orbit fewer than 120 days, Viasat does not know if the apparent predominance of early failures reflects infant mortality (*i.e.*, early failure), or is dominated by random failures with constant failure rate over the longer term.

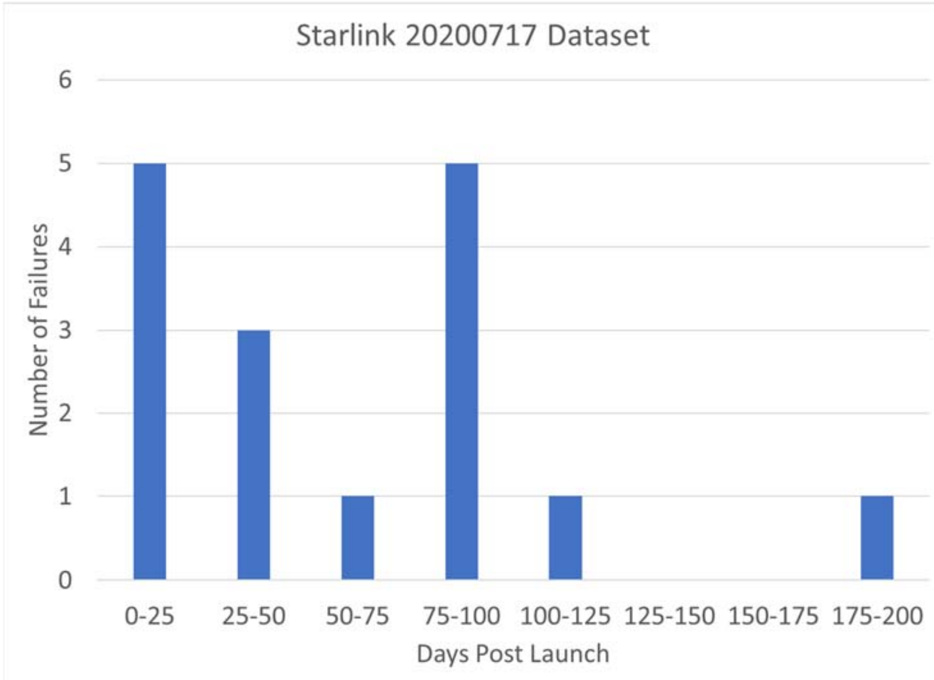

Figure 2: Failures of v1.0 Starlink Satellites

On his Bad Starlinks website,[57] Jonathan McDowell[58] has identified 13 of the v1.0 Starlink satellites that he believes have failed (4 in decayed orbits plus 9 in decaying orbits), and 2 additional which have possibly failed. Elias Eccli's July update[59] (as of July 31) indicates that 20 of the v1.0 Starlink satellites have failed (4 in decayed orbits plus 16 non-operational), out of 478 launched. Whether the correct number is 13 (2.7% failed), 16 (3.4% failed), or 20 (4.2% failed), the apparent trend it troubling and is worse than SpaceX has reported.

Moreover, the failure rate of the first 60 Starlink satellites also needs to be considered—the so-called "v0.9" satellites. As detailed in Viasat's Petition, those satellites alone have a

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57 *See* Jonathan McDowell, "Bad Starlinks," https://planet4589.org/space/stats/megacon/starbad.html (last visited Aug. 6, 2020).

58 Dr. McDowell is an astrophysicist at the Harvard-Smithsonian Center for Astrophysics.

59 *See* Elias Eccli, Twitter (July 31, 2020, 1:09 PM), https://twitter.com/eliaseccli/status/1289246852450312200.

reported failure rate of at least 10%,[60] and SpaceX has not explained: (i) why those failures are irrelevant, (ii) whether and how it resolved the root cause(s) of those failures, (iii) what has changed to make these satellites a "prior version" of what subsequently was launched, or (iv) why similar failures should not be expected in the future. Moreover, any v0.9 satellites with lost or degraded maneuverability present collision risks in their own right.

It is imperative that the Commission require SpaceX to explain the measures it is taking to address this unacceptable creation of orbital debris (non-maneuverable satellites) that risk both (i) causing collisions and (ii) generating even more orbital debris that can affect the orbits that SpaceX and others share, as well as other LEO orbits separated by hundreds of kilometers.

An important question is how many Starlink satellites can be expected to fail over the 15-year life of the constellation. SpaceX has said that it expects to launch approximately 10,000 satellites over that time. We consider three models:

1. Extremely optimistic: All of the failures to date are infant mortality and there will be zero random failures.
2. Very optimistic: Wear out failures occur approaching end-of-life at the same rate as infant mortality and there are zero random failures in between.
3. Current failure rate: The failures are random and representative of an ongoing (continuous) failure rate.

The following table fits the available data to these models and predicts the number of failed Starlink satellites assuming that SpaceX does not take any action to improve reliability on subsequent launches. (Without a better understanding of root cause analysis, it seems quite unlikely that SpaceX can improve the reliability of the satellites already in space, and quite

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[60] *See Viasat Petition*, at 21-22.

likely that any additional satellites launched with the same design, components, processes, etc. will experience the same failure rates).

Failure Rate	Model		
	Extremely Optimistic	Very Optimistic	Current Failure Rate
2.7%	270	540	3,420
3.4%	340	680	4,310
4.2%	420	840	5,320

Table 3: Predicted Number of Failed Starlink Satellites Over 15-Year Constellation Life

Given the actual in-orbit performance of the Starlink satellites, it appears that SpaceX has changed its approach from (i) the one represented in its original application of building safe, reliable satellites, to (ii) an approach based on the assumption that since its orbits are low, and failed satellites will de-orbit in less than 5 years, reliability does not matter.[61] That is a very dangerous approach to commercializing space.

As noted above, were the Commission to sanction this approach (expressly or implicitly), it effectively would signal that industry may prioritize low levels of satellite reliability for the sake of commercial expediency, and make iterative changes to satellite designs to achieve that priority goal—all at the expense of space safety. Encouraging the deployment of satellites with low levels of reliability (and creating the associated risks of collisions and resulting debris clouds) would increase the likelihood of a Kessler syndrome in which so much debris is created that certain orbits become unusable for decades or centuries.

However, if the Commission provides clear guidance about the importance of satellite reliability and space safety, the market will positively respond by fostering the mass-production of innovative, low-cost, and reliable satellites and satellite components.

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[61] *See Viasat Petition*, at 26-31; *see also supra* at 3-4, 17.

E. No Assumptions About Starlink Collision Risk Are Warranted in This Case

Viasat's Petition details why newly-available evidence about Starlink satellite failures and SpaceX's departure from the commitments made in its initial applications warrant a thorough examination by the Commission. SpaceX responds by acting as if all of these matters already have been resolved by the International Bureau. A review of the law, the facts, and what the Bureau actually decided, shows this simply is not the case.

Viasat's Petition details why the Commission will not make simplifying assumptions about collision risk in a case, like this, where evidence exists of SpaceX's experiential satellite failure rates, lost maneuverability capabilities on a number of its satellites, and the apparent lack of redundant systems that were promised to mitigate such risks:[62]

> *[I]n individual cases, to the extent there is evidence that a particular system or operator is unable to effectively maneuver* or is maneuvering only at risk thresholds that raise reasonable questions about its ability to meet the 0.001 collision risk metric even with some degree of maneuverability, *this assumption will not be applied*.[63]

The Petition also explains that SpaceX's recently-disclosed experiential failure rates (i) indicate that SpaceX is not achieving the level of reliability it assured the Commission it would achieve, (ii) raise questions about SpaceX's ability to maneuver effectively and meet the 0.001 large object collision risk metric, and (iii) thus present the type of circumstances in which the Commission no longer should make simplifying assumptions about the risk of collisions with large objects.[64]

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[62] *See Viasat Petition*, at 19 (citing *Mitigation of Orbital Debris in the New Space Age*, Report and Order and Further Notice of Proposed Rulemaking 35 FCC Rcd 4156 (2020), at ¶ 35 ("*2020 Orbital Debris Order and FNPRM*")).

[63] *2020 Orbital Debris Order and FNPRM*, at ¶ 35 (emphasis supplied).

[64] *See Viasat Petition*, at 14-16, 21-25.

Viasat's Petition further explains that circumstances such as these, where the reality of implementation does not match what was promised in SpaceX's initial applications, call for the Commission to take the types of more significant actions it indicated would be appropriate when it becomes aware of information that materially departs from assurances made at the application stage:[65]

> The Commission could also require reporting as a result of information that comes to the attention of the Commission during the licensee's operations. In appropriate circumstances, the Commission could subsequently modify the license in accordance with Section 316 of the Communications Act *to address a rate of failure that departs materially from the expected reliability level, since that departure would affect the public interest assessment underlying grant of the license*.[66]

SpaceX responds by claiming that the International Bureau already considered the risk associated with SpaceX's failures in its June 4, 2020 *SpaceX Recon Order* and decided that an assumption of zero collision risk still should apply.[67] Little could be further from the truth.

Putting aside for the moment that the *SpaceX Recon Order* did not address the factual circumstances presented in this case, even a cursory review of that decision reveals that the Bureau did not have before it any evidence that SpaceX was *"unable to effectively maneuver."* Specifically, the Bureau accepted SpaceX's claim that the submissions on Starlink failures by one party contained only "conjecture" and that no specific information about failures of SpaceX's maneuverability capabilities had been provided.[68] By contrast, now before the Commission in this proceeding are (i) SpaceX's own admissions and disclosures about a high rate of failure of Starlink maneuverability systems, (ii) the further failure analysis contained in

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[65] *See id.* at 32.

[66] *2020 Orbital Debris Order and FNPRM,* at ¶ 99 (footnotes omitted) (emphasis supplied).

[67] *SpaceX Opposition,* at 15 (citing *Space Exploration Holdings, LLC*, Order on Reconsideration, 35 FCC Rcd 5649 (IB 2020), at ¶ 20 ("*SpaceX Recon Order*")).

[68] *SpaceX Recon Order,* at ¶ 20.

Section I.D above, and (iii) new evidence about the collision risk associated with both the authorized Starlink system, and the proposed modified system, as discussed in Sections I.B and I.C. above.

Moreover, it bears emphasis that SpaceX failed to place relevant information about its failure rates in the docket of the *SpaceX Recon Order* proceeding, even though the failures of its satellites were an issue of decisional significance, as discussed further in Section IV below. SpaceX failed to do so with respect to its *May 15 Letter* and also with respect to its *2020 Annual Report* (filed just a few weeks after that order), both of which disclose material information about Starlink satellite failure rates. The only reasonable conclusion to draw from the *SpaceX Recon Order* with respect to this proceeding is that SpaceX withheld material information that could have changed the result under the *SpaceX Recon Order*.

F. SpaceX's Other Arguments on Collision Risk Miss the Mark

Instead of responding substantively to the (i) failure rate of the Starlink satellites, (ii) SpaceX's failure to honor its commitments about reliability in its initial applications, and (iii) SpaceX's pivot to a deployment approach based more on disposability than reliability, SpaceX makes a series of irrelevant and unsupported arguments. Each of those arguments is readily addressed in turn.

To start with, SpaceX points to "the total volume of SpaceX's satellites compared to the volume of space in which they will operate"[69]—essentially arguing that "space is big," so the risk of failed satellites colliding is low. This response makes no sense. As an initial matter, assessing the risk of collision in space is the very point of conducting a DAS analysis. Moreover, the risks associated with having hundreds to thousands of failed Starlink satellites in

[69] *SpaceX Opposition*, at 6-7.

orbit at any given time[70] are not at all trivial. Furthermore, SpaceX's logic quickly breaks down when an analogous situation is considered. As SpaceX's logic would have it, merely because the ocean is vast, the likelihood of any vessel in a fleet of oil tankers hitting a reef is zero, simply because the tankers have rudders—even though we know that the systems that control the rudders on those tankers have failed in many cases and the root cause has not been identified or remediated. The "vastness of space" is no answer to SpaceX's failures and unreliable satellite designs.

SpaceX's response to concerns over its near-miss with a European Space Agency ("ESA") satellite is entirely inadequate. SpaceX's claim that its failure to react was due to an "error in an on-call paging system"[71] provides no comfort at all. If anything, it adds the unreliability of SpaceX's communications hardware and software as yet another risk factor for its system. SpaceX does not address concerns in the record over the maneuverability of the SpaceX satellite involved; the Opposition merely states that SpaceX would have been "willing to coordinate" had it received ESA's message, but is silent on whether the satellite was in fact maneuverable at the time.[72] That silence is deafening.

SpaceX's continued commitment to coordinate with other satellite operators[73] rings hollow considering that satellites with failed or ineffective maneuverability capabilities cannot be controlled, will drift away from their intended orbits, and cannot maintain required spacing from other satellites. Nor can SpaceX itself prevent those failed satellites from colliding with other space objects.

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[70] *See Viasat Petition*, at 16, Table 2.

[71] *SpaceX Opposition*, at 17.

[72] *Id.*

[73] *See id.* at 11-12.

Similarly non-responsive is SpaceX's claim that its use of an "iterative design" approach somehow addresses the demonstrated risks of the Starlink system to space safety.[74] As detailed above and in Viasat's Petition, Starlink failure rates are increasing and SpaceX has refused to address the root causes of its failures. Moreover, as Viasat has noted in connection with SpaceX's recent request for special temporary authority to transmit at eight times the currently authorized power levels, SpaceX has not addressed the impact of its failures on the operation of its communications payloads, including with what level of certainty those payloads cease transmitting when the satellite fails or otherwise cannot be controlled.[75]

SpaceX grossly mischaracterizes Table 3 in Viasat's Petition as somehow constituting a "wildly unrealistic scenario where each SpaceX satellite loses propulsion capabilities simultaneously."[76] Table 3 in the Viasat Petition simply depicts the "Expected Numbers of Large Object Collisions Under 0.001 Standards" that would be allowed under a per-satellite metric, and under a per-constellation metric. The accompanying text is clear that any failure or impairment of reliable maneuverability capabilities in a given number of satellites could result in the number of expected collisions reflected in that table.[77] And contrary to SpaceX's assertion, nowhere in Viasat's Petition is there an assumption that the entire Starlink constellation loses propulsion capabilities at the same time. This is yet another example of SpaceX's rhetoric not matching reality.

SpaceX also falsely claims that parties who raise concerns about SpaceX's actual failure rates and the aggregate collision risk for the Starlink system seek to apply standards that are not

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[74] *Id.* at 16.

[75] *See* Viasat, Inc., Petition to Deny or Defer, IBFS File No. SAT-STA-20200610-00071 (filed Aug. 3, 2020).

[76] *SpaceX Opposition*, at 18-19.

[77] *See Viasat Petition,* at 19.

being proposed or applied to others.[78] To start with, the Commission expressly *has* proposed a 0.001 aggregate collision risk standard, contrary to SpaceX's assertion.[79] The pending FNPRM in the *Mitigation of Orbital Debris* proceeding provides:

> In the *Notice*, we proposed to refer to the 0.001 probability of collision metric in assessing total collision probability as a whole. Some commenters agreed that total collision risk should be assessed, but disagreed about whether the 0.001 metric should apply. We seek comment on using a total collision probability metric as a threshold or safe harbor, and ask whether commenters may have different views on the application of a 0.001 probability of collision metric to the satellite constellation as a whole, if that metric was used only to identify those systems that would require additional review. In addition, is there a metric other than 0.001 that should be used as a threshold or safe harbor?[80]

Clearly, that the Commission has *proposed* to adopt an aggregate collision risk metric means it has not "specifically declined to adopt" such a standard, as SpaceX wrongly suggests.[81]

Moreover, far from applying a "double standard,"[82] Viasat *has made* such an aggregate collision risk showing in its recent request to modify its NGSO authorization—demonstrating its system's ability to satisfy not only all of the Commission's *existing* orbital debris mitigation standards but also its *proposed* 0.001 aggregate collision risk metric.[83]

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78 *See, e.g.*, *SpaceX Opposition*, at ii, 4, 13, 19.

79 *See id.* at 19. SpaceX conspicuously fails to offer its own estimate of the aggregate collision risk posed by the Starlink system.

80 *2020 Orbital Debris Order and FNPRM,* at ¶ 159.

81 *See SpaceX Opposition*, at 19. Indeed, the *2020 Orbital Debris Order and FNPRM* discusses assessing aggregate collision risk at multiple points. *See, e.g.*, *2020 Orbital Debris Order and FNPRM,* at ¶ 29 ("We address these concerns in connection with individual rules, including whether in particular cases the Commission needs to consider the full factual scenario relevant to a licensing decision, including understanding of the complete scope of the risk involved with the proposed operations."); and at ¶ 36 ("Commenters expressed a variety of views on assessing probability of collision with large objects on a system-wide basis, including on what specific metrics, if any, should apply. . . . As described in the Further Notice below, we seek to develop the record further on this issue and how to address multi-satellite systems, including large constellations.").

82 *SpaceX Opposition*, at 18-19.

83 *See* Viasat, Inc., IBFS File No. SAT-MPL-20200526-00056, Exhibit B at 6-11 (filed May 26, 2020).

Such a showing also is consistent with current Commission practice in processing large LEO constellation applications. In an order issued last week concerning the Kuiper system, the Commission conditioned its grant "on Kuiper presenting, and the Commission granting, a modification of this authorization to provide for review of the final orbital debris mitigation plan." [84] The Commission further explained: "The updated plan *should address in greater detail, for the system as a whole, the collision risk (including consideration of reliability of post-mission disposal and the effect of failed satellites on risk)* and re-entry casualty risk."[85] The *Kuiper Order* demonstrates the standard that the Commission is applying today to large LEO constellations. SpaceX's complaint about being singled out and subjected to more stringent standards rings hollow.

The Commission also should disregard SpaceX's attempts to hype its investment in "advanced propulsion capabilities."[86] Investments are meaningful only if they lead to improvements in performance and/or reliability. As detailed above, and in the Petition,[87] the experiential failure rate of Starlink satellites and SpaceX's demonstrated failure to honor its commitments are the precise circumstances where the Commission has said it will *not* assume zero collision risk,[88] and where it will examine the basis for the original grant of authority.[89]

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84 *Kuiper Systems, LLC*, IBFS File No. SAT-LOA-20190704-00057, Order and Authorization, FCC 20-102 (rel. July 30, 2020), at ¶ 32 ("*Kuiper Order*").

85 *Id.* (emphasis supplied).

86 *SpaceX Opposition*, at 14.

87 *See Viasat Petition,* at 19, 32.

88 *See 2020 Orbital Debris Order and FNPRM,* at ¶ 35 ("[I]n individual cases, to the extent there is evidence that a particular system or operator is unable to effectively maneuver or is maneuvering only at risk thresholds that raise reasonable questions about its ability to meet the 0.001 collision risk metric even with some degree of maneuverability, this assumption [of zero collision risk] will not be applied.").

89 *See id.* at ¶ 99 ("In appropriate circumstances, the Commission could subsequently modify the license in accordance with Section 316 of the Communications Act to address a rate of failure that departs materially from the expected reliability level, since that departure would affect the public interest assessment underlying grant of the license.").

Moreover, vague references to "autonomous collision avoidance technology"[90] without showings about the effectiveness of the asserted capability are meaningless. Autonomous operations require a combination of complex orbital dynamics calculations, orbital parameter estimation, and effective and timely maneuverability. If by "autonomous" SpaceX means estimating the orbits of other objects, identifying conjunctions, and taking evasive action without ground intervention, this is no trivial task, and it should not be assumed this capability exists and is effective merely because of SpaceX's assertions. Estimating the orbits of objects that fly by at 15 km/s is very challenging; rapid maneuvers in time to avoid an object closing at 15 km/s are *impractical* with today's propulsion systems—even if they work reliably.

Finally, SpaceX's reference to an antenna anomaly that reduced the originally-predicted throughput of ViaSat-2[91] has nothing whatsoever to do with the loss of maneuverability of Starlink satellites that creates collision risks and imperils the operations of other systems. But now that SpaceX has introduced the issue of the throughput of its competitors' satellites, Viasat welcomes the Commission to investigate whether *SpaceX* is achieving the per-satellite throughput that it represented it would achieve in its initial application—an average of 20 Gbps per satellite[92]—and if so, under what assumptions, and if not, why not. The Commission also should ask SpaceX if any "*space station(s) . . . not performing to [any other] specifications*" delineated in its various applications were not reported in its *2020 Annual Report*.[93]

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90 *SpaceX Opposition*, at 17-18.

91 *See SpaceX Opposition*, at 16. SpaceX also misstates the number of satellites that Viasat operates.

92 *See* Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20161115-00118 (filed Nov. 15, 2016), Narrative, at 5 ("Each satellite in the SpaceX System provides aggregate downlink capacity to users ranging from 17 to 23 Gbps, depending on the gain of the user terminal involved. Assuming an average of 20 Gbps, the 1600 satellites in the Initial Deployment would have a total aggregate capacity of 32 Tbps.").

93 *2020 Annual Report*, at 1.

II. THE PROPOSED MODIFICATION WOULD SUBSTANTIALLY INCREASE INTERFERENCE

A. The Proposed Modification Would Increase the Number of Band-Splitting Events with Other NGSO Systems

In its Opposition, SpaceX fails yet again to demonstrate that its operations would stay within the operating envelope with respect to other NGSO systems as defined by its initial authorization[94]—a failure that requires consideration of SpaceX's modification application in the March 2020 Processing Round.

Specifically, SpaceX does not contest Viasat's observation that, according to the interference-to-noise ("I/N") curves in SpaceX's modification application, the proposed modification would increase otherwise expected interference into other NGSO systems.[95] SpaceX claims that Viasat's analysis of SpaceX's own data "fail[s] 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 . . . in the absence of a coordination agreement."[96] That response is nonsensical, because as Viasat explained in its Petition, SpaceX itself presented those I/N curves in the modification application in an attempt to prove that very point:

> SpaceX compares before (pre-mod) and after (post-mod) I/N CDF curves to demonstrate that the proposed modification does not increase interference, stating that "the new interference levels resulting with the modification are mostly less than (and at worst equal to) the interference levels that would have been experienced with the current constellation in the noise-dominated environment (*i.e.*, I/N ≤ 0 dB)."[97]

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94 *See SpaceX Initial Authorization*.

95 *See Viasat Petition*, at 45-46.

96 *SpaceX Opposition*, at 27 (citation omitted).

97 *Viasat Petition*, at 45 (citing Application, Attachment A, Annex 1, at A1-1).

Despite having relied on this very test in both of its prior modification applications,[98] and apparently because SpaceX now realizes that its own data shows increased interference into other NGSO systems, SpaceX pivots to a new argument: interference from other NGSO systems *into SpaceX's system* somehow will be a limiting factor on the interference SpaceX generates into others.[99] SpaceX fails to explain how this approach would work in the real world to define the interference levels it may generate into other NGSO systems. In particular, it is not clear how SpaceX intends to distinguish the interference SpaceX experiences because of its modification application from the interference SpaceX otherwise would experience under its original system design,[100] which defines the relevant operating envelope with respect to other NGSO systems for purposes of this proceeding.[101] SpaceX's new approach to defining whether the modification application would create "significant interference problems"[102] has not been shown to be verifiable or practically implementable.

In light of SpaceX's tacit admission about its I/N curves and other record evidence that the modification would cause greater interference to other systems authorized in the prior processing round, the Commission should consider SpaceX's modification application in the March 2020 Processing Round—rather than treating it as on par with earlier-authorized systems. This approach would be consistent with Commission precedent, including the recent *Kuiper*

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98 *See* Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20181108-00083 (filed Nov. 8, 2018), Attachment A, at 24-37; Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20190830-0087 (filed Aug. 30, 2019), Attachment A, at Annex A.

99 *SpaceX Opposition*, at 28-29.

100 *See SpaceX Initial Authorization.*

101 *See Viasat Petition*, at 37.

102 Application, Narrative, at 9 (citation omitted).

Order, where the proposed system "raised interference concerns for earlier authorized operators" that the applicant failed to address.[103]

B. Starlink Satellite Power Levels on the Earth's Surface Would Be Substantially Higher than Previously Stated

In its Opposition, SpaceX makes several assertions about the downlink power that its satellites would emit under the proposed modification—claims that are inconsistent with the technical information underlying that application:

- "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"[104] (said with reference to SpaceX's first modification application, IBFS File No. SAT-MOD-20181108-00083 ("MOD1")).
- "With respect to downlinks from its satellites, SpaceX will transmit at lower power in light of its satellites' lower altitudes."[105]
- "SpaceX will also operate at lower power levels …."[106]

The technical information included in the modification application tells a very different story. This is clear by comparing the Schedule S forms attached to SpaceX's MOD 1 application approved in April 2019 with the pending April 2020 modification application ("MOD3").

The following Table 4 compares parameters from the MOD3 Schedule S for "Transmitting Beams 1" with the parameters from the MOD1 Schedule S for "Transmitting Beams 12". Both beams have the same Beam ID, Tx1, and the same frequency range, 10.7 – 12.7 GHz. Some differences in the gain and EIRP are expected due to the different altitudes.

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[103] *See Kuiper Order,* at ¶ 44.

[104] *SpaceX Opposition*, at 25.

[105] *Id.*

[106] *Id.* at iii.

Parameter	MOD3 Schedule S	MOD1 Schedule S
Beam ID	Tx1	Tx1
Transmit Beam Frequency	10700.0 MHz -12700.0 MHz	10700.0 MHz -12700.0 MHz
Beam Type	Both Steerable and Shapeable	Both Steerable and Shapeable
Polarization	RHCP	RHCP
Peak Gain	34.0 dBi	37.1 dBi
Antenna Pointing Error	0.1 deg	0.1 deg
Antenna Rotational Error	0.1 deg	0.1 deg
Polarization Alignment	45 deg	45 deg
Max Tx EIRP Density	-51.1 dBW/Hz	-52.8 dBW/Hz
Max Transmit EIRP	32.7 dBW	31.0 dBW
Polar Mode	C	C
Service Area	Global	Global

Table 4: Comparison of Proposed Versus Authorized Starlink Transmit Parameters

The following Table 5 compares the Max Power Flux Density ("PFD") values provided in the respective Schedules S for these beams. The PFDs for elevation angles between 25° and 90° are the same; however, *the MOD3 values are significantly higher than the MOD1 values for all other elevation angles. In fact, in the region between 20° and 25°, the MOD3 values are over 20 dB higher (over a factor of 100 times higher).*

	MOD3 Schedule S	MOD1 Schedule S	Increase
0° - 5°	-170.4 dBW/m^2/4-kHz	-174.7 dBW/m^2/4-kHz	4.3 dB
5° - 10°	-167.0 dBW/m^2/4-kHz	-173.0 dBW/m^2/4-kHz	6.0 dB
10° - 15°	-162.1 dBW/m^2/4-kHz	-171.4 dBW/m^2/4-kHz	9.3 dB
15° - 20°	-154.1 dBW/m^2/4-kHz	-170.0 dBW/m^2/4-kHz	15.9 dB
20° - 25°	-147.5 dBW/m^2/4-kHz	-169.0 dBW/m^2/4-kHz	21.5 dB
25° - 90°	-146.0 dBW/m^2/4-kHz	-146.0 dBW/m^2/4-kHz	0.0 dB

Table 5: Comparison of Proposed Versus Authorized Maximum PFD Levels

In addition to attaching Schedule S forms to its applications, SpaceX also includes a database with the complete Schedule S information.[107] SpaceX changes the format of this

[107] *See* Application, Wavier Requests, at 1-2 ("SpaceX will … deliver to the Commission a database with the complete information required on Schedule S, including orbital parameters, for inclusion in the record of this application.").

database with each modification application, making it difficult for the Commission and other interested parties to evaluate what has changed and whether SpaceX's certification about changed parameters is in fact accurate.[108] With respect to PFD, the MOD1 and MOD2[109] databases have the same values for the transmit beams. There are 3 Ku-band service link PFD masks in the MOD1 and MOD2 databases. The MOD3 database has 4 Ku-band service link PFD masks.

These various values are compared in the following Table 6. The values shown are PFD in units of dBW/m^2/4-kHz. As it is not clear how to match the beams and mask between the various modification applications, the minimum increase[110] from the MOD1/2 values to the MOD3 values is shown in the bottom row. When comparing the PFD masks from the Schedules S, the PFDs for elevation angles between 25° and 90° are the same; however, the MOD3 values are significantly higher than the MOD1/MOD2 values for all other elevation angles. The MOD3 values are almost 20 dB higher in the region between 20° and 25°.

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108 As noted above, SpaceX has certified the all other information provided in its Ku/Ka-band applications, as modified, remains unchanged by the modification application. Viasat's comparisons are based on that factual certification.

109 *See* Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20190830-00087 (filed Aug. 30, 2019) ("MOD2").

110 Computed as the smallest MOD3 value for each elevation angle range minus the largest MOD1/MOD2 value for that range.

Mask		0° - 5°	5° - 10°	10° - 15°	15° - 20°	20° - 25°	25° - 90°
MOD1	TX1	-174.7	-173	-171.4	-170	-169	-146
	TX19	-172.9	-171.2	-169.7	-168.3	-167.3	-146
	TX7	-172.9	-171.2	-169.7	-168.3	-167.3	-146
MOD3	540_1	-170.4	-167.0	-162.0	-154.0	-147.4	-146
	550_1	-170.4	-167.0	-162.1	-154.1	-147.5	-146
	560_1	-170.5	-167.1	-162.2	-154.2	-147.7	-146
	570_1	-170.5	-167.1	-162.2	-154.2	-147.8	-146
Min Increase		2.4	4.1	7.5	14.1	19.5	0.0

Table 6: Minimum Increase in PFD Values for Various Starlink Beams

These substantially higher PFD values are an interference threat to terrestrial services, NGSO systems, and GSO networks alike. In light of the 100x increase in some cases, it is apparent that SpaceX is at best terribly mistaken, and at worst misleading, in claiming: "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."[111]

As to the power levels transmitted by its satellites (effective isotropic radiated power, or EIRP), as clearly can be seen from Table 4 above, SpaceX plans to increase the maximum transmit EIRP of the Tx1 beam by 1.7 dB (from 31.0 dBW to 32.7 dBW).

Looking at the technical parameter databases attached to each SpaceX modification application, with respect to transmit EIRP, the MOD1 and MOD2 databases have the same values for the transmit beams. As with the PFD masks, it is not clear how to match the beams between the various modifications. The following Table 7 compares the ranges of max EIRP for each frequency range between MOD1/MOD2 and MOD3. In the 10.7 – 12.7 GHz band, the bottom of the maximum EIRP range has increased by 1.7 dB and the top by 0.1 dB. In the 19.7

[111] *SpaceX Opposition*, at 25 (emphasis supplied).

– 20.2 GHz band, the bottom of the range has increased by 5.6 dB and the top of the range by 3.2 dB. A 3.2 dB increase is a far cry from "will transmit at lower power."[112]

Frequency Band (GHz)	MOD1/MOD2		MOD3	
	#Beams	Max EIRP Range (dBW)	#Beams	Max EIRP Range (dBW)
10.7 – 12.7	3	31.0 – 32.7	8	32.7 – 32.8
17.8 – 18.6	4	36.7 – 39.5	12	29.4 – 33.5
18.8 – 19.3	4	36.7 – 39.5	12	29.4 – 33.5
19.7 – 20.2	4	23.8 – 26.6	8	29.4 – 29.8

Table 7: Comparison of Proposed Versus Authorized Transmit EIRP Levels

C. SpaceX Obfuscates the Potential for Harmful Interference into GSO Operations

SpaceX does not address the substantiated concerns that Viasat raised about SpaceX's EPFD certification and the validity of the assumptions underlying that certification. Viasat's Petition underscored SpaceX's lack of transparency regarding whether its EPFD compliance certification is based on a "single entry" value of its NGSO system as a whole or whether instead SpaceX is seeking to "aggregate the single entry EPFD levels of each of the several ITU NGSO system filings on which it relies for its Starlink system."[113]

SpaceX does not dispute Viasat's analysis that relying on both its Norwegian and U.S. filings would cause SpaceX to exceed EPFD levels. Moreover, while SpaceX explains that it "has conducted its EPFD analysis based on procedures and software approved by the ITU," it provides no information about which systems it included in that analysis.[114]

The Commission should not countenance SpaceX's attempt to dance around this issue. In its recent *Kuiper Order*, the Commission conditioned its grant "on Kuiper meeting the single

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112 *Id.*

113 *Viasat Petition*, at 40-41.

114 *SpaceX Opposition*, at 33.

entry EPFD limits in Article 22 for its complete system and *require[d] that the ITU finding to be submitted to the Commission explicitly indicate that the joint effect of Kuiper's ITU filings associated with its constellation was taken into account when verifying compliance with the applicable EPFD limits*."[115] This approach is critical for purposes of ensuring that the EPFD limit for a single NGSO system achieves its purpose of protecting GSO satellites from harmful interference. The Commission should require the same with respect to SpaceX's modification application.

D. SpaceX Has Not Justified Its Request for Permanent Authority During "Transition Phases"

SpaceX also has fallen well short of justifying its request for permanent "authority for communications with SpaceX satellites during transition phases before and after reaching authorized orbital positions."[116] This broad and vague request extends beyond TTAC during orbit raising and deorbiting and payload testing.[117] SpaceX has made no interference showing for this new authority that would apply to 10,000 satellites over 15 years (*i.e.,* spare satellites, any failed satellites that it still can control, satellites in orbit-raising, and satellites in disposal orbits). SpaceX has not shown that it will heed the EPFD limits that are designed to protect GSO networks from interference. And SpaceX has not shown that its operations would stay within the operating envelope with respect to other NGSO systems as defined by its initial 2018 authorization.

SpaceX's only response is that "it has conducted such operations on a non-interference basis . . . over the last year without complaint from any other licensed spectrum user."[118] Merely

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[115] *Kuiper Order,* at ¶ 26 (emphasis supplied).

[116] Application, Narrative, at 4; *see SpaceX Opposition*, at 35-36.

[117] *See* Application, Narrative, at 4.

[118] *SpaceX Oppos*ition, at 36.

pointing to a lack of complaints about, or an awareness of, certain operations does not, as SpaceX suggests, "confirm[]" that they are being conducted on a non-interference basis.[119] This is particularly true when SpaceX has launched only about 1/20th of its expected fleet. Moreover, that argument is akin to claiming that someone who has never received a speeding ticket has never broken the speed limit. *SpaceX* has the burden to provide the necessary technical analysis to substantiate a proposal to operate on a non-interference basis for the next 15 years, and with an expected 10,000 satellites,[120] which SpaceX has not done. Nor is it at all clear that what SpaceX would be doing under this permanent authority would be consistent with its activities under prior special temporary authority ("STA"), particularly when the scope of the permanent authority sought is much broader.[121]

Moreover, SpaceX's recently filed STA request[122] undercuts this request for permanent "transition phases" authority. SpaceX's stated reason for requesting permanent authority is to obviate the need for STAs[123]—which begs the question why SpaceX is continuing to file STAs in tandem with this application. And the proposed 8x power increase and admitted EPFD exceedances in the pending STA request[124] call into question how SpaceX will comply with EPFD on a permanent basis during these "transition phases," especially when SpaceX launches

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119 *See id*.

120 *See, e.g., Rulemaking to Amend Parts 1, 2, 21 and 25 of the Commission's Rules to Redesignate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and Fixed Satellite Services*, Third Report and Order, 12 FCC Rcd 22310 (1997), at ¶ 39 ("To ensure non-interfering operations, we will require all secondary operators to submit to the Commission a technical demonstration that it can operate on a non-harmful interference basis to the type of satellite system with licensing priority. This technical demonstration will be subject to public comment before we authorize any secondary operations in the bands.").

121 *See Viasat Petition*, at 39-40.

122 *See* Space Exploration Holdings, LLC, IBFS File No. SAT-STA-20200610-00071 (filed June 10, 2020).

123 *See SpaceX Opposition*, at 35-36.

124 *See* Space Exploration Holdings, LLC, IBFS File No. SAT-STA-20200610-00071 (filed June 10, 2020), Narrative at 1-2; *see also Viasat Petition*, at 38-39.

400 satellites at a time.[125] SpaceX attempts to wave off these concerns by characterizing the STA request as "unrelated" to the instant application.[126] But both the STA request and the instant application concern SpaceX's operation of the Starlink constellation, and statements made in the former about SpaceX's intent to ignore applicable EPFD limits undoubtedly are relevant to certifications made in the latter. SpaceX's unwillingness to engage on this issue speaks volumes.

III. SPACEX'S XENOPHOBIC STATEMENTS DO NOT BEAR SCRUTINY

In a further effort to deflect the focus of this proceeding away from (i) the failure rates of the Starlink satellites, and (ii) SpaceX's failure to honor its commitments about designing and manufacturing reliable Starlink satellites, SpaceX attempts to cast Viasat as different than SpaceX, in that Viasat's NGSO system relies on an ITU filing from another Administration. SpaceX further suggests that Viasat is not willing to live by the same standards that it asks the Commission to apply to SpaceX.[127] These claims are absurd on their face and belied by the facts.

To begin with, the Starlink system relies on an ITU filing made by Norway—a "foreign" nation,[128] and SpaceX has no qualms about relying on the relative ITU priority of its Norwegian filing when convenient. Moreover, SpaceX provided the EPFD files for its Norwegian filing (and not its U.S. filing) when Viasat requested the EPFD data on which SpaceX relies (and

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[125] *See* Michael Sheetz, *SpaceX Wants to Land Starship on the Moon Within Three Years, President Says, with People Soon After*, CNBC (Oct. 27, 2019), https://www.cnbc.com/2019/10/27/spacex-president-we-will-land-starship-on-moon-before-2022.html.

[126] *Viasat Petition*, at 33.

[127] *See, e.g.*, *SpaceX Opposition*, at ii, 4, 13.

[128] *See* Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20161115-00118, Legal Narrative at 4 (filed Nov. 15, 2016) ("[The SpaceX System] will operate under network filings made on behalf of SpaceX at the International Telecommunication Union ("ITU") by both the United States and Norway.").

which provides the basis for the EPFD analysis in Viasat's Petition). And as noted above, SpaceX still has not addressed Viasat's showing that the joint effect of its Norwegian ITU filing and other filings would cause it to exceed ITU single entry limits.[129]

Meanwhile, Viasat is a Delaware corporation, is headquartered in California, and nearly two-thirds of Viasat's offices and over 90% of its employees are located in the United States. Viasat designs and manufactures all of its satellites in the United States. Viasat has been serving the American mass-market, retail broadband sector for more than 15 years, and—reflecting its dedication to bridging the digital divide in this country—was awarded 26.7% of the covered locations in the CAF Phase II auction. Viasat also holds a large number of Commission authorizations. And far from seeking to avoid the safe space standards discussed in its Petition, Viasat's latest NGSO modification application shows that its planned NGSO system is capable of meeting the *very same Commission requirements* Viasat is asking that SpaceX meet, as noted above.[130]

IV. SPACEX'S CONTINUED FAILURE TO PROVIDE ALL RELEVANT INFORMATION WARRANTS INVESTIGATION

Particularly when considering SpaceX's assertions in this proceeding and the issues raised in the comment cycle so far (some of which are discussed above), there is good reason to conclude that SpaceX has not provided all material information regarding its application and all matters of decisional significance, as required by the Section 1.65 Commission's rules:

> Each applicant is responsible for the continuing accuracy and completeness of information furnished in a pending application or in Commission proceedings involving a pending application.[131]

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[129] *See supra* at 36-37.

[130] *See supra* at 26-28.

[131] 47 C.F.R. § 1.65(a).

> Except as otherwise required by rules applicable to particular types of applications, whenever there has been a substantial change as to any other matter which may be of decisional significance in a Commission proceeding involving the pending application, the applicant shall as promptly as possible and in any event within 30 days, unless good cause is shown, submit a statement furnishing such additional or corrected information as may be appropriate, which shall be served upon parties of record in accordance with §1.47.[132]

This duty lasts "from the time [the application] is accepted for filing by the Commission until a Commission grant or denial of the application is no longer subject to reconsideration by the Commission or to review by any court."[133]

It is already apparent that SpaceX violated this duty in the recent proceeding concerning the Bureau's reconsideration of its grant of SpaceX's April 2019 modification application. There, the failure rate of SpaceX's satellites was at issue,[134] and SpaceX characterized one party's assertions about these failures as mere "conjecture."[135] Yet SpaceX withheld material information about its failure rate from that proceeding. SpaceX failed to submit in that docket the report it filed on May 15, 2020 in this proceeding—three weeks before the *SpaceX Recon Order* was adopted—disclosing new information about the actual failure rates of the Starlink satellites.[136] SpaceX also failed to submit the additional failure rate information provided in its *2020 Annual Report*, which it disclosed three weeks after the *SpaceX Recon Order* was adopted[137] SpaceX had a clear responsibility under Section 1.65 to supplement the record in that

[132] *Id.*

[133] *Id.*

[134] *See SpaceX Recon Order*, at ¶ 20.

[135] Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20181108-00083, Consolidated Opposition to Petitions, at 8 (filed Oct. 30, 2019).

[136] *See May 15 Letter*, at 4-5.

[137] *See 2020 Annual Report*, at 1-2.

proceeding as to these "substantial changes" and matters "of decisional significance," but it did not do so.

The same is now happening in this proceeding. SpaceX has yet to place failure rate information from its *2020 Annual Report* into this docket, despite its clear relevance to the collision risk issues that are contested and of decisional significance in this proceeding. That information is in the record only because Viasat located it and brought it to the Commission's attention. Under Section 1.65, it is SpaceX's responsibility—not Viasat's—to put this information into the docket and serve other parties to this proceeding. SpaceX's failure to meet that responsibility yet again raises serious questions about its candor, and warrants a thorough investigation by the Commission.

V. SPACEX'S PUBLIC INTEREST CLAIMS DO NOT BEAR SCRUTINY

Viasat's Petition provided a list of unsupported assertions from SpaceX's application with respect to the purported public interest benefits of the modification application.[138] SpaceX does not dispute that these are unsubstantiated assertions on its part and SpaceX makes no effort to support them in its Opposition. There accordingly is no basis to rely on such assertions to justify the pending modification application.

However, SpaceX doubles down on unsubstantiated latency claims by claiming that "operations at [550 km] *ensure* that SpaceX can offer service that far surpasses the Commission's definition of a low-latency system."[139] This claim is both *unsupported and unsupportable*. The Commission has explained that "the latency experienced by customers of a specific technology is not merely a matter of the physics of one link in the transmission," and

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138 *See Viasat Petition*, at 47-48.

139 *SpaceX Opposition*, at i (emphasis supplied); *see id.* at v, 2 (making similar claims).

that "[p]ropagation delay in a satellite network does not alone account for latency in other parts of the network such as processing, routing, and transporting traffic to its destination."[140] And critically, the Commission provided this explanation in response to SpaceX's prior claim that "because its low earth orbit satellite system operates at an altitude of 550 kilometers, it can deliver roundtrip latency at less than 50 ms."[141]

Significantly, the Commission defines low latency in the RDOF context as the value achieved 95% of the time in the busiest hour, and there is no indication that SpaceX can achieve its claimed performance under this metric (as opposed to simply presenting a best possible case).

To further rebut these SpaceX claims, an explanation of how latency affects LEO systems is in order. Free-space propagation associated with round trip RF communications through a LEO satellite at 550 km (*i.e.,* ping time) ranges from 7 ms to 15 ms, depending on user terminal and gateway locations within the satellite footprint. Then the latency typically associated with any satellite ground network (including scheduling for multiple access and transport) needs to be added, which itself could involve over 3x as much latency (*i.e*., over 45 ms). As the Commission is well aware, the transit time between satellite gateways and IXPs can vary greatly depending on the location of each such facility. On top of that, one needs to factor in the latency specific to use of the processor-based payloads on the Starlink satellites.[142] Onboard processing introduces queuing, buffering, and other delays that can add many milliseconds to the transit time, especially during times of heavy traffic load that can cause congestion.

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140 *Rural Digital Opportunity Fund*, Public Notice, 35 FCC Rcd 6077 (2020), at ¶ 112.

141 *Id.* at ¶ 111, n.257 (quotation marks and citations omitted).

142 *See* Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20161115-00118 (filed Nov. 15, 2016), Attachment A, at 2.

The following is a representative latency budget, which shows that free-space propagation is but a small element of the overall latency to be expected on a LEO broadband system.

<table>
<tr><td rowspan="12">Outbound (from User)</td><td>User Modem to Satellite Terminal</td><td rowspan="2">User Site Processing</td></tr>
<tr><td>Satellite Terminal Processing</td></tr>
<tr><td>Free-Space Propagation to Satellite</td><td>Uplink</td></tr>
<tr><td>Satellite Demodulation/Decoding</td><td rowspan="3">On-Board Processing</td></tr>
<tr><td>On-Board Switching/Routing</td></tr>
<tr><td>Satellite Encoding/Modulation</td></tr>
<tr><td>Free-Space Propagation to Gateway Earth Station</td><td>Downlink</td></tr>
<tr><td>Gateway Earth Station Processing</td><td rowspan="10">Ground Network Transport and Processing</td></tr>
<tr><td>Terrestrial Network Transport</td></tr>
<tr><td>Core Node Processing</td></tr>
<tr><td>Operator Network Transport</td></tr>
<tr><td>Operator Network Handoff to FCC IXP</td></tr>
<tr><td rowspan="12">Return (to User)</td><td>FCC IXP Handoff to Operator Network</td></tr>
<tr><td>Operator Network Transport</td></tr>
<tr><td>Core Node Processing</td></tr>
<tr><td>Terrestrial Network Transport</td></tr>
<tr><td>Gateway Earth Station Processing</td></tr>
<tr><td>Free-Space Propagation to Satellite</td><td>Uplink</td></tr>
<tr><td>Satellite Demodulation/Decoding</td><td rowspan="3">On-Board Processing</td></tr>
<tr><td>On-Board Switching/Routing</td></tr>
<tr><td>Satellite Encoding/Modulation</td></tr>
<tr><td>Free-Space Propagation to User</td><td>Downlink</td></tr>
<tr><td>Satellite Terminal Processing</td><td rowspan="2">User Site Processing</td></tr>
<tr><td>Satellite Terminal to User Modem</td></tr>
</table>

Table 8: Representative Latency Budget for a LEO System

The additional latency associated with on-board processing, and highlighted in Table 8, bears special note. A processor-based payload must acquire and synchronize to signals transmitted by terminals on the ground in both forward and return directions. In particular, on the return link side, each of the tens or even hundreds of user terminal transmissions per spot beam must be synchronized. This must occur for each satellite or beam handover that occurs as a LEO satellite moves across the sky, introducing multiple additional sources of latency to the flow of traffic along the way.

When the network is loaded with many terminals generating lots of traffic, the latency effects for processed payloads become more pronounced. Essentially the on-board processing can start to congest. This means that early (lightly-loaded) demonstrations of the service may not be representative of a fully-loaded network, and quality of experience may degrade due to higher latency and packet loss.

As to satellite handovers, these events occur when LEO satellites move across the sky—user terminals and gateways must frequently switch between a satellite going out of view and one coming into view. The frequency of such satellite handovers is determined by the number of satellites in the constellation and their altitude. In the case of LEO satellites operating at ~550 km, and passing overhead quickly, satellite handovers would be frequent, ranging from tens of seconds to a few minutes between handovers when employing minimum elevation angles of 25 degrees, and requiring more frequent handovers if the user terminals are constrained to higher elevation angles to avoid using mechanical steering.

SpaceX's broad statement about the end-to-end latency expected on its Starlink system improperly focuses on the free-space propagation associated with proposed orbits and does not even acknowledge the additional sources of delay associated with end-to-end networks. This makes it impossible to credit assertions about the "low latency" of SpaceX's modified system and its claimed ability to "far surpass[] the Commission's definition of a low-latency system."[143]

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[143] *SpaceX Opposition*, at i.

VI. CONCLUSION

SpaceX's modification application presents the Commission with a choice that goes to the heart of its policies on space safety and large LEO constellations:

- Require that SpaceX do what it committed in its initial Starlink application—design and manufacture satellites with a sufficiently-high level of reliability that they can be maneuvered to avoid debris-generating collisions over their 5-year design life; *or*
- Allow SpaceX to continue its current course, and signal to the entire industry (and the world) that operators may launch large LEO constellations without ensuring that their satellites reliably can be maneuvered, on the hope that failed and non-maneuverable satellites will passively decay and enter the Earth's atmosphere before they cause collisions.

The right policy choice should be apparent. Many different LEO systems need to share outer space, and unreliable satellites create collision risks that (i) imperil the orbits they share (as well as orbits above and below) and (ii) increase the likelihood of a Kessler syndrome—"a space-asset destructive chain reaction" that would put a tragic end to the New Space Age for well beyond our lifetime.

The Commission must address this precedent-setting issue before many hundreds (or even thousands) more LEO satellites are launched to form large constellations. Waiting until the resolution of the pending *Mitigation of Orbital Debris in the New Space Age* proceeding would be too late.

Respectfully submitted,

/s/

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August 7, 2020

DECLARATION OF MARK A. STURZA

I, Mark A. Sturza, hereby make the following declarations under penalty of perjury:

1. I am President of 3C Systems Company, which has acted as consultant to Viasat, Inc. ("Viasat") regarding the matters addressed in the foregoing Reply of Viasat, Inc. in Support of Its Petition to Deny or Defer ("Reply").

2. I have reviewed the Reply and certify that, to the best of my knowledge, information and belief, the factual assertions in the Reply are truthful and accurate.

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

/s/
Mark A. Sturza
President
3C Systems Company

August 7, 2020

CERTIFICATE OF SERVICE

I, Kayla Ernst, hereby certify that on this 7th day of August, 2020, I caused to be served a true copy of the foregoing Reply of Viasat, Inc. in Support of Its Petition to Deny or Defer via first-class mail upon the following:

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