March 2, 2021

BY ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
45 L Street, N.E.
Washington, DC 20554

Re: *IB Docket No. 18-313; IBFS File Nos. SAT-MPL-20200526-00056, SAT-MOD-20200417-00037*

Dear Ms. Dortch:

Throughout these proceedings, Viasat, Inc. ("Viasat") has attempted to gaslight the Commission into believing that operating non-geostationary orbit ("NGSO") satellites at lower altitudes—where atmospheric drag ensures that orbital debris demises in a matter of months or years—is more dangerous than operating at higher altitudes where such debris will persist for centuries. This position is directly contrary to the findings of both the Commission and NASA. Yet Viasat continues to make this claim in its latest submission, introducing new gimmicks and distractions while also recycling previous assertions in its ongoing effort to subject Space Exploration Holdings, LLC ("SpaceX") to standards the Commission has never applied to any other applicant.[1] Obviously, Viasat has not found a way through its untenable attempts to stifle competition by feigning concern about a sustainable space environment while simultaneously trying to grow its own system 14 times larger and move it to a much riskier altitude.

SpaceX has proposed that the Commission update its orbital debris rules to better account for the true safety risks presented by persistent debris at higher altitudes and has also demonstrated with respect to modifications proposed for its own system and by Viasat that operations at lower altitudes enhance operational safety compared to operations at higher altitudes.[2] In this letter, SpaceX briefly responds yet again to Viasat's false claims to the contrary. As demonstrated below, operations at lower altitudes such as those proposed by SpaceX are safer and therefore would serve the public interest.

Viasat begins with the verifiably incorrect assertion that the risk of collision with large objects posed by SpaceX's NGSO constellation has increased with each modification to operate some or all satellites at lower altitudes.[3] Viasat only reaches its pre-determined conclusion by relying on incorrect assumptions and selective data. Viasat also insinuates that this result arises

[1] *See* Letter from Amy R. Mehlman to Marlene H. Dortch, IB Docket No. 18-313 and IBFS File Nos. SAT-MOD-20200417-00037 and SAT-MPL-20200526-00056 (Jan. 15, 2021) ("Viasat Jan. 15 Letter").
[2] *See* Further Comments of Space Exploration Technologies Corp., IB Docket No. 18-313, at 7-11 (Oct. 9, 2020).
[3] *See* Viasat Jan. 15 Letter at 9.

1155 F Street, NW Suite 475 Washington, DC 20004
phone 202.649.2700 fax 202.649.2701
spacex.com

from its application of the most recent version of NASA's Debris Assessment Software ("DAS" v. 3.1.0) and the solar flux table updated in December 2020.[4] For purposes of its analysis of the SpaceX constellations, Viasat assumed a January 2021 launch date for all satellites, a 5-year mission life, 260 kg mass, 0.0974 m^2/kg area-to-mass ratio, and 300 km post mission disposal orbit perigee.[5] To provide an apples-to-apples comparison, SpaceX will also use these assumptions and the most recent version of DAS (including the latest updated flux data) for its analysis.

However, SpaceX will also make two corrections for apparent (and presumably intentional) oversights by Viasat. First, Viasat inexplicably ignores non-maneuverable satellites in its calculations by assuming all satellites will successfully be moved into their post-mission disposal orbits, an action that would not be possible for a satellite that loses propulsion capabilities. Given how stridently Viasat asserts that the Commission must consider non-maneuverable SpaceX satellites, it might seem surprising that Viasat did not include them in its DAS analysis—until you realize that Viasat does not want to have to account for its own non-maneuverable satellites at a much higher operational altitude. Once again, Viasat is caught between a rock and a hard place by trying to stop competition while distracting from the debris risk its own modified system would cause. SpaceX will assume a 2 percent failure rate for its satellites at their operational altitudes. This will allow DAS to model the collision risk for non-maneuverable satellites as they lose altitude and ultimately demise in the atmosphere. Second, SpaceX will apply the presumption from the Commission's rules that maneuverable satellites should be deemed to present essentially zero risk of collision, rather than use Viasat's assumption that operational satellites take no measures to avoid other satellites and trackable orbital debris.[6]

With all of these assumptions, the per-satellite collision risk calculated by DAS decreases with each modification of the SpaceX constellation—and markedly so for the current proposal—as shown in Table 1.

Constellation	Average Collision Probability Using Truncated DAS
SpaceX 2016 (original)	0.000149
SpaceX 2018 (current)	0.000122
SpaceX 2020 (proposed)	0.00000178

Table 1. Average Probability of Large Object Collisions Using Truncated DAS Analysis

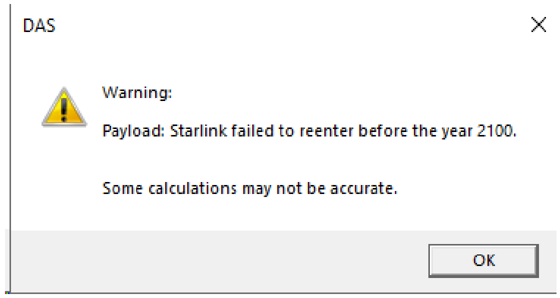
This directly refutes Viasat's central claim that SpaceX's efforts to move its satellites to lower operating altitudes would result in greater risk of collision. But as SpaceX has explained before,

4 Viasat refers to "DAS 3.1.1" but the latest release of DAS is 3.1.0. *See* Release Notes, *NASA Debris Assessment Software (DAS) version 3.1 (20 May 2020)*, https://orbitaldebris.jsc.nasa.gov/library/das/das3.1.0_release_notes.txt. As Viasat notes, NASA did release an updated solar flux table in December 2020, and SpaceX has used that data in its analysis herein.

5 *See* Viasat Jan. 15 Letter, Annex A at Att-5.

6 *Mitigation of Orbital Debris in the New Space Age*, 35 FCC Rcd. 4156, ¶ 35 (2020) ("*Orbital Debris Update Order*"); 47 C.F.R. § 25.114(d)(14)(iv)(A)(1) (when using DAS, "[t]he collision risk may be assumed zero for a space station during any period in which the space station will be maneuvered effectively to avoid colliding with large objects").

DAS will only report up to 100 years of decay time and will zero out any risk after 2130. As a result, it will significantly understate the risk for satellites like those currently licensed to SpaceX or proposed by Viasat that are operating at altitudes above 1,000 km, which would take more than a century to reach atmospheric demise.[7] Indeed, DAS provides a warning to this effect, noting the limitations of its analysis as shown below.



However, this limitation can be overcome to reach a much more accurate assessment by recursively feeding the final altitude at the end of each 100-year analysis into a new DAS analysis until the satellite reenters the atmosphere. Using this approach, the steady reduction in collision risk becomes even more apparent as shown in Table 2.

Constellation	Average Collision Probability Using Recursive DAS
SpaceX 2016 (original)	0.001
SpaceX 2018 (current)	0.000682
SpaceX 2020 (proposed)	0.00000178

Table 2. Average Probability of Large Object Collisions Using Recursive DAS Analysis

This should come as no surprise. The Commission has noted the correlation between operating at lower altitudes and reduced risk of collision.

> Satellites deployed below 650 km will typically re-enter Earth's atmosphere within 25 years, even absent any propulsive or other special de-orbit capabilities. Thus, the collision risks presented by such satellites are generally lower, even if the satellites fail on-orbit and are unable to perform any affirmative de-orbiting maneuvers.[8]

NASA has reached a similar conclusion.

> Because of the weak atmospheric drag above the 1000 km altitude, defunct spacecraft in that region have orbital lifetimes on the order of thousands of years or longer. They are a danger to the operations of [large constellations] and more

---

[7] *See* Petition to Deny or Defer of Space Exploration Holdings, LLC, IBFS File No. SAT-MPL-20200526-00056, at 24 (Aug. 31, 2020) ("SpaceX Petition to Deny").

[8] *Mitigation of Orbital Debris in the New Space Age*, 33 FCC Rcd. 11352, ¶ 31 (2018) (footnotes omitted).

> importantly, are a long-term threat to the LEO environment—defunct spacecraft can and will collide with other debris over time, increasing the potential of generating more debris to trigger a collision cascade effect in the region.[9]

Indeed, applying DAS to determine the collision risk at various altitudes yields a fairly smooth curve, demonstrating that the risk is exponentially higher at altitudes over 1,100 km (where SpaceX is currently authorized to deploy and Viasat would like to operate) as compared to altitudes near 550 km (where SpaceX proposes to deploy), as shown in Figure 1 below.

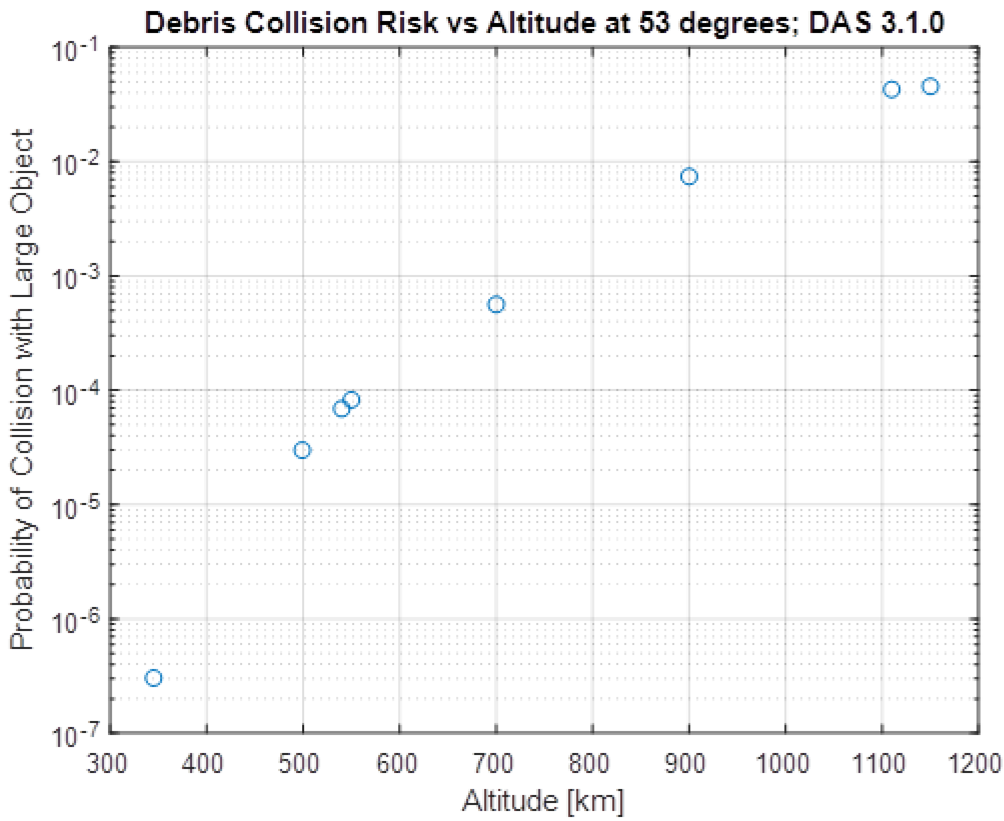


Figure 1. DAS Collision Risk at Different Altitudes

In addition, Viasat makes much of the fact that its latest submission uses the most up-to-date debris flux information available from NASA. However, that information actually has only a miniscule effect on the DAS analysis. Figure 2 (for truncated DAS) and Figure 3 (for recursive DAS) show just how little the change in flux data affects collision risk compared to the effect of the change in altitude.

---

9 J.-C. Liou, et. al., *NASA ODPO's Large Constellation Study*, NASA Orbital Debris Quarterly News, Sept. 2018, at 7, https://www.orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv22i3.pdf.

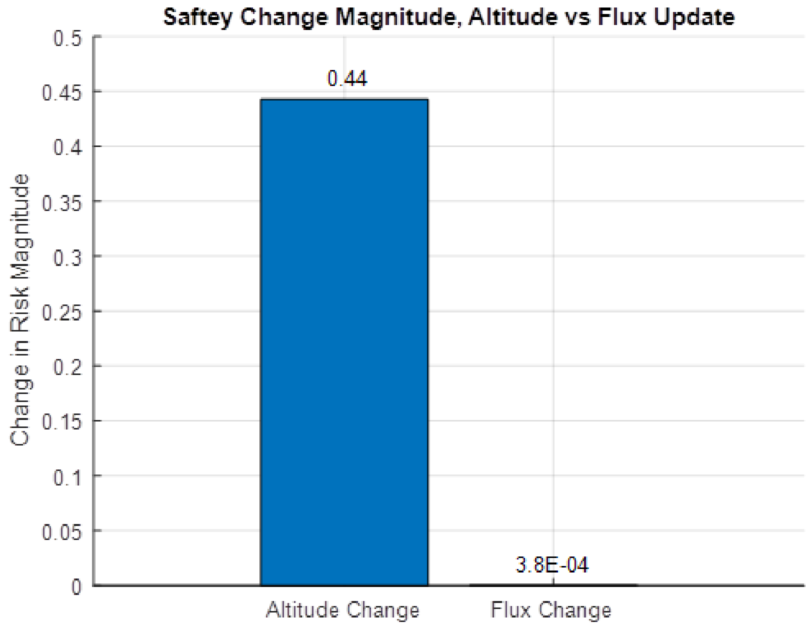


Figure 2. Relative Effect on Collision Risk Due to Change in Altitude vs. Flux – Truncated DAS

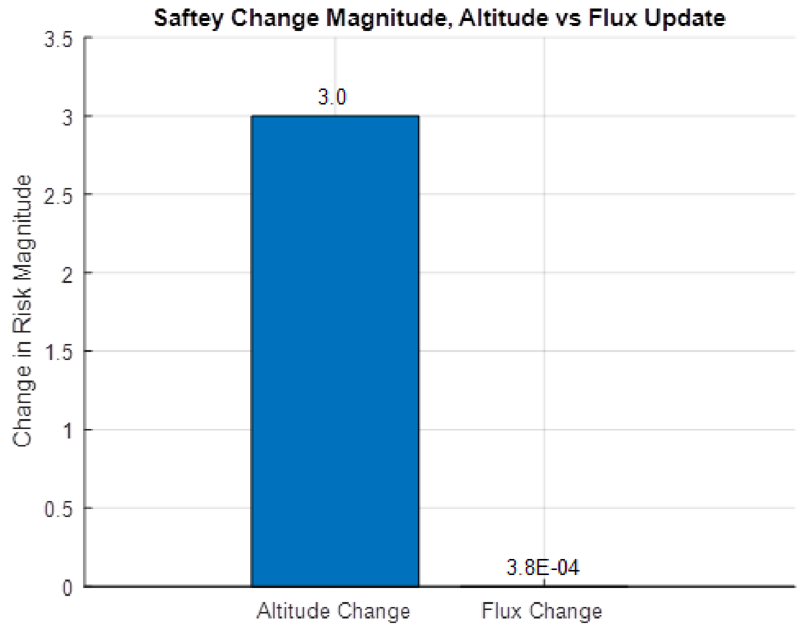


Figure 3. Relative Effect on Collision Risk Due to Change in Altitude vs. Flux – Recursive DAS

Moving to its next line of attack, Viasat asserts that "SpaceX does not account for the collision risks that persist from the time a Starlink satellite no longer can be reliably and effectively maneuvered until the satellite's orbit passively decays (which can be as much as six years)."[10] To the contrary, it is Viasat that has presented orbital debris calculations for its system that fail to account for any satellites that lose maneuverability at their proposed operational altitude of 1,300 km.[11] As shown in Figure 4, the time required for such a satellite's orbit to decay, regardless of its area-to-mass ratio, is more than a century, while satellites operating in the neighborhood of 550 km demise in a matter of a few years.

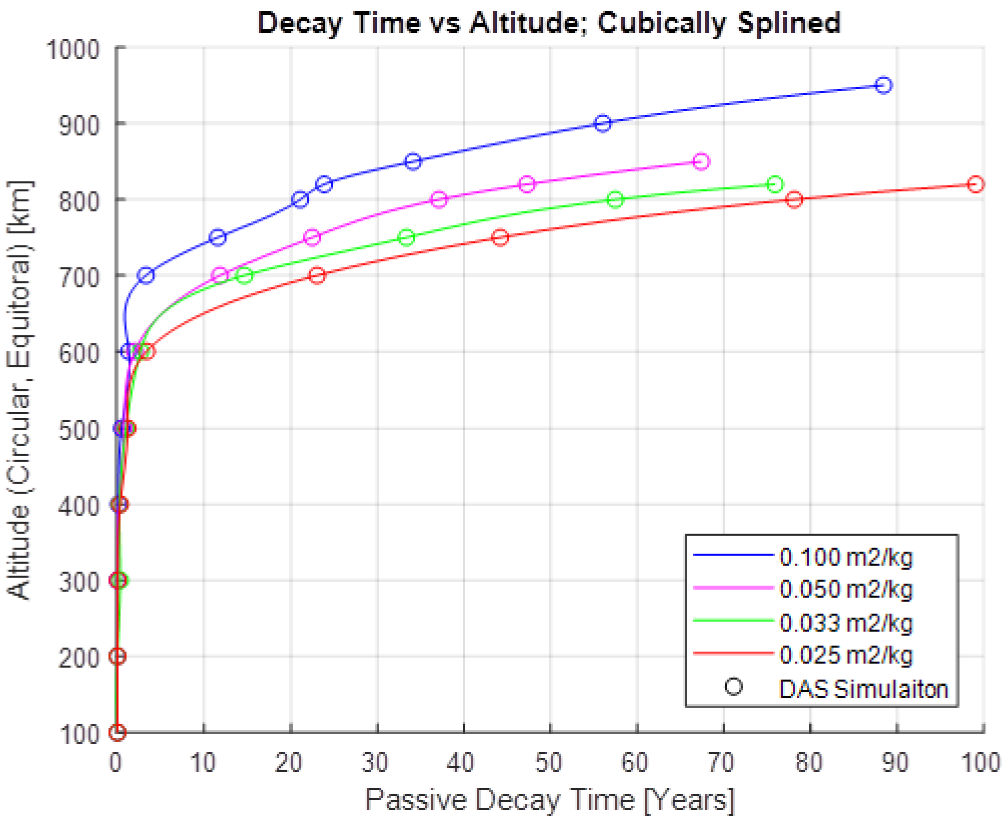


Figure 4. DAS Decay Time at Different Altitudes

Accordingly, Viasat is simply wrong in asserting that DAS predicts that the proposed modification would increase the risk of collision with large objects. To the contrary, even the truncated DAS approach shows that moving the remaining satellites to lower altitudes would decrease the average risk while the more realistic recursive DAS approach shows that this risk will be reduced by orders of magnitude.

Viasat also struggles to condemn SpaceX with regard to trackable debris, while still defending its much riskier proposed system. In its failed attempt to thread this needle, Viasat presents a study showing that there are marginally more trackable debris objects in the altitudes

10 Viasat Jan. 15 Letter at 3.
11 *See* SpaceX Petition to Deny at 19-26.

where SpaceX proposes to operate (495) than in the higher altitudes where Viasat proposes to operate (374 and 237).[12] Of course, the more relevant comparison with respect to the SpaceX modification is to the altitudes where SpaceX is currently authorized to operate, which have a higher average level of trackable debris (746 and 454). Moreover, as Viasat notes, that same study shows over 7,000 debris objects in the 600 km to 1000 km altitudes through which any NGSO satellites operating at higher altitudes must travel during orbit raising after launch and de-orbit at end of life—risks that SpaceX will not face (but Viasat will) if all of its satellites remain below 600 km. Taking all this into consideration, NASA and other NGSO operators have determined that lower altitudes offer greater safety.

> Choosing a mission trajectory that occupies a region of space with a lower debris density is thus a favorable selection for two reasons: first, it lowers the risk of a lethal collision with an untracked object; and second, it in general reduces the rate at which serious conjunctions with cataloged objects will occur. As many O/Os have determined, ***choosing orbits with lower orbital altitudes both achieves the above two goals . . . and facilitates complying with the 25-year disposal guidelines***.[13]

Viasat also cites this same study for its estimations of collision rates at various altitudes, taking into account all proposed NGSO constellations (including Starlink).[14] Yet like Viasat's flawed DAS analysis, this study also makes clear that it "expressly assumes no effective remediation or effective avoidance maneuver is performed."[15] Treating controlled satellites as if they are uncontrolled orbital debris—contrary to the zero collision presumption the Commission has adopted for maneuverable satellites—significantly overstates the collision potential and renders this analysis irrelevant.

Perhaps aware that its DAS analysis was suspect, Viasat proffers two additional analyses that purport to capture intra-system collision risk—one based on the kinetic theory of gases (the "Kinetic Theory") and the other using the Number of Encounters Assessment Tool ("NEAT").[16] Yet the Commission has never considered, much less used or endorsed, either of these analyses. To the contrary, in updating its orbital debris rules last year, the Commission stated that it "has required orbital debris mitigation plans since 2004, and the updated rules build on the Commission's existing framework, taking into consideration practices that have been common among applicants, such as using the NASA Debris Assessment Software tool, thus promoting regulatory certainty."[17] To obscure the risk of its own proposal, Viasat seeks to inject

---

[12] *See* Viasat Jan. 15 Letter at 5-6 (citing Salvatore Alfano, Daniel L. Oltrogge, and Ryan Sheppard, *LEO Constellation Encounter and Collision Rate Estimation: An Update*, 2nd IAA Conference on Space Situational Awareness (ICSSAA) (2020) ("*Collision Rate Update*"), https://assets.documentcloud.org/documents/6747529/LEO-CONSTELLATION-ENCOUNTER-and-COLLISION-RATE.pdf).

[13] NASA, *NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook*, Appendix G at 77 (Dec. 2020) (emphasis added), https://nodis3.gsfc.nasa.gov/OCE_docs/OCE_50.pdf.

[14] *See* Viasat Jan. 15 Letter at 6.

[15] *Collision Rate Update* at 3.

[16] *See* Viasat Jan. 15 Letter at Annexes B and C.

[17] *Orbital Debris Update Order* ¶ 153 n.521.

uncertainty—and to hold SpaceX alone to a new standard—by introducing these new analyses for the first time at this late stage in this proceeding.

Misuse of academic work to support misrepresentations about SpaceX is unfortunately becoming common practice for Viasat. For example, to support its claims about SpaceX's operations, Viasat relied extensively on research by Professor Jonathan McDowell—but Professor McDowell took the extraordinary step of filing a letter in the record of this proceeding to make clear that Viasat's arguments are a "misreading of my results" and that Viasat's analysis is an "inexplicable interpretation."[18] Similarly, Viasat cited a number of studies it claimed would support its argument that moving SpaceX satellites from their currently authorized altitudes above 1,100 km to the area around 550 km would increase reflected sunlight and thereby interfere with astronomical observation. To the contrary, those studies concluded exactly the opposite[19]—and the American Astronomical Society felt compelled to file comments in this proceeding to make clear that, "as astronomical observations are concerned, lower altitude is a better option" and that SpaceX had also taken other steps to lower the apparent brightness of its satellites.[20] In addition, Viasat made a series of technical arguments in opposition to SpaceX's participation in the Rural Digital Opportunity Fund ("RDOF"),[21] claiming that SpaceX could not meet the requirements for low-latency service—a claim the Commission rejected in finding SpaceX qualified to participate in the RDOF auction at the lowest latency level.

Even if this were not the case, the Commission would have good reason to reject the two novel analyses Viasat proffers here. For example, Viasat offers the NEAT analysis to quantify "collisions not avoided"—i.e., the residual risk of collision where avoidance maneuvers have not been deemed necessary due to the inherent uncertainty with orbit predictions.[22] As NASA has explained, "[t]he calculation of on-orbit collision avoidance residual risk can be approached in different ways and requires a number of assumptions, each of which should sustain formal examination and testing before implementation in order to ensure their reasonableness."[23] The Commission has done no such formal examination of NEAT or the assumptions that go into the model. Accordingly, its use here—and uniquely with respect to SpaceX—would not be appropriate.

As for the Kinetic Theory, although Viasat claims that there is "significant literature" supporting use of that theory to calculate intra-system collision risk,[24] the literature it cites does

---

18 *See* Letter from Jonathan McDowell, Center for Astrophysics, to FCC, IBFS File No. SAT-MOD-20200417-00037 (Sep. 21, 2020).

19 *See* Opposition of Space Exploration Holdings, LLC to Petition Pursuant to Section 1.1307(c) of Viasat, Inc., IBFS File Nos. SAT-MOD-20200417-00037 and SAT-MPL-20200526-00056, at 11-15 (Jan. 6, 2021) (detailing findings contrary to Viasat's assertions).

20 *See* Comments of the American Astronomical Society on the Petition of Viasat, Inc. Dated 12/22/20, IBFS File No. SAT-MOD-20200417-00037 (Jan. 7, 2021).

21 *See, e.g.*, Letter from John P. Janka to Marlene H. Dortch, IBFS File No. SAT-MOD-20200417-00037, at 1-6 (Oct. 5, 2020) (contesting various aspects of SpaceX's latency showing); Letter from John P. Janka to Marlene H. Dortch, IBFS File No. SAT-MOD-20200417-00037 (Sep. 25, 2020) (same).

22 *See* Viasat Jan. 5 Letter at 12.

23 Letter from Anne E. Sweet to Marlene Dortch, IB Docket No. 18-313, at 2 (Apr. 4, 2019).

24 Viasat Jan. 15 Letter at 10.

not support that claim. Indeed, the first reference cited by Viasat makes clear that this theory is just one element of larger approaches to modelling collision rates and applies, if at all, only over relatively small areas of space—and not the full orbital shells that Viasat has used.[25] In addition, the theory assumes random interaction between objects—a far cry from the orderly operation of a constellation of satellites under the control of a single operator—which the study candidly admits "is likely to result in over-prediction of collision rates within a constellation when modelled as independent objects."[26] After reviewing two applications of the Kinetic Theory to orbital debris, the study found that each of these methodologies "provide[] a very different assessment of the risk" which "suggests that there is currently a poor level of understanding of the rates at which collisions can be expected to occur in the future."[27] Based on the evidence, the study concluded that "[t]his leaves doubt as to whether these models can be trusted as providing an accurate representation of the likelihood of collisions in the debris environment."[28]

Thus, Viasat's latest filing continues its streak of error-filled submissions. Rather than encourage more such filings, the Commission should finally bring this proceeding to a close by granting the modification application to authorize SpaceX to deploy its constellation even more safely than currently contemplated.

Sincerely,

/s/ David Goldman

David Goldman
Director of Satellite Policy

SPACE EXPLORATION TECHNOLOGIES CORP.
1155 F Street, NW
Suite 475
Washington, DC 20004
Tel: 202-649-2641
Email: David.Goldman@spacex.com

---

25 *See* Samuel Diserens, Hugh G. Lewis, and Joerg Fliege, *Assessing collision algorithms for the newspace era*, Journal of Space Safety Engineering 7.3, at 278 (2020) ("For simulations of the space debris environment a cube with side length of 10 km is normally used, roughly 0.15% of the semi-major axis of the lowest objects in LEO.").

26 *See id.* at 282.

27 *Id.*

28 *Id.*