

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

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Application of)	
SPACE EXPLORATION HOLDINGS, LLC)	Call Signs: S2983 and S3018
For Modification of Authorization for the)	File No. SAT-MOD-20200417-00037
SpaceX NGSO Satellite System)	
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PETITION PURSUANT TO SECTION 1.1307(c) OF VIASAT, INC.

SUMMARY

In July 2020, Viasat filed a petition to deny or defer an application by Space Exploration Holdings, LLC (“SpaceX”) to relocate almost 3,000 of its Starlink satellites to lower orbital altitudes. Viasat demonstrated that SpaceX’s plan to crowd lower orbital altitudes and trajectories with thousands of satellites presents significant issues: The combination of (1) a proposed significant densification of certain low-Earth orbits (LEOs), (2) SpaceX’s experiential failure rate with its Starlink satellites, (3) the inability of its satellites to avoid collisions when they cannot be maneuvered effectively and reliably, and (4) the manner in which such collisions create significant additional orbital debris that further pollutes space, pose an unreasonable threat to the continued use of the shared orbital environment, and thereby compromise that environment. This is the case not only for the altitudes and trajectories that SpaceX is authorized to use, but also for the altitudes hundreds of kilometers above and below, as well as for satellite missions that need to traverse the affected orbits.

After Viasat filed its petition, new research, studies, and filings raised serious environmental concerns relevant to SpaceX’s proposed modification. These materials include a study on the atmospheric impacts of satellite reentry, a report on the light pollution caused by Starlink satellites, and a new filing by NASA relating to the increase of space debris. These studies bear on the environmental impacts of SpaceX’s proposal, and thus on the Commission’s obligations under the National Environmental Policy Act (“NEPA”) and its public-interest inquiry.

As a satellite operator who shares the skies with SpaceX, Viasat values the tremendous potential for satellites to help close the digital divide, monitor global warming, detect and mitigate natural or man-made environmental disasters, and enhance myriad other aspects of modern life. But it is our obligation as users of orbital space—and the Commission’s responsibility as a regulator of its commercial use—to ensure that technologies are deployed responsibly and

efficiently, informed by an understanding of potential impacts to the Earth, its orbital environment, and its inhabitants. NEPA was adopted to ensure that these environmental considerations enter the Commission’s decisionmaking calculus. SpaceX’s proposal to deploy a massive fleet of satellites at a low orbital altitude implicates at least three broad categories of environmental impacts that warrant particular attention.

First, the Commission must carefully consider the environmental risks associated with thousands of satellites launching through the atmosphere and then reentering it in a short period of time, particularly when SpaceX is pursuing a strategy that emphasizes (1) disposability and replaceability over (2) reliability and safety, simply to advance its own commercial interests. Petition to Deny or Defer of Viasat, Inc. at 37, IBFS File No. SAT-MOD-20200417-00037 (July 13, 2020) (“Viasat Petition”). Instead of deploying a smaller fleet of environmentally friendly satellites, SpaceX treats its satellites as disposable commodities with little regard for the harmful environmental impacts they may have. SpaceX maintains that modifying the orbital altitude of the nearly 3,000 operating satellites at issue here will greatly accelerate and compress the time period within which they burn up in the Earth’s atmosphere, and will require launching at least 10,000 satellites (based on proposed satellite lifetimes, and possibly more depending on actual lifetimes) to maintain that fleet over 15 years, each of which is supposed to ultimately burn up in the atmosphere. The launch and reentry of these satellites is likely to release harmful chemical compounds into the air that could contribute to ozone depletion and to global warming. And given the satellite quantities at issue, there is also a risk that satellites that do *not* burn up on reentry could harm humans and the environment.

Second, lowering the orbital altitudes of such a vast number of non-geostationary satellites could significantly increase “light pollution” in the night sky, tarnishing its natural aesthetic beauty

and interfering with important scientific work by ground-based astronomers, among other effects. Lowering the altitude of the satellites can be expected to reflect sunlight with a brighter apparent magnitude, and SpaceX's recent efforts to reduce this light pollution have not eliminated scientific concerns.

Third, as Viasat has separately demonstrated, the densification of the orbital altitude range at issue with so many satellites will likely greatly increase the risk of collisions with other space objects. These collisions, in turn, would likely produce a significant amount of new orbital debris that remains in orbit for decades or even a century or more, threatening the viability of access to space for current and future generations.

These impacts are significant in their own right. And the manner in which the Commission addresses them also will have a significant effect on the environmental impacts to be expected from other large LEO constellations. Commission action on SpaceX's pending modification application will set the precedent for the design and deployment of large constellations by other operators—consisting of many tens (or hundreds) of thousands of additional LEO satellites.

Because SpaceX's application is likely to have significant impacts on the environment, and because the full scope of these effects remains unknown to and unexplored by the Commission (particularly in light of the new evidence cited herein), the Commission should prepare an environmental impact statement ("EIS") under NEPA before acting on SpaceX's proposed modification. At the very minimum, an environmental assessment ("EA") is required.

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Viasat, Inc. respectfully requests that the Commission deny or defer consideration of the above-referenced modification application of SpaceX. For the reasons explained below, the Commission should prepare an EIS fully evaluating the environmental impacts of SpaceX’s proposed action pursuant to NEPA, before acting upon SpaceX’s application. In the alternative, the Commission should prepare an EA before acting upon SpaceX’s application. This request for relief is supplemental to the relief sought in Viasat’s initial petition.

¹ Pursuant to Sections 1.1307(c) and 1.1313(a) of the Commission’s rules, 47 C.F.R. §§ 1.1307(c), 1.1313(a), Viasat respectfully submits this petition as a supplement to the July 13, 2020 Petition to Deny or Defer of Viasat, Inc., IBFS File No. SAT-MOD-20200417-00037. This petition brings to the Commission’s attention recently released studies and expands on the issues raised in Viasat’s initial petition. It is timely because it raises authorities that had not yet been released at the time of Viasat’s initial petition, which itself was timely filed under § 25.154(a)(2), 47 C.F.R. § 25.154(a)(2). In the alternative, the Commission may deem this an informal objection under Sections 1.1313(b) and 25.154(b), *id.* §§ 1.1313(b), 25.154(b).

Regardless of how this petition is classified, the National Environmental Policy Act requires the Commission “to consider every significant aspect of the environmental impact of a proposed action,” *Balt. Gas & Elec. Co. v. NRDC*, 462 U.S. 87, 97 (1983), including the impacts set forth in this petition, *see* 42 U.S.C. § 4332(2)(C). The issues addressed herein also bear on whether the requested modification would “serve the public interest, convenience, and necessity.” 47 C.F.R. § 25.117(d)(2)(ii).

INTRODUCTION

Commercial use of space is at a crossroads. Recent developments in satellite technology may deliver high-speed, low-latency Internet access to people in geographic areas that are otherwise difficult to serve. Some applicants propose to provide this service primarily by launching unprecedented numbers of low-cost satellites into LEO. But history has shown that rapidly deploying new technology in new ways, without pausing to carefully consider the environmental consequences, is a recipe for disaster. Here, SpaceX seeks permission to lower the orbital altitude of its growing fleet of Starlink satellites—to be followed by tens of thousands of additional LEO satellites proposed in its other filings. SpaceX views these satellites as disposable assets, which it predicts will reenter the atmosphere in a steady stream during the life of the program. Yet new scientific evidence suggests that crowding large fleets of such satellites into lower orbits could cause serious environmental harms related to global warming, light pollution, and orbital debris. Viasat accordingly supplements its earlier petition in this proceeding to bring these matters to the Commission’s attention, and it respectfully urges the Commission to fully consider the environmental consequences of SpaceX’s application in accordance with NEPA and considerations of the public interest.

By way of background, the Commission in March 2018 authorized SpaceX to “construct, deploy, and operate a proposed non-geostationary orbit (NGSO) satellite system comprising 4,425 satellites for the provision of fixed-satellite service (FSS) around the world.” *Space Expl. Holdings, LLC*, 33 FCC Rcd. 3391, 3391 (2018). Later that year, the Commission authorized SpaceX to “add a very-low-Earth orbit (VLEO) NGSO constellation, consisting of 7,518 satellites,” for a total of about 12,000 authorized satellites. *Space Expl. Holdings, LLC*, 33 FCC Rcd. 11,434, 11,435 (2018). SpaceX has since sought to modify the March 2018 authorization three times, including its most recent request to relocate 2,824 satellites that were previously authorized for operation at

altitudes ranging from 1,100 km to 1,330 km to new altitudes ranging from 540 km to 570 km. *See* Application for Modification of Authorization for SpaceX NGSO Satellite System at i, IBFS File No. SAT-MOD-20200417-00037 (Apr. 17, 2020) (“SpaceX Application”).

Viasat opposed SpaceX’s proposal in a July 2020 petition, citing concerns about space safety, collision risks, and the need to facilitate the “shared use of space.” Viasat Petition at 48. Shortly after Viasat filed its petition, new evidence about the environmental effects of SpaceX’s proposal came to light. For example, the Aerospace Corporation published a preliminary study analyzing the environmental impacts of satellite reentry on the Earth’s atmosphere. Researchers presented that data at a conference just this month. *See* Debra Werner, *Aerospace Corp. Raises Questions About Pollutants Produced During Satellite and Rocket Reentry*, SpaceNews (Dec. 11, 2020), <http://spacenews.com/aerospace-agu-reentry-pollution/>. Members of the SATCON1 Scientific Organizing Committee published a thorough report in August 2020 analyzing the light-pollution effects of Starlink satellites. Constance Walker et al., *Impact of Satellite Constellations on Optical Astronomy and Recommendations Toward Mitigation* (2020). And NASA recently wrote to the Commission about the ways in which certain LEO satellite constellation deployments could exacerbate the space-debris crisis. Letter from Samantha Fonder, NASA Representative to the Commercial Space Transp. Interagency Grp., to Marlene Dortch, Sec’y, FCC (Oct. 29, 2020). None of these materials was available when Viasat filed its petition, and further research has revealed a significant body of additional studies, reports, and articles addressing matters directly relevant to SpaceX’s proposed modification.

These publications bear on the Commission’s legal responsibilities in reviewing SpaceX’s application. NEPA embodies a national policy against acting first and thinking later by imposing an affirmative, statutory obligation on federal agencies “to consider every significant aspect of the

environmental impact of a proposed action.” *Balt. Gas & Elec. Co. v. NRDC*, 462 U.S. 87, 97 (1983). The Commission also has an independent obligation to reject “[a]pplications for modifications of space station authorizations” that “would not serve the public interest, convenience, and necessity.” 47 C.F.R. § 25.117(d)(2)(ii).

Here, numerous studies, articles, and papers indicate that SpaceX’s proposal to dramatically increase its fleet of lower-altitude satellites could increase the generation of particles that contribute to global warming and significantly alter the chemistry of the atmosphere; harm humans and their environment if its satellites do not fully burn up on reentry; create excessive light pollution that interferes with the ability of astrophotographers, astronomers, and ordinary stargazers to study and enjoy space; and increase the risk of collisions due to excessive space junk and overcrowding in space. To be clear, these potentially significant environmental harms are specific to proposals (like SpaceX’s) to deploy and maintain massive LEO satellite constellations; smaller-scale, more routine deployments may well avoid significant environmental impacts. But given the sheer quantity of satellites at issue here, as well as the unprecedented nature of SpaceX’s treatment of them as effectively expendable, the potential environmental harms associated with SpaceX’s proposed modification are significant. NEPA accordingly demands that the Commission prepare an EIS before acting on SpaceX’s application—or, at a minimum, that it prepare an EA to further explore these issues before doing so. While SpaceX contends that some of these risks have been or will be reduced, experience teaches that SpaceX’s claims do not always match reality, and in any event NEPA requires that the analysis be performed, even if the Commission ultimately concludes that some of the effects can be mitigated with appropriate conditions.

Inaction, however, is not a viable option. Relying on the Commission’s decades-old categorical exemption to avoid even *inquiring* into the environmental consequences of SpaceX’s modification proposal would not only violate NEPA, but also would needlessly jeopardize the environmental, aesthetic, health, safety, and economic interests that it seeks to protect, and harm the public interest. Commission action (or inaction) on SpaceX’s pending modification application will set the precedent for the design and deployment of large LEO constellations by other operators—consisting of many tens (or hundreds) of thousands of additional satellites.

Now is the time for satellite operators and federal regulators to proactively analyze the consequences of recently emerging satellite technologies and practices, ensuring that the numerous benefits of innovative satellite technology can be enjoyed for years to come in a way that reflects responsible stewardship of the Earth and the skies.

DISCUSSION

I. NEPA Requires That Agencies Take a Hard Look at the Potential Environmental Consequences of Their Actions.

NEPA establishes the “continuing responsibility of the Federal Government to use all practicable means, consistent with other essential considerations of national policy, to improve and coordinate Federal plans, functions, programs, and resources to the end that the Nation may,” among other things, “fulfill the responsibilities of each generation as trustee of the environment for succeeding generations,” and “assure for all Americans safe, healthful, productive, and esthetically and culturally pleasing surroundings.” 42 U.S.C. § 4331(b). To that end, NEPA requires every agency, before taking a “major Federal actio[n] significantly affecting the quality of the human environment,” to prepare an EIS that details the environmental impacts of the proposed action, their significance, and possible alternatives to the proposed action. *Id.* § 4332(2)(C). Agency approval of a project conducted by a private party—whether “approved by

permit or other regulatory decision”—may qualify as a major federal action. 40 C.F.R. § 1508.1(q)(3)(iv).

In implementing NEPA, the Council on Environmental Quality (“CEQ”) has grouped federal actions into three overarching categories. First, an agency may conclude that a certain type of action “[n]ormally does not have significant effects” on the environment. 40 C.F.R. § 1501.3(a)(1). Such actions may be “categorically excluded” from further NEPA review, *id.*, unless “extraordinary circumstances” indicate that the action “may have a significant effect,” *id.* § 1501.4(b). Second, if an action “[i]s not likely to have significant effects or the significance of the effects is unknown,” the agency must prepare an “environmental assessment” (“EA”) before taking the action. *Id.* § 1501.3(a)(2). An EA briefly discusses the purpose and need for the proposed action, alternatives to the proposed action, the environmental impacts of the proposed action and alternatives, the agencies and persons consulted, and provides sufficient evidence and analysis for determining whether to prepare an EIS or a finding of no significant impact. *Id.* § 1501.5(c). If the EA determines that no significant impact to the environment will occur, agencies typically issue a Finding of No Significant Impact (“FONSI”) to document their decision. Finally, if an action is “likely to have significant effects” on the environment, the agency must prepare an EIS. *Id.* § 1501.3(a)(3); *see also Sierra Club v. Peterson*, 717 F.2d 1409, 1415 (D.C. Cir. 1983) (“If *any* ‘significant’ environmental impacts might result from the proposed agency action then an EIS must be prepared *before* the action is taken.”).

When determining the significance of environmental effects, agencies must consider, among other things, both the short-term and long-term effects of the action, both the beneficial and adverse effects of the action, and the effects of the action on public health and safety. 40 C.F.R.

§ 1501.3(b)(2). Agencies must also consider the affected environmental area and its resources. *Id.* § 1501.3(b)(1).

The CEQ has directed agencies to adopt their own regulations identifying which types of actions typically are categorically exempt from NEPA review, which typically require an EA, and which typically require an EIS. 40 C.F.R. § 1507.3(e)(2). The Commission’s regulations, adopted in 1986, construe the categorical exemption broadly: They extend the exemption to *all* Commission actions that do not fall within three narrow categories. *See* 47 C.F.R. §§ 1.1306(b), 1.1307(a)–(b) (excepting only actions involving special locations, such as wildlife preserves and historic sites; actions involving high-intensity lighting; and actions resulting in human exposure to excessive radiofrequency levels).

Under § 1.1307(c), however, any interested person may submit a petition explaining that “a particular action, otherwise categorically excluded, will have a significant environmental effect.” 47 C.F.R. § 1.1307(c). The Bureau must review the petition and, if it determines that the action “*may* have a significant environmental effect,” it must require the applicant to prepare an EA. *Id.* (emphasis added).

Given the breadth of the Commission’s categorical exemption, NEPA requires the Commission to seriously consider petitions asserting that an otherwise exempted action is likely to have a significant environmental impact. *See Am. Bird Conservancy, Inc. v. FCC*, 516 F.3d 1027, 1032–34 (D.C. Cir. 2008); *see also* 40 C.F.R. § 1501.4(b) (stating that categorical exclusions do not apply if “extraordinary circumstances” indicate that the action “may have a significant effect”). A lack of specific scientific evidence or consensus is not itself a sufficient reason to decline to prepare an EA. Indeed, the existence of conflicting scientific studies “confirms, rather than refutes,” that an action *may* have a significant impact and thus is ineligible for a categorical

exemption. *Id.* at 1033–34. And because “the basic thrust of an agency’s responsibilities under NEPA is to predict the environmental effects of proposed action before the action is taken and those effects fully known,” courts “reject any attempt by agencies to shirk their responsibilities under NEPA by labeling any and all discussion of future environmental effects as ‘crystal ball inquiry.’” *Scientists’ Inst. for Pub. Info., Inc. v. Atomic Energy Comm’n*, 481 F.2d 1079, 1091–92 (D.C. Cir. 1973).

NEPA plays a particularly important role in requiring federal agencies to seriously consider the environmental impacts of new forms of technology. Indeed, “[o]ne of NEPA’s main functions was to bolster [the] capacity to understand and control the effects of new technology.” *Found. on Econ. Trends v. Heckler*, 756 F.2d 143, 147 (D.C. Cir. 1985); *see* 42 U.S.C. § 4331(a) (expressing concern that the effects of “new and expanding technological advances” might threaten the environment). NEPA thus requires the Commission to take a “hard look” at the environmental impact of allowing SpaceX to relocate its satellites—*before* approving the proposed modification. *WildEarth Guardians v. Jewell*, 738 F.3d 298, 303 (D.C. Cir. 2013); *see Sierra Club*, 717 F.2d at 1413.

II. SpaceX’s Modification Proposal Would Likely Have a Significant Impact on the Environment.

SpaceX’s proposal to lower the orbital altitude of nearly 3,000 satellites is likely to have a significant effect on the environment in at least three main ways. First, SpaceX expects that the proposal will dramatically accelerate the time period within which its satellites will reenter and burn up in the atmosphere. As explained by SpaceX, this application is the first step in launching a massive amount of satellites in the future. At least 10,000 satellites are expected to be launched within 15 years to maintain the fleet at issue (possibly many more when early failures are factored in). These reentries and launches could affect the chemical composition of Earth’s atmosphere,

and could also pose safety risks to aircraft and human populations. Second, the proposal threatens to create significant light pollution, as the apparent magnitude of the satellites would be brighter. And third, the proposal would densify the orbital altitude at issue, and, coupled with SpaceX's experiential failure rate, would unreasonably increase the risks of collisions and the creation of new space debris.

A. According to SpaceX, Its Modification Proposal Would Accelerate the Time Period Within Which Its Satellites Reenter the Atmosphere.

If SpaceX's modification proposal were granted, the 2,824 satellites at issue would join a fleet of 1,584 operating satellites that the Commission already permitted SpaceX to relocate from altitudes above 1,110 km to lower altitudes around 550 km, producing a total fleet of 4,408 operating satellites at altitudes ranging from about 540 km to about 570 km. *See Space Expl. Holdings, LLC*, 34 FCC Rcd. 2526 (Apr. 26, 2019). SpaceX explains that this reduction in orbital altitude would dramatically accelerate the time period within which many thousands of its satellites would burn up in the Earth's atmosphere. At the previously authorized altitudes, it would take centuries for the satellites to passively deorbit; at lower altitudes, SpaceX says that it "will take less than five years (even under worst-case assumptions)." SpaceX Application at 7. SpaceX touts this as beneficial to the environment, claiming that the hastened reentry of its satellites into the Earth's atmosphere will promote a cleaner orbital environment. SpaceX Application at ii, 7; SpaceX Ex Parte Filing at 9, IBFS File No. SAT-MOD-20200417-00037 (Sept. 14, 2020).

But the reduced time in orbit is not an unalloyed good. Maintaining this fleet of 4,408 operating satellites would require SpaceX to launch what it estimates as about 10,000 satellites over the course of 15 years (based on proposed satellite lifetimes). Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Div., Int'l Bureau, FCC at 5–6, IBFS File No. SAT-MOD-20200417-00037 (May 15, 2020). This number could be even

higher if SpaceX needs to replenish its fleet at a faster rate due to unanticipated failures or shorter-than-expected actual life, as has happened for many of the satellites that SpaceX has already launched. See Morgan McFall-Johnsen, *About 1 in 40 of SpaceX's Starlink Satellites may have Failed*, Business Insider (Oct. 16, 2020), <http://www.businessinsider.com.au/spacex-starlink-internet-satellites-percent-failure-rate-space-debris-risk-2020-10>. To put these numbers into perspective, humans have launched about 9,000 satellites *total* since space exploration first began. *Why in the Next Decade Companies Will Launch Thousands More Satellites than in All of History*, CNBC (Dec. 15, 2019), <http://www.cnbc.com/2019/12/14/spacex-oneweb-and-amazon-to-launch-thousands-more-satellites-in-2020s.html>. In effect, SpaceX anticipates treating its satellites as disposable, with little regard for the harmful environmental impacts they may have, rather than deploying a smaller, more efficient and environmentally friendly fleet of satellites.

Given the unprecedented nature of SpaceX's proposal, there is no base of experience on which the Commission can draw to determine that granting the proposed modification—and thus permitting the launch and decay of at least 10,000 low-Earth-orbit satellites within the span of less than two decades—will have “no significant effect on the quality of the human environment” and thus can be “categorically excluded from environmental processing.” 47 C.F.R. § 1.1306(a). SpaceX's plan to dramatically accelerate the time period within which its satellites will reenter the atmosphere could create several potentially significant atmospheric and safety-related impacts—impacts that the Commission must consider.

1. Impacts on Atmosphere

SpaceX's modification proposal could affect Earth's atmosphere in several ways. First, each satellite launch contributes to ozone depletion because rockets emit ozone-destroying compounds. Martin Ross et al., *Limits on the Space Launch Market Related to Stratospheric Ozone Depletion*, 7 *Astropolitics* 50 (2009). Many rockets emit highly reactive compounds that

“accumulate in the stratosphere,” where they “drive ozone destroying catalytic reactions.” *Id.* at 52. Because these reactive compounds naturally comprise only about one-thousandth of the ozone layer, “relatively small absolute amounts of these reactive compounds can significantly modify ozone levels.” *Id.* Rockets thus “have a significant potential to become a significant contributor to the problem of stratospheric ozone depletion.” *Id.*

Ozone depletion significantly harms the human environment. Among other things, it increases the amount of ultraviolet radiation that reaches Earth, which leads to increased rates of skin cancer and cataracts. M. Norval et al., *The Effects on Human Health from Stratospheric Ozone Depletion and Its Interactions with Climate Change*, 6 *Photochemical & Photobiological Scis.* 232 (2007). Based on SpaceX’s launches to date, each of which has carried about 60 satellites, see Jeff Foust, *SpaceX Reaches 100 Successful Launches with Starlink Mission*, *SpaceNews* (Oct. 24, 2020), <http://spacenews.com/spacex-reaches-100-successful-launches-with-starlink-mission>, more than 165 launches can be expected to launch at least 10,000 satellites over 15 years. NEPA requires the Commission to consider the impact on stratospheric ozone levels of authorizing the deployment of such a large number of satellites into low-altitude orbit.

Second, the dramatic acceleration of satellites burning up in the atmosphere during their reentry and demise could harm the stratosphere and global climate. When satellites built from aluminum burn up, they can produce aluminum oxide (also called “alumina”), a substance that may contribute to radiative forcing—a phenomenon partially responsible for climate change. See Martin N. Ross & Patti M. Sheaffer, *Radiation Forcing Caused by Rocket Engine Emissions*, 2 *Earth’s Future* 177 (2014). This is so because alumina absorbs more radiation coming up from the Earth than it reflects coming from the sun, thus warming the stratosphere and likely the upper troposphere. *Id.* at 193. The Starlink satellites are of “predominantly aluminum construction.”

SpaceX Application, Attachment A, at 24. Just weeks ago, researchers predicted that the reentry of satellite constellations like SpaceX's could cause as much as 22,050,000 lbs of alumina to exist in the atmosphere at one time. Lee Organski et al., Aerospace Corp., *Environmental Impacts of Satellites from Launch to Deorbit and the Green New Deal for the Space Enterprise* (presented Dec. 2020). The Commission must evaluate what effects such a large increase in atmospheric alumina might have on our climate.

The high volume of reactive chemicals produced by 10,000 or more satellites burning in the atmosphere could also have significant impacts that would remain unknown without NEPA review. Recent research suggests that “particles from reentering space junk will be a zoo of complex chemical types,” that “[r]eentry is as much of an ‘emission’ as launch,” and “[v]ery little is known about reentry dust production, the microphysics of the particles and how reentry dust could affect climate and ozone.” Martin N. Ross & Leonard David, *An Underappreciated Danger of the New Space Age: Global Air Pollution*, Sci. Am. (Nov. 6, 2020), <http://www.scientificamerican.com/article/an-underappreciated-danger-of-the-new-space-age-global-air-pollution/>. Moreover, “[s]ome particles are very reactive, so small amounts of them could have a significant effect on atmospheric chemistry.” Leonard David, *How Much Air Pollution Is Produced by Rockets?*, Sci. Am. (Nov. 29, 2017), <http://www.scientificamerican.com/article/how-much-air-pollution-is-produced-by-rockets/>.

Moreover, this application cannot be considered in isolation; the Commission must account for the fact that SpaceX is building out, not reducing, the size of its low-Earth-orbit fleet. SpaceX already has authorization for about 12,000 operating low-Earth-orbit satellites, and it has separately proposed launching 30,000 additional operating satellites, for a total of about 42,000 operating satellites. See Application for Approval for Orbital Deployment and Operating

Authority for the SpaceX Gen2 NGSO Satellite System at ii, IBFS File No. SAT-LOA-20200526-00055 (May 26, 2020). Maintaining that fleet will require launching *multiples* of that number over a 15-year license term, given the 5-year design life of the satellites, and an equal number will demise in the Earth's atmosphere.

Because “the basic thrust of an agency’s responsibilities under NEPA is to predict the environmental effects of proposed action before the action is taken and those effects fully known,” *Scientists’ Inst. for Pub. Info.*, 481 F.2d at 1091–92, NEPA obligates the Commission to conduct further research to understand the impacts of SpaceX’s proposal on atmospheric chemistry.

2. Impacts on Aircraft and Surface

As a general matter, it is estimated that about 60–90% percent of a satellite’s mass burns up during reentry, leaving about 10–40% that reaches the surface. *Satellite Reentry: Manipulating the Plunge*, Aerospace Corp. (May 5, 2018), <http://aerospace.org/article/satellite-reentry-manipulating-plunge>. This falling space debris ordinarily does not pose a grave threat because, as the National Environmental Satellite Data and Information Service notes, it’s “largely a numbers game.” *Does Space Junk Fall from the Sky?*, Nat’l Env’t Satellite Data & Info. Serv. (Jan. 19, 2018), <http://www.nesdis.noaa.gov/content/does-space-junk-fall-sky>. The fact that humans inhabit a relatively small percentage of the Earth’s surface, combined with the currently small number of objects entering the atmosphere each year (between 200 and 400), makes it relatively unlikely that a human settlement will be harmed by space debris. *Id.*

But SpaceX’s plan to launch and operate over 10,000 satellites at lower altitudes (from one of its authorized constellations alone) could increase the risk of health-related harm to the human environment to an unacceptable level. *See* 40 C.F.R. § 1508.1(g)(1) (effects on human environment include “health effects”). In particular, “[r]isks to aircraft posed by small debris surviving a reentry might be a major problem” if SpaceX’s proposal is granted. William H. Ailor,

Aerospace Corp., *Large Constellation Disposal Hazards* 14 (2020). By 2030, SpaceX’s 4,425 operating low-orbit satellites could have a cumulative aircraft-related casualty expectation of as high as 0.13 per year, or about 1 casualty every 8 years, and SpaceX’s 7,518 operating very-low-orbit satellites (between 340 and 370 km) could have a casualty expectation as high as 1 every 4 years. *Id.* at 12. The cumulative aircraft-related casualty expectation for *any* debris striking aircraft (not limited to SpaceX) could approach 1 per year. *Id.* at 13. Even if some of these precise figures are “likely overstated” to some extent, *id.* at 12, the risks of health-related environmental harms they identify are nevertheless significant and real.

Similarly, “[h]azards to people on the ground will also be a problem.” Ailor, *supra*, at 15. By 2030, it is predicted that falling satellite debris could harm a person on the Earth’s surface as often as every 4 years. *Id.* at 8. SpaceX’s 4,425 operating low-orbit satellites could cause a casualty (again, based on their originally authorized altitude) on the surface as often as once every 18 years, whereas SpaceX’s 7,518 operating very-low-orbit satellites could cause such a casualty once every 9 years. *Id.* This problem is not purely hypothetical; in the picture below, Lottie Williams is holding a piece of reentered debris that brushed her shoulder:



Id. at 5–6.

One way of mitigating these hazards to people on Earth’s surface is to design satellites with longer lifetimes and “reduce the number reentering each year.” Ailor, *supra*, at 14. SpaceX does

exactly the opposite: expecting tens of thousands of satellites to burn up in the atmosphere in a couple of decades. The Commission is required to consider the long-term effects of SpaceX's proposal on public health and safety. *See* 40 C.F.R. § 1501.3(b)(2).

And harm to humans is only one environmental concern associated with space debris. Any debris that survives re-entry will land *somewhere*, polluting the Earth's natural landscape and oceans. Burning debris, moreover, could cause a fire, resulting in potentially severe environmental consequences. In 2017, for example, parts of a rocket used for a Russian space launch fell to Earth and caused a fire on the steppes of Kazakhstan that spread almost 10 miles. *Kazakh Man Dies in Fire After Russian Rocket Launch: Govt.*, Phys.org (June 15, 2017), <http://phys.org/news/2017-06-kazakh-dies-russian-rocket-govt.html>. The Commission must consider these potential impacts on Earth's natural resources, especially if, as SpaceX claims, reentries will occur sooner.

SpaceX has said that it now expects its satellites to completely burn up in the atmosphere. *See* Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Div., Int'l Bureau, FCC at 3, IBFS File No. SAT-MOD-20181108-00083 (Mar. 13, 2019) (stating that "SpaceX has now developed a system architecture that will be completely demisable"). But the Commission cannot take that assertion at face value; NEPA obligates the Commission to take a "hard look" at whether satellite debris is likely to have environmental impacts on Earth's surface. *WildEarth Guardians*, 738 F.3d at 303. And in any event, even if SpaceX's satellites completely burn up in the atmosphere, this means *more* alumina accumulating in the stratosphere and contributing to radiative forcing—another factor the Commission must consider.

The environmental effects caused by satellite launches and reentries are likely to be significant, requiring the Commission to prepare an EIS. *See* 40 C.F.R. § 1501.3(a)(3). At the very least, the environmental effects of SpaceX's proposed modification are unknown, requiring

an EA to further study them. *See id.* § 1501.3(a)(2). There is no basis to conclude that SpaceX’s proposal will have no significant environmental impacts.

B. SpaceX’s Modification Proposal Would Likely Increase Light Pollution.

New research also raises serious light-pollution concerns related to SpaceX’s modification proposal. Large satellite fleets can reflect sunlight towards the Earth’s surface. Often visible even to the naked eye, this light pollution “significantly affect[s] the quality of the human environment” by creating aesthetic, scientific, social, cultural, and health effects. 42 U.S.C. § 4332(2)(C); 40 C.F.R. § 1508.1(g)(1).

1. Impacts of Light Pollution

Aesthetic Effects. Light pollution from Starlink mega-constellations can create an aesthetic distraction for any stargazer and can pose particular challenges for astrophotographers by leaving bright streaks of light across the exposures they capture. *See* Luc H. Riesbeck et al., Aerospace Corp., *The Future of the Night Sky: Light Pollution from Satellites* 2–3 (2020). Consider this photograph of Bryce Canyon, in Utah, “photobombed” by a Starlink constellation:

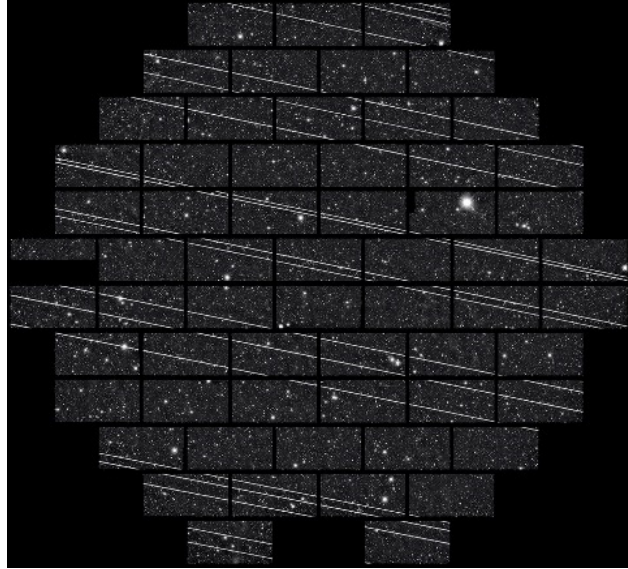


Walker et al., *supra*, at 4. Or consider this photograph of the Comet NEOWISE (C/2020 F3), which reportedly was ruined by Starlink satellites:



Chris Young, *Starlink Satellites Ruin Comet NEOWISE Time-Lapse Image*, Interesting Eng'g (July 24, 2020), <http://interestingengineering.com/starlink-satellites-ruin-comet-neowise-time-lapse-image>.

Scientific Effects. The aesthetic problems of Starlink mega-constellations are not limited to casual stargazers and photographers. Light pollution poses a particular threat to professional astronomers' enjoyment and study of the night sky because “no currently apparent combination of known mitigations can completely avoid the impacts of the satellite trails on the science programs of the coming generation of optical astronomy facilities.” Walker et al., *Appendices to “Impact of Satellite Constellations on Optical Astronomy and Recommendations Toward Mitigations”* 49 (2020) (emphasis omitted) (“*Appendices*”). This picture from an observatory illustrates the problem:



D.L. Cade, *Astronomers Warn Starlink Satellites Could Have a ‘Fatal’ Impact on Astrophotography*, PetaPixel (Aug. 28, 2020), <http://petapixel.com/2020/08/28/astronomers-warn-starlink-satellites-may-have-a-fatal-impact-on-astrophotography/>.

Social & Cultural Effects. Beyond aesthetics, the night sky also has “cultural and social value that is difficult, if not impossible, to quantify in dollars.” *Appendices, supra*, at 106. Among those affected by light pollution visible to the naked eye are “casual stargazers and people whose cultural and religious practices involve use of the night sky.” *Id.* at 107. Hundreds of amateur astronomy organizations exist across the country, many of which host viewing nights and stargazing parties that could be affected by light pollution. Go Astronomy, *Astronomy Club Directory* (last accessed Dec. 21, 2020), <http://www.go-astronomy.com/astro-club-search.htm>.

Health Effects. Light pollution in general is known to have negative health consequences. See Fabio Falchi et al., *Limiting the Impact of Light Pollution on Human Health, Environment and Stellar Visibility*, 10 J. Env’t Mgmt. 2714 (2011); Ron Chepesiuk, *Missing the Dark: Health Effects of Light Pollution*, 117 Env’t Health Persps. 20 (2009). More specifically here, though, light pollution from satellites may affect human health because of its impact on stargazing—an

activity that can contribute to health and well-being. See Rebecca Bell et al., *Dark Nature: Exploring Potential Benefits of Nocturnal Nature-Based Interaction for Human and Environmental Health*, 5 Eur. J. Ecopsychology 1, 10 (2014) (“Stargazing might cultivate wellbeing through increased physical and social activity in addition to developing personal growth through sense of achievement. A range of transcendent and spiritual elements which are seen as an integrative component in health and wellbeing . . . were highlighted by participants.”).

2. The Proposed Modification’s Effect on Light Pollution

Astronomical organizations have recently drawn attention to the light-pollution problems caused by launching large numbers of satellites. For example, the American Astronomical Society warned that mega-constellations create “the potential for substantial adverse impacts to ground- and space-based astronomy.” Am. Astronomical Soc’y, *AAS Issues Position Statement on Satellite Constellations* (June 10, 2019), <http://aas.org/press/aas-issues-position-statement-satellite-constellations>. Other organizations have voiced significant scientific concerns about the Starlink program specifically and how it will affect astronomical research. See, e.g., Royal Astronomical Soc’y, *RAS Statement on Starlink Satellite Constellation* (June 7, 2019), <http://ras.ac.uk/news-and-press/news/ras-statement-starlink-satellite-constellation>; see also Int’l Astronomical Union, *IAU Statement on Satellite Constellations* (June 3, 2019), <http://www.iau.org/news/announcements/detail/ann19035/>.

These concerns are well founded. New scientific research suggests that light pollution from satellite mega constellations orbiting at the altitude requested in SpaceX’s proposed modification may have substantial adverse astronomical effects. In particular, visibility simulations indicate that astronomers should expect “significant negative impacts” from the Starlink program for satellites orbiting below 614 kilometers—even among SpaceX’s proposed second-generation satellites. Walker et al., *supra*, at 3. At the altitude proposed in the

modification, “wide-field astrophotography would be severely impacted by the fully-deployed Starlink Generation 2 . . . constellation[.]” *Id.* at 15.

Starlink’s light-pollution problems are especially pronounced given (1) the sheer quantity of satellites in the overall proposal, and (2) the altitude at which they will orbit. Light pollution can be mitigated by reducing the number of satellites in orbit. *Id.* at 5. But, as noted, SpaceX is moving toward 42,000 operating satellites. *See* Application for Approval for Orbital Deployment and Operating Authority for the SpaceX Gen2 NGSO Satellite System at ii, IBFS File No. SAT-LOA-20200526-00055 (May 26, 2020). In its application requesting approval for an additional 30,000 operating satellites, SpaceX goes so far as to “guarante[e]” that there will be “*multiple satellites in view* for every customer located at *any* point on the ground.” *Id.* (emphases added).

Moreover, the proposal directly at issue here would bring nearly 3,000 operating satellites hundreds of kilometers *closer* to Earth than originally contemplated. Because the brightness of a satellite “is a function of the altitude of [that] satellite[.]” lowering the altitude of Starlink satellites generally risks making them brighter—the lower the satellite, the brighter the apparent magnitude. Riesbeck et al., *supra*, at 12. These concerns remain despite SpaceX’s recent mitigation efforts and promises to darken its satellites; indeed, SpaceX has admitted that it is impossible to fully eliminate its satellites’ light pollution. SpaceX, *Astronomy Discussion with National Academy of Sciences* (Apr. 28, 2020), <http://www.spacex.com/updates/starlink-update-04-28-2020/>.

The Commission cannot duck these concerns on the asserted ground that it “does not have jurisdiction over the visibility of satellites.” SpaceX Application at 12. There is no doubt that light pollution is a relevant consideration for the Commission. *See* 47 C.F.R. § 1.1307(a)(8). And NEPA permits—indeed, *requires*—the Commission “to consider every significant aspect of the environmental impact of [the] proposed action.” *Balt. Gas & Elec. Co.*, 462 U.S. at 97. Granting

SpaceX's proposed modification would bring the satellites closer to Earth, making those satellites appear brighter. The Commission's decision thus will directly affect the amount of light pollution in the environment, placing NEPA responsibilities squarely on the Commission's shoulders. *See Dep't of Transp. v. Pub. Citizen*, 541 U.S. 752, 765–70 (2004).

At the very least, the effects of light pollution from large satellite constellations “remain underexamined.” Riesbeck et al., *supra*, at 2. And NEPA review is especially important in cases involving “expanding technology” with unknown environmental impacts. Note, *The Fault in Our Stars: Challenging the FCC's Treatment of Commercial Satellites as Categorically Excluded from Review Under the National Environmental Policy Act*, 22 Vand. J. Ent. & Tech. L. 923, 943 (2020); *see also Found. on Econ. Trends*, 756 F.2d at 147. The Commission should prepare an EIS to study these effects; at a minimum, it must prepare an EA.

C. SpaceX's Modification Would Likely Increase Space Debris.

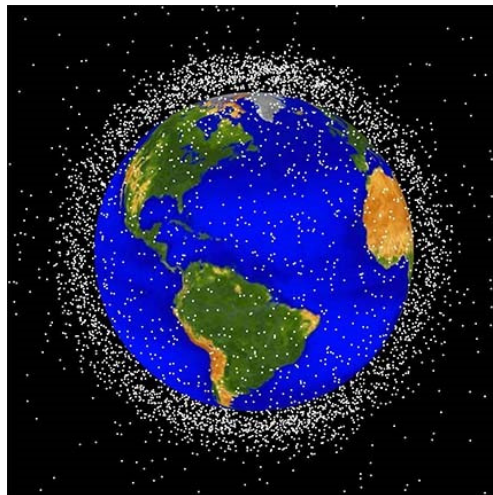
Finally, SpaceX's proposed modification is likely to worsen the space-debris crisis, foreclosing a finding that it will not cause a significant environmental impact.

1. Space Debris Poses Serious Environmental Harms.

Space debris, or orbital debris, refers to any artificial material orbiting Earth other than functioning spacecraft, “ranging from flakes of paint from a spacecraft to an intact satellite that has stopped functioning.” *The Fault in Our Stars*, *supra*, at 931; *see* Space Debris, NASA, http://www.nasa.gov/centers/hq/library/find/bibliographies/space_debris (last visited Dec. 21, 2020). Satellites can become space debris after failures—including the types of satellite failures that SpaceX has experienced to date at unexpected levels—render them unable to be maneuvered into lower orbits and disposed of as originally planned, causing them to remain in space longer than expected. *See* Viasat Ex Parte Filing at 3–5, IBFS File No. SAT-MOD-20200417-00037 (Dec. 21, 2020); Viasat Ex Parte Filing at 1–4, IBFS File No. SAT-MOD-20200417-00037 (Nov.

19, 2020). Satellites also can become space debris due to collisions with other space objects that fragment them into many small pieces that spread into orbits many hundreds of kilometers away, with orbital lifetimes of up to 100 (or even more) years, polluting other orbits, endangering other satellites, and disrupting vital communications services, both near- and long-term. Viasat Petition at iii, 3, 7, 17, 36. Indeed, the “largest source of debris in the future is expected to be accidental collisions.” Marlon Sorge, Aerospace Corp., *Commercial Space Activity and Its Impact on U.S. Space Debris Regulatory Structure* 5 (2017).

Space debris is already pervasive above the Earth’s atmosphere. There are “millions of pieces of space junk flying in [low-Earth orbit],” which “can reach speeds of 18,000 miles per hour, almost seven times faster than a bullet.” *Space Debris, supra*. As the following picture illustrates, low-Earth orbit has been described as “the world’s largest garbage dump,” and removing space debris is an expensive endeavor—if doing so is even possible for large amounts of small fragments. *Id.*



Id.

The Commission has long acknowledged that such debris “poses a potential risk” to (1) “the continued reliable use of these orbital regimes for space-based services and operations” and

(2) “the continued safety of persons and property in space and on the surface of the Earth.” *Mitigation of Orbital Debris*, 19 FCC Rcd. 11,567, 11,570 (2004). Collisions involving even very small debris moving at high speeds “are capable of producing significant damage.” *Id.* And collisions further amplify the debris problem by “produc[ing] a large amount of additional debris, which can be disbursed over a wide orbital area.” *Id.*

Because of those risks, space debris threatens to “significantly affect[t] the quality of the human environment” in multiple ways. 42 U.S.C. § 4332(2)(C).

First, space debris may cause severe “ecological” harm to the “functioning of [the] affected ecosyste[m],” *i.e.*, the near-Earth orbital environment. 40 C.F.R. § 1508.1(g)(1). “The main cost and risk of collisions with debris is the generation of further debris, which could ultimately lead to the so-called Kessler syndrome of cascading, self-generating collisions” and “render certain orbits unusable.” Marit Undseth et al., *Space Sustainability: The Economics of Space Debris in Perspective* 7 (2020). Even short of that “ecological tipping point,” *id.*, space debris interferes with human efforts to explore and develop near-Earth space.

Second, space debris may cause severe “economic” harm. 40 C.F.R. § 1508.1(g)(1). In 2016 alone, the space industry generated about \$158 billion in the United States. Tina Highfill et al., *Measuring the Value of the U.S. Space Economy*, 99 J. U.S. Bureau Econ. Analysis 1, 4 (2019). Space debris “reduces the realized value of space activities by increasing the probability of damaging existing satellites or other space vehicles.” Nodir Adilov et al., *Economic Dynamics of Orbital Debris: Theory and Application* 5 (2019). As the amount of space junk grows, the opportunity to use near-Earth space for scientific and economic purposes diminishes. That is not a hypothetical possibility. Just two months ago, NASA voiced concerns about how space debris could interfere with its assets and operations, thus threatening U.S. scientific interests, among

various other vital U.S. interests. *See* Letter from Samantha Fonder, NASA Representative to the Commercial Space Transp. Interagency Grp., to Marlene Dortch, Sec’y, FCC (Oct. 29, 2020).

These harmful effects of generating additional space debris trigger NEPA obligations, even if debris originating from the proposed action may travel outside the space directly above the United States. Federal agencies must analyze impacts that are caused by proposed federal actions, even if the impact will be felt in “the global commons outside the jurisdiction of any nation.” Exec. Order No. 12,114, § 2-3(a), 44 Fed. Reg. 1957 (Jan. 4, 1979). Space is such a global commons, *see* Vito De Lucia & Viviana Lavicoli, *From Outer Space to Ocean Depths: The ‘Spacecraft Cemetery’ and the Protection of the Marine Environment in Areas Beyond National Jurisdiction*, 49 Cal. W. Int’l L.J. 345, 352 (2019), so the problems of space debris at issue here fall within the ambit of NEPA.

2. The Proposed Modification Risks Worsening the Harms Associated with Space Debris.

SpaceX’s proposed modification would crowd lower altitudes of near-Earth orbit with thousands more operational satellites. That densification creates an increased risk of collision with other satellites at the same orbital altitude, with those in overlapping orbits, and with those traversing those orbits. SpaceX, knowing that it can maintain that fleet simply by launching thousands more satellites, has not adequately ensured that its fleet will not collide with other space objects or otherwise clutter space with harmful debris. SpaceX admits, as it must, that its modification involves greater collision risks than before, and Viasat has shown that SpaceX is substantially underestimating those risks. Reply of Viasat Inc. in Support of its Petition to Deny or Defer at 4–8, IBFS File No. SAT-MOD-20200417-00037 (Aug. 7, 2020).

Recent experience with Starlink satellites illustrates how real these collision concerns are. As recently as September 2019, “a satellite within the Starlink constellation nearly collided with

European Space Agency satellite Aeolus despite an earlier warning from the US military to the two operators that a collision was likely.” *The Fault in Our Stars, supra*, at 943 n.171. If and when collisions occur, they will create more space debris—thus worsening an already serious problem. Even one collision can create hundreds to thousands of pieces of debris. *See, e.g.*, Brian Weeden, *2009 Iridium-Cosmos Collision Fact Sheet*, Secure World Found. (Nov. 10, 2010), http://swfound.org/media/6575/swf_iridium_cosmos_collision_fact_sheet_updated_2012.pdf.

Notably, NASA itself has weighed in on the issue, voicing concerns about mega-constellations and orbital debris. NASA explained to the Commission that SpaceX’s originally proposed constellation raised a number of concerns:

[T]he reliability of the design and fabrication of the [SpaceX] spacecraft and the reliability that the spacecraft can accomplish the post-mission disposal are of particular interest from the perspective of keeping the orbital environment safe. A design or fabrication flaw can potentially lead to malfunction or even explosion of many spacecraft during the deployment or mission operations of the constellation. Likewise, clearing an operational orbit of non-operating spacecraft becomes more important when applied to a large constellation.

Letter from Anne E. Sweet, NASA Representative to the Commercial Space Transp. Interagency Grp., to Marlene Dortch, Sec’y, FCC (June 26, 2017). The Commission acknowledged that these issues must be addressed, “agree[ing] 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, as well as the reliability of these systems’ methods for deorbiting the spacecraft.” *Space Expl. Holdings, LLC*, 33 FCC Rcd. at 3398.

The Commission cannot take SpaceX’s word for it that the thousands of satellites it is seeking to pack into a lower orbit will not materially increase the risks of collisions and produce excessive space debris—especially because SpaceX knows that when its satellites do collide with

other space objects and fragment or fail, it can always launch more. NEPA requires the Commission to evaluate the serious risks that SpaceX's proposed modification poses to the orbital environment. The Commission should prepare an EIS to evaluate these risks; at a minimum, it must prepare an EA.

CONCLUSION

For all of these reasons, Viasat respectfully requests that the Commission deny or defer consideration of SpaceX's proposed modification. More specifically, the Commission should prepare an EIS fully evaluating the environmental impacts of the proposed action pursuant to NEPA, before acting upon SpaceX's application. In the alternative, the Commission should prepare an EA before acting upon SpaceX's application. This request for relief is supplemental to the relief sought in Viasat's initial petition.

Date: December 22, 2020

Respectfully submitted,

/s/ Helgi C. Walker

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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 Petition Pursuant to Section 1.1307(c) (“NEPA Petition”).
2. I am the technically qualified person responsible for preparation of engineering information contained in the NEPA Petition. I have reviewed the NEPA Petition and certify that, to the best of my knowledge, information and belief, the factual assertions in the NEPA Petition are truthful and accurate.

/s/ Mark. A. Sturza

Mark A. Sturza

President

3C Systems Company

December 22, 2020

CERTIFICATE OF SERVICE

I, Helgi C. Walker, hereby certify that on this 22nd day of December, 2020, I caused to be served a true copy of the foregoing Petition Pursuant to Section 1.1307(c) of Viasat, Inc. and accompanying documents via first-class mail upon the following:

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