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

Application of	)	
SPACE EXPLORATION HOLDINGS, LLC	)	Call Sign: S2992
For Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System	)	File No. SAT-LOA-20170301-00027

CONSOLIDATED RESPONSE TO COMMENTS
OF SPACE EXPLORATION HOLDINGS, LLC

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SUMMARY

Space Exploration Holdings, LLC ("SpaceX") hereby responds to the comments filed with respect to its application for operating authority for a non-geostationary orbit ("NGSO") satellite system in the Fixed-Satellite Service ("FSS") using V-band frequencies. The SpaceX constellation is designed to achieve an ambitious and compelling goal: connecting the hundreds of millions of Americans and billions of global citizens to the high-speed broadband Internet services that can then fuel education and entertainment, grow healthcare and agriculture, and propel commerce and connected government. The advanced SpaceX constellation has been designed for unprecedented levels of adaptability, spectral efficiency, and coordination flexibility. The preservation of a viable space environment and safety on Earth are paramount in the project. The majority of the satellites are intentionally placed at orbital altitudes at which friction from the Earth's atmosphere is sufficient to safely de-orbit any non-responsive satellite or other debris in a matter of weeks.

Only four parties filed comments on SpaceX's V-band application, and none asked the Commission to deny the application. Questions raised by commenters focused on three areas that have been addressed extensively by SpaceX in its application: spectrum sharing, requested waivers, and protection of space.

Regarding spectrum sharing, SpaceX has included extensive discussion in its application of the system's unique capabilities to share spectrum resources equitably and efficiently with other licensed systems, including geostationary orbit ("GSO") satellites. SpaceX is employing advanced operational techniques and technologies to maximize its spectral efficiency and ability to co-exist with other space- and ground-based systems. These include using high-elevation angles when communicating with earth stations, using highly directional space station and earth station beams, and satellite diversity that allows service to any given customer location from many different satellites. It should be noted that neither the Commission nor the International Telecommunication

Union ("ITU") has yet adopted GSO/NGSO sharing criteria for the V-band, such as the equivalent power flux-density ("EPFD") limits applicable in the Ku- and Ka-bands. SpaceX has encouraged the development and adoption of such limits, and notes that because there are no legacy systems already operating in V-band, there is an ideal opportunity to develop sensible rules that protect eventual GSO V-band systems without unduly restricting the next generation of highly advanced NGSO satellite systems proposed in the same bands. Accordingly, SpaceX has no objection to commenters' request that the Commission condition grant of its application on spectrum sharing rules (including EPFD limits) adopted in the future.

Second, commenters questioned whether the Commission's recent update of its NGSO rules would eliminate the need for the waivers requested by SpaceX relating to the time to deploy the constellation and its geographic coverage. SpaceX has supported the Commission's efforts to update the NGSO rules, which were badly out of date.

With respect to deployment milestones, SpaceX requested a limited waiver of the earlier requirement to deploy its entire NGSO system within six years of licensing, proposing instead that it be allowed to satisfy this milestone through an Initial Deployment of 1,600 satellites. The recently adopted NGSO rules require deployment of only half of an authorized NGSO system within six years, with the remainder deployed within three years thereafter. This additional flexibility is a welcome development, but it does not obviate the need for a waiver or undermine the rationale for granting one. The Commission imposes a deployment milestone in order to ensure that the licensee is committed to deploying its authorized system, so that valuable spectrum and orbital resources are used efficiently. SpaceX's Initial Deployment involves the manufacturing, launch, and bringing into service of more satellites than are currently in operation worldwide – more than sufficient to provide robust broadband service and to demonstrate SpaceX's

commitment. Deploying a large number of satellites over a six-year period, and the full constellation over a nine-year period, would require an unprecedented launch cadence and volume. SpaceX requested the waiver out of an abundance of caution against such requirements, which are considerable even for a company like SpaceX, which has led the drive to innovate launch and reusability capabilities. Indeed, even as the Commission adopted the revised milestone requirement, Commissioner O'Rielly questioned whether current launch capabilities are sufficient to meet the new performance benchmarks, and whether specific waivers of the rule may be required.

With respect to geographic coverage, SpaceX also requested a second, related waiver of the Commission's requirement that all NGSO systems provide coverage of all 50 states and U.S. territories. Once fully deployed, the SpaceX NGSO system will fully meet this requirement, as it will provide service to customers located virtually anywhere on the entire planet. At its Initial Deployment, however, SpaceX will cover all of the required area save for the northernmost parts of Alaska. SpaceX requested a waiver consistent with the waiver granted to another NGSO operator in an abundance of caution, as it was not clear at the time of filing whether the Commission's original geographic service requirements would apply to an interim stage of NGSO deployment. Notably, the Commission has now proposed to eliminate this coverage requirement, concluding that it would not serve the public interest to deny NGSO operators flexibility to determine their geographic areas of business operation, especially given that multiple NGSO systems can share the same frequency bands. In these circumstances, even assuming any requirement applies to an interim stage of deployment, there is good cause for the Commission to grant a waiver.

With respect to safety, SpaceX has demonstrated an unparalleled commitment to safe space operations in its current and planned space-based activities. In this application, SpaceX has provided more detailed information and analysis related to orbital debris mitigation and end-of-life disposal plans than any other applicant in this processing round. SpaceX's satellites will de-orbit far sooner than the international standard of 25 years, with the low-Earth orbit ("LEO") satellites re-entering the Earth's atmosphere within approximately one year and the very-low-Earth orbit ("VLEO") satellites at just a few weeks after completion of their mission. SpaceX's constellation will operate at a level of safety that more than satisfies every requirement established by NASA and regulatory authorities in other countries, based on an assessment using NASA's own Debris Assessment Software ("DAS"). In addition, SpaceX has been a partner with NASA for years on space reliability matters, and will continue to work with NASA as new reliability standards and best practices are evaluated, codified, and implemented.

Notably, only one commenter, WorldVu Satellites Limited ("OneWeb"), referenced any issues related to the safety of SpaceX's proposed NGSO system. Many of OneWeb's comments overlook, or fail to acknowledge, technical information that SpaceX has already submitted to address these matters in great detail and that OneWeb has yet to submit in its own application. For example, SpaceX provided detailed information on the orbital tolerances that its system will maintain – information that OneWeb itself has not provided. OneWeb also suggests that the Commission apply standards to SpaceX that the Commission has neither considered nor applied to any other licensed satellite system, whether within this processing round or outside of it. For example, OneWeb suggests a "buffer zone" of at least 125 km between the altitudes of NGSO systems, but provides no analysis that shows why such a large buffer zone is necessary – and ignores the fact that this recommendation would have the unfortunate consequence of

monopolizing large portions of the available LEO altitudes to a single operator. Similarly, OneWeb suggests that the Commission should impose a special condition on the de-orbit procedures for SpaceX satellites, without any technical foundation or precedent for such procedures and despite the fact that SpaceX already far surpasses the U.S. and international standards for de-orbit safety. Should the Commission wish to consider new de-orbit standards, these should be considered and adopted in a formal rulemaking proceeding, and then applied to all NGSO applicants – not exclusively to SpaceX.

OneWeb's comments also greatly overstate the potential risk of conjunctions within the SpaceX constellation. OneWeb ignores information already provided regarding operational features of the SpaceX system that reduce conjunction risk, including more than 55 km along-track separation of satellites within SpaceX altitude shells, the frequent availability of high-precision data on the position and velocity of all SpaceX satellites, and the tight station keeping (both along-track and in altitude). Moreover, OneWeb patently misconstrues NASA information to suggest potential for risk to the International Space Station ("ISS"). For nearly a decade, the station has operated at a higher altitude that is more than 50 km above that proposed for use by SpaceX. OneWeb based its concerns on a graph of ISS operational altitudes over time that actually depicts an anomalous period in 2006 when the ISS operated at an unusually low altitude in order to facilitate delivery of very heavy construction payloads.

As demonstrated herein, SpaceX has thoroughly considered and fully addressed the technical issues raised by commenters. Its NGSO system has been designed with the operational agility needed to facilitate spectrum sharing. Its deployment plans will be more than sufficient to demonstrate its commitment to making productive use of assigned resources. Its advanced technology and conservative operational approach will achieve a high level of safety to ensure that

all interested parties will be able to operate in space for the benefit of the public interest. Accordingly, there is no reason for the Commission to delay grant of the application.

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CONSOLIDATED RESPONSE TO COMMENTS OF SPACE EXPLORATION HOLDINGS, LLC

Space Exploration Holdings, LLC ("SpaceX") hereby responds to the comments[1] filed with respect to the above-referenced application for operating authority for a non-geostationary orbit ("NGSO") satellite system in the Fixed-Satellite Service ("FSS") using V-band spectrum.[2] SpaceX has proposed an ambitious and technically advanced NGSO satellite system designed to make intensive use of valuable spectrum resources to deliver global end-user broadband services, while sharing spectrum equitably with other licensed space- and ground-based systems. The requested authorization of V-band capability is in part an overlay to the SpaceX NGSO system already

1 *See* Letter from Jennifer A. Manner to Marlene H. Dortch, IBFS File Nos. SAT-LOA-20170301-00027, SAT-PDR-20170301-00023, and SAT-AMD-20170301-00026 (filed Sep. 25, 2017) ("HNS Comments"); Comments of SES S.A. and O3b Limited, IBFS File Nos. SAT-LOA-20170301-00027 and SAT-PDR-20170301-00023 (filed Sep. 25, 2017) ("SES/O3b Comments"); Consolidated Comments of ViaSat, Inc., IBFS File Nos. SAT-LOA-20170301-00027, SAT-PDR-20170301-00023, and SAT-AMD-20170301-00026 (filed Sep. 25, 2017) ("ViaSat Comments"); Comments of WorldVu Satellites Limited, IBFS File No. SAT-LOA-20170301-00027 (filed Sep. 25, 2017) ("OneWeb Comments").

2 *See* Space Exploration Holdings, LLC, Application, IBFS File No. SAT-LOA-20170301-00027 (Mar. 1, 2017) ("SpaceX Application").

proposed for operation in low-Earth orbit ("LEO") in Ku-band and Ka-band frequencies,[3] as well as an additional constellation operating at very-low-Earth orbit ("VLEO") altitudes. As a result, the combined SpaceX NGSO system will be able to both provide broadband services to widely dispersed end-users around the world and meet higher capacity requirements of more concentrated population areas, all with enhanced operational flexibility. Accordingly, grant of this application would clearly serve the public interest.

Only four parties filed comments, none of which asked the Commission to deny the application. In the comments, questions focused on sharing spectrum with geostationary orbit ("GSO") satellites, planned space operations, and the continuing need for requested waivers in light of the Commission's recent update of its NGSO rules.[4] As discussed below, SpaceX has carefully considered these questions in designing its system, and none of them should delay grant of the application.

DISCUSSION

I. SPACEX HAS DESIGNED AN AMBITIOUS NGSO CONSTELLATION TO MEET THE CHALLENGE OF SATISFYING THE GROWING DEMAND FOR HIGH-CAPACITY, LOW-LATENCY BROADBAND SERVICE DIRECT TO END USERS

SpaceX proposes to launch and operate an NGSO FSS constellation of 11,943 satellites. While this is a large number of spacecraft, SpaceX has specifically designed the constellation to fulfill its primary service objective of providing high-speed broadband directly to end users globally, with three key technical goals in mind: maximum spectrum efficiency, adaptability to

3 *See* Space Exploration Holdings, LLC, Application, IBFS File No. SAT-LOA-20161115-00118 (Nov. 15, 2016).

4 *See Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Systems and Related Matters*, Report and Order and Further Notice of Proposed Rulemaking, FCC 17-122 (rel. Sep. 27, 2017) ("*NGSO Update Order*"). The Commission determined that the newly adopted rules would be applicable to the current processing round. *Id.* ¶ 71.

share spectrum equitably with other licensed systems, and safeguarding space for all those who want to operate there.

In response to the large and rapidly expanding demand for broadband connectivity, the SpaceX system encompasses a large number of satellites in two orbital configurations (LEO and VLEO). Each spacecraft will feature a large number of very narrow beams, reusing frequencies many times over to generate a level of capacity that can meaningfully bridge the broadband connectivity gap.[5] By designing a satellite constellation that can scale to high levels of capacity by achieving efficient and equitable spectrum usage, SpaceX can play an important role in closing this divide and giving everyone – whether in metropolitan areas, suburbs, rural communities, or remote locations – access to the same caliber of broadband speeds and reliability as users enjoy in the nation's leading markets. With two constellations operating close to the Earth, the SpaceX broadband service will be able to offer nationwide the advantages of low-latency services similar to terrestrial broadband, and to support real-time conferencing, telemedicine, gaming, and other latency-sensitive Internet applications that customers in urban areas of America take for granted.

SpaceX's consumer focus sets it apart from most of the NGSO systems proposed in this processing round. Other applicants indicate that they are pursuing different business objectives, such as providing connectivity to terrestrial telecom carriers (*e.g.*, backhauling traffic and middle-mile connectivity), to large enterprises, or to niche audiences. By contrast, SpaceX has designed its system with the primary purpose of providing broadband service directly to end-users, particularly individual households and small businesses. Meeting this distinct direct-to-end-user

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5 For example, according to the Commission's most recent estimate, there are nearly 34 million people who do not have access to broadband service in the U.S. alone. *See Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, 2016 Broadband Progress Report, 31 FCC Rcd. 699, Appendix D (2016) ("*2016 Broadband Deployment Report*").

goal demands far more on-orbit capacity, which in turn drives the larger number of satellites in the design and the focus on unprecedented spectrum reuse efficiency. Thus, as it considers comments on SpaceX's application, the Commission should bear in mind the crucial link between the scale of SpaceX's proposed NGSO system and the ambitious consumer-facing mission it is designed to fulfill.

II. SPACEX'S NGSO SYSTEM WILL COMPLY WITH COMMISSION RULES ON SHARING V-BAND SPECTRUM WITH GSO SATELLITE SYSTEMS

SpaceX recognizes that the V-band spectrum it proposes to use is a critical input to support growth of the broadband satellite industry. It is therefore fully cognizant that all satellite systems operating in this band will need to share this spectrum. Accordingly, SpaceX included extensive discussion in its application to describe the techniques it will employ to share spectrum resources equitably and efficiently with other licensed systems.[6] Examples of these techniques include using high elevation angles of at least 35 degrees to communicate with ground-based gateways and user terminals; highly directional space station and earth station beams; and satellite diversity, with many satellites in view, offering multiple paths to and from any given customer location. Using these and other highly intelligent techniques, SpaceX is confident that it can successfully coordinate its constellation with other authorized systems, whether in space or terrestrial.

No commercial V-band services are yet on-orbit, and very few terrestrial systems have deployed to date. No specific sharing criteria have been adopted by either the Commission or the International Telecommunication Union ("ITU") to outline how proposed NGSO and GSO operations in the V-band will be expected to co-exist.[7] In light of this, Hughes Network Systems,

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6 *See, e.g.*, SpaceX Application, Technical Attachment at 22-34.

7 While there are no specific requirements for spectrum sharing, Article 22.2 of the ITU Radio Regulations generally provides that NGSO systems shall not cause unacceptable interference to, and shall not claim protection

LLC ("HNS") and ViaSat, Inc. ("ViaSat") urge the Commission to condition any grant in this proceeding upon the outcome of any future proceeding that may specifically address V-band NGSO operational or sharing issues, including equivalent power flux-density ("EPFD") limits designed to protect GSO systems.[8]

SpaceX has no objection to such a condition. Indeed, SpaceX believes that the current effort to develop EPFD limits for V-band spectrum presents a significant opportunity. Unlike the Ku-band, where EPFD limits were first utilized, there are no legacy GSO systems in the band that must be accommodated. Thus, any limits adopted for the V-band can reflect the current state of technology, and not burden today's systems with overly conservative assumptions based on yesterday's technology.[9] By using more realistic assumptions, the ITU process could lead to development of EPFD limits that protect GSO systems without unduly restricting the operations of the highly advanced generation of NGSO satellites systems currently being proposed.

SES S.A. and O3b Limited ("SES/O3b"), however, would go a step further, arguing that the Commission should defer action on the pending application until the Commission has actually

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from, GSO satellite networks. *See* ITU Rad. Regs., Art. 22.2. The Commission recently adopted a nearly identical provision into its own rules. *See NGSO Update Order* ¶¶ 37-39 and new Section 25.289. SpaceX recognizes its obligation to comply with these general requirements.

8 *See* HNS Comments at 2; ViaSat Comments at 2-3. HNS also suggests that the Commission consider applying interim EPFD limits comparable to those applicable in the Ka-band, and require applicants to provide a compliance showing prior to any grant. *See* HNS Comments at 2. HNS does not, however, suggest any basis for determining appropriate EPFD levels for this purpose.

9 For example, the EPFD limits applicable in the Ku-band are designed in part to protect earth stations with elevated backlobes that not only greatly exaggerate the degree to which these backlobes increase an antenna's susceptibility to harmful interference, but also are far more sensitive to energy hitting the antenna 90º off-axis than are modern antenna designs, and thus yield overly pessimistic results. *See, e.g.*, Letter from William M. Wiltshire to Marlene H. Dortch, IBFS File No. SAT-LOA-20161115-00118, at 3 and Attachment at 7 (filed Aug. 17, 2017) (discussing backlobe issue).

adopted comprehensive spectrum sharing rules for NGSO operations in this band.[10] SpaceX agrees with SES/O3b that it would be optimal for the Commission to adopt spectrum sharing rules as soon as possible, so that NGSO licensees will have greater certainty as they devise and implement compliance strategies and proceed with development of their systems. Accordingly, SpaceX joins SES/O3b in urging the Commission to initiate a proceeding to develop and adopt such sharing rules in the near future.

In the meantime, however, the Commission has already rejected SES/O3b's request to defer licensing until new EPFD rules are adopted, concluding that withholding action on pending applications until EPFD deliberations have been completed would unnecessarily delay authorization of pending systems.[11] SpaceX agrees, noting that if a delay in adopting final rules leads to a delay in actual development of NGSO systems, the Commission can handle the situation based on the facts presented at that time. For now, there is no reason to deny a qualified applicant such as SpaceX, which has committed to comply with sharing rules adopted in the future, the license it needs to proceed with its V-band NGSO system.

III. SPACEX'S REQUEST FOR LIMITED WAIVER OF THE GEOGRAPHIC SERVICE REQUIREMENT, IF NEEDED UNDER THE RULES, IS WELL JUSTIFIED

Under Section 25.143(b)(2), NGSO systems must have at least one satellite that would be visible above the horizon at an elevation angle of at least 5 degrees at all times throughout the fifty states, Puerto Rico, and the U.S. Virgin Islands. Once fully deployed, the SpaceX NGSO system will provide broadband service on a full-time basis to customers located virtually anywhere on the entire planet, fully complying with the Commission's requirements for geographic coverage. At

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10 *See* SES/O3b Comments at 3-5. SES/O3b also requested that the Commission apply its in-line events spectrum sharing regime to SpaceX's V-band operations. *Id.* at 6. The Commission has now done so for all V-band systems, mooting this request. *See NGSO Update Order* ¶ 52.

11 *See NGSO Update Order* ¶ 72.

Initial Deployment of 1,600 satellites, however, service will be continuous to the area approximately between 60º North Latitude and 60º South Latitude – which would not cover the northernmost sections of Alaska.

It is not clear how the Commission's geographic service requirements for NGSO systems would apply in this situation, where the system as authorized would comply in full, but not at various interim stages of deployment (proposed for compliance with the Commission's system implementation milestone). Because Section 25.112 of the Commission's rules compels an applicant for a satellite system authorization to request a waiver of any Commission rule that is in conflict with its application, SpaceX requested a partial waiver of the Commission's geographic service requirements out of an abundance of caution.

WorldVu Satellites Limited ("OneWeb") argues that the Commission should deny SpaceX's waiver request with respect to the domestic coverage requirements. It contends that SpaceX's failure to cover the upper portion of Alaska (*i.e.*, the portion above 60º North Latitude) with its interim Initial Deployment would significantly undercut the Commission's efforts to close the digital divide by denying service in those rural areas.[12] At the same time, however, the Commission has proposed to eliminate this coverage requirement, concluding that it would not serve the public interest to deny NGSO operators flexibility, especially given that multiple NGSO systems can share the same frequency bands.[13] Recognizing this, OneWeb urges the Commission to apply any revised coverage rule that is adopted.

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12 *See* OneWeb Comments at 9. The Commission recently deleted the international coverage requirements. *See NGSO Update Order* ¶ 69.

13 *See NGSO Update Order* ¶¶ 75-76.

To be clear, the SpaceX NGSO system when fully deployed will reach the entire U.S. territory and comply fully with the Commission's current domestic coverage requirements. Even OneWeb does not dispute this fact. Yet even at the Initial Deployment of 1,600 satellites, SpaceX's constellation will provide robust service to the vast majority of populated areas on the planet, including remote areas not only in the continental U.S., Puerto Rico, and Hawaii, but also in the lower portions of Alaska, where it will cover nearly 50% of the unserved population of that state.[14] Moreover, unlike many other NGSO systems, SpaceX would have the capacity to provide robust broadband service directly to a meaningful number of residents in its coverage area.

It is unclear whether the requested waiver is even necessary – especially if the Commission revises its geographic coverage requirements as proposed in the *NGSO Update Order*. However, should the Commission feel the need to consider this waiver, SpaceX has cited precedent for granting the requested relief.[15] In these circumstances, even assuming the domestic coverage requirement applies to an interim stage of deployment, there is good cause for the Commission to grant a waiver.

IV. SPACEX IS DEDICATED TO ENSURING THE SAFETY OF SPACE FOR ALL USERS

SpaceX's current and planned space-based activities underscore its unparalleled commitment to safe space. SpaceX has had extensive experience in safe-flight design and operation through many missions of both its Falcon 9 launch vehicle and the Dragon spacecraft

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14 *See 2016 Broadband Deployment Report*, Appendix E (data by county), *available at* https://www fcc.gov/reports-research/reports/broadband-progress-reports/2016-broadband-progress-report. For this calculation, SpaceX excluded the following counties from coverage: Denali, Fairbanks North Star, Matanuska-Susitna, Nome, North Slope, Northwest Arctic, Southeast Fairbanks, Valdez-Cordova, Wade Hampton, and Yukon-Koyukuk, which collectively account for 101,922 unserved inhabitants (or 52.4%).

15 The Commission granted a similar geographic coverage waiver to O3b, thus establishing that deployment of an NGSO system could serve the public interest even if it was not designed to serve all areas covered by the rule. *See* O3b Limited, Stamp Grant, IBFS File Nos. SAT-LOI-20141029-00118 and SAT-AMD-20150115-00004, at condition 14 (Jan. 22, 2015).

carrying out missions to the International Space Station ("ISS") under contract to the National Aeronautics and Space Administration ("NASA"). SpaceX is highly experienced with cutting-edge debris mitigation practices and has deep ties with the domestic and international institutions tasked with ensuring the continued safety of space operations. Accordingly, SpaceX is committed both to maintaining a debris-free environment in space and to disposing of orbital assets in a responsible and safe manner.

SpaceX has provided more detailed information and analysis related to its orbital debris mitigation and end-of-life disposal plans than any other applicant in this processing round. These materials include a demonstration that SpaceX satellites will re-enter the Earth's atmosphere within approximately one year (for LEO satellites) or a few weeks (for VLEO satellites) after completion of their mission – much sooner than the international standard of 25 years. They also include the inputs and outputs of an assessment using NASA's Debris Assessment Software ("DAS"), which indicates a level of safety that more than satisfies the requirements established by NASA and regulatory authorities in other countries.[16] To further improve the analysis for its proposed system, SpaceX is also working directly with NASA on a higher fidelity re-entry analysis. This analysis will employ NASA's proprietary Object Reentry Survival Analysis Tool ("ORSAT"), a more comprehensive model that provides a greater level of precision and insight over the standard DAS analysis that can help guide SpaceX as it continues to refine its system and operations. In addition, SpaceX has been working with NASA's Orbital Debris Program Office for years, and will continue to do so as new reliability standards and best practices are evaluated, codified, and implemented. SpaceX looks forward to continuing its collaborative relationship with

16 *See* SpaceX Application, Technical Attachment at 39-59 (discussing DAS analysis).

NASA, including with respect to protection of the ISS and visiting vehicles (such as SpaceX's own Dragon capsule).

Nonetheless, one commentator – OneWeb – raises several potential issues related to safety of space that it believes could be presented by SpaceX's proposed NGSO system. Many of these claims appear to overlook, or fail to acknowledge, technical information that SpaceX has already submitted to address these matters. At some points, OneWeb raises unjustified demands for more "detail" on top of the voluminous and detailed information that SpaceX has already submitted, in excess of any other NGSO applicant. At other points, OneWeb asks the Commission to impose new standards that it has neither considered nor applied to any other licensed satellite system. If such standards are to be applied, they should be considered and adopted in a formal rulemaking proceeding, and then applied to all NGSO applicants. As demonstrated below, SpaceX has thoroughly considered and fully addressed the technical issues raised by OneWeb, applying advanced analysis and technology and a conservative approach to ensure that its system will achieve a high level of safety so that all interested parties will be able to make productive use of space in the public interest.

A. SpaceX Has Taken Steps to Manage the Potential Risk of Conjunction

OneWeb questions whether the SpaceX system poses satellite conjunction risk within its own system as well as with respect to other NGSO systems. In evaluating these claims, the Commission must recognize that SpaceX has designed its spacecraft with the capability to avoid potential collisions, a capability it will use as necessary to ensure safe operating distances among its own spacecraft and with respect to other orbiting objects. SpaceX will also receive regular ephemeris data updates from its own spacecraft, which will provide precise and accurate location information and thereby enable SpaceX to operate with a high level of confidence to avoid any potential conjunctions internal to its own system.

Moreover, SpaceX continues to refine its operational strategies to enhance safety and overall constellation operations. For example, SpaceX has an ongoing simulation with the Joint Space Operations Center ("JSpOC"), in which a fleet of 100 simulated satellites are receiving warnings of conjunction events from JSpOC's actual catalog, and performing simulated maneuvers in response. SpaceX has designed a rigorous maneuver response procedure to react to any JSpOC conjunction warning messages, including future enhancements afforded by the Space Fence, in order to tightly control overall constellation risk. Practicing this activity with JSpOC will help ensure readiness to implement conjunction avoidance strategies with a larger constellation. In addition, SpaceX satellites are designed with propulsion systems capable of performing frequent maneuvers to avoid any satellite or trackable orbital debris. All satellites will be designed with sufficient propellant and capability to perform any avoidance maneuvers that may be required throughout all phases of the satellites' mission, prior to and during active disposal, and with operational agility allowing uninterrupted mission conduct so that there is no conflict between mission objectives and safe space objectives. SpaceX will continue to develop methods to minimize the likelihood of a conjunction event of any kind involving a SpaceX satellite.

Nonetheless, OneWeb asserts (without any supporting analysis) that the orbital locations selected by SpaceX are in such close proximity to a large number of satellites from multiple NGSO operators that they will overlap due to orbital perturbations and/or failed satellites.[17] This, OneWeb concludes, is the result of SpaceX's refusal to agree to what OneWeb self-defines to be a "reasonable buffer zone" between operators of at least 125 km (and, preferably, 200 km).[18]

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17 OneWeb Comments at 5.

18 *Id.* at 4-5.

SpaceX fully understands the importance of dedicating critical design and operational focus to preventing satellite collisions, and has taken steps to ensure that its constellation will maintain its position and pose no threat to other NGSO systems. However, OneWeb cites no Commission, ITU, or other regulatory source that endorses (much less enforces) its preferred and expansive "reasonable buffer zone" between NGSO systems – and it provides no analysis that shows the genesis of the buffer zone's calculation or why such a large buffer zone is necessary under these circumstances. There is therefore no basis for accepting OneWeb's arbitrary "reasonable buffer zone" proposal, and applying it only to SpaceX. If the Commission has concerns about spacing between NGSO applicants, it has many legitimate tools at its disposal to address its concerns in a reasoned and deliberative manner, in a way that treats all applicants equally, without targeting a single operator for special scrutiny.

SpaceX chose the orbital characteristics of its NGSO constellation based on a number of factors, including a search for altitudes with minimal debris and limited radiation flux, and will be operating LEO orbital shells comfortably with 20 km altitude spacing. The unfounded and extensive buffer zone that OneWeb imagines would effectively crowd out competitors by monopolizing large portions of the available LEO altitudes. This would effectively allow a single NGSO system to warehouse valuable orbital real estate with the most favorable characteristics – the very sort of warehousing OneWeb decries elsewhere in its comments.[19] Moreover, it is notable that OneWeb does not seem to employ this same proposed buffer zone in its own constellation planning. OneWeb and Boeing recently worked to resolve an orbital conflict by relocating some of Boeing's satellites to an altitude only 118 km below OneWeb's – which also happens to be only

[19] *See, e.g.*, OneWeb Comments at 2.

28 km below an altitude used by SpaceX.[20] Although neither Boeing nor SpaceX has raised concerns over this separation distance, OneWeb's own silence on the matter is telling. It would appear that OneWeb's commitment to its "reasonable buffer zone" applies only when it directly benefits OneWeb. The Commission should reject this unsupported and self-serving demand.

OneWeb also raises concerns about the potential for conjunctions within SpaceX's own constellation. In perhaps the most overblown rhetoric in its comments, OneWeb postulates a scenario in which a series of collisions within SpaceX's VLEO constellation combine to create a debris field, "which could be virtually impenetrable for passing space missions."[21] OneWeb's assertion assumes a wildly unrealistic collision rate among SpaceX satellites. OneWeb offers no justification for the assumption that SpaceX VLEO satellites would somehow routinely collide with each other – despite the greater than 55 km nominal along-track separation within altitude shells, the frequent availability of high-precision data on the position and velocity of all VLEO satellites, and the tight station keeping (both along-track and in altitude) of all VLEO satellites. OneWeb also ignores the properties of the very low altitude of the SpaceX VLEO system. Even in the unlikely circumstance where control for multiple SpaceX VLEO satellites were lost simultaneously, any affected satellites would de-orbit so rapidly from their very low altitude that collisions would be extraordinarily unlikely. Further, OneWeb's assertions about atmospheric drag wildly overstate the magnitude of the related station keeping challenges, particularly for a system with active sensing and propulsive hardware designed specifically for this very low orbital environment. Indeed, the necessarily high thrust maneuver cadence offers proportionally more

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20 *See* Letter from Brian D. Weimer and Bruce A. Olcott to Marlene H. Dortch, IBFS File Nos. SAT-LOI-20160428-00041, SAT-LOA-20160622-00058, and SAT-AMD-20170301-00030 (filed Mar. 23, 2017) (discussing agreement for Boeing to relocate to 1,082 km to avoid OneWeb at 1,200 km).

21 OneWeb Comments at 6.

opportunities for exerting station keeping control than contemplated by systems operating at more standard LEO altitudes.

OneWeb also raises concerns about collision between de-orbiting SpaceX LEO satellites and operational satellites in the SpaceX VLEO constellation. It asserts that the disposal orbit of SpaceX's passivated LEO satellites will cross the operational altitude of its VLEO satellites, and that in this high-drag environment it will be difficult for SpaceX to accurately predict the positions of its LEO and VLEO satellites at any given time in order to avoid conjunction.[22] Operational compatibility between the upper LEO and lower VLEO constellations is obviously an area of high focus for SpaceX and, since filing its application, SpaceX has further refined its de-orbit process to, among other things, reduce the disposal phase even more. SpaceX will continue to receive high-precision data on satellite position and velocity throughout this process. In the rare case where location data indicates an elevated level of conjunction risk, the VLEO satellites will retain full maneuvering capability to avoid any LEO satellites for the duration of their very short de-orbit period.

Lastly, OneWeb raises concerns about the effect of SpaceX's proposed NGSO system on the ISS. To support its claim, OneWeb provides wholly misleading information about the ISS's operational altitude, taking out of context information from 2006 during the station's construction as though it represented "occasional" variations in operational altitude. OneWeb reproduces a graph taken from an article that itself makes perfectly clear, through a statement from NASA, that it captures the lowest altitude at which the ISS had ever operated, as part of a long-range plan for a now-concluded phase of orbital assembly that involved particularly heavy payloads that would

[22] *Id.*

be easier to deliver to a lower altitude.[23] Once that construction phase was completed, NASA re-boosted the ISS to its current operational altitude of 400 km or above, as shown in the depiction of ISS altitude over the last year in Figure 1 below.[24] This higher altitude, more than 50 km above the SpaceX VLEO system, not only significantly reduces the amount of fuel needed for the ISS to maintain position,[25] but also obviates any operational risks between the SpaceX VLEO constellation and the ISS.

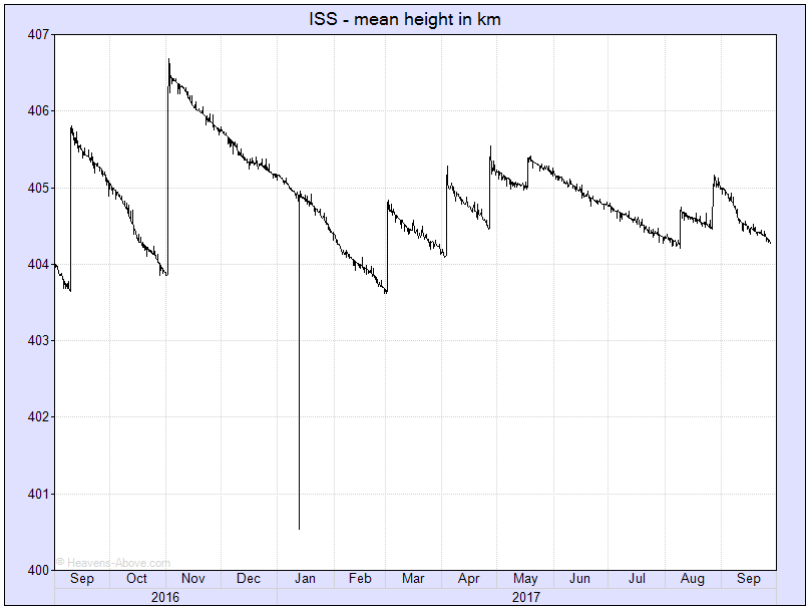

Figure 1. Orbital Altitude of ISS (2016-2017)

OneWeb's attempt to apply patently misleading facts to raise unsupported concerns should be wholly disregarded.

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23 *See* OneWeb Comments at 7; James Oberg, "Space station sinks to new low – but it's OK," MSNBC (Mar. 15, 2007), *available at* http://www.nbcnews.com/id/17630218/ns/technology_and_science-space/t/space-station-sinks-new-low-its-ok/.

24 *See* Heavens Above, "Height of the ISS," *available at* http://www heavens-above.com/IssHeight.aspx (last visited Oct. 10, 2017).

25 *See* NASA, "Higher Altitude Improves Station's Fuel Economy" (Feb. 14, 2011), *available at* https://www.nasa.gov/mission_pages/station/expeditions/expedition26/iss_altitude.html.

SpaceX has a longstanding and positive relationship with NASA, including an active, ongoing engagement with the agency about SpaceX's constellation plans and other space operations in general and ISS conjunction analysis in particular. Specifically, SpaceX is in regular communication with both the ISS program office and NASA's Conjunction Assessment Risk Analysis group to ensure its designs do not cause significant burden or risk to NASA programs. SpaceX fully intends to continue this collaboration with NASA through all stages of design and operations of the SpaceX NGSO system, in order to ensure that NASA is satisfied with SpaceX's system designs and its operational practices.

B. The SpaceX System Far Surpasses All U.S. and International Standards for Safeguarding Humans Against Casualty Risk

OneWeb also raises concerns about the potential risk of human casualty arising from de-orbit of SpaceX satellites, and asks the Commission to require SpaceX to either undertake a controlled re-entry or achieve complete disintegration of its spacecraft.[26] Again, OneWeb offers no Commission precedent for the application of these new standards. OneWeb also does not dispute that the SpaceX system already far surpasses the U.S. and international standards for de-orbit operations. Using conservative assumptions and a DAS software tool that is designed to yield conservative results,[27] SpaceX has already demonstrated that it exceeds the risk metrics considered by the Commission for total spacecraft risk of human casualty. Depending upon

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26 *See* OneWeb Comments at 8.

27 The DAS User's Guide makes clear that the human casualty portion of the software "is intended to be a 'first cut' assessment tool" that provides conservative results. *See* NASA Orbital Debris Program Office, *Debris Assessment Software User's Guide – Version 2.1* at 35 (Oct. 2016). It does not, for example, include any consideration of the degree to which people would be located within structures that would provide shelter from potential impact, which could significantly decrease potential casualties even further below international standards. *See, e.g.*, Letter from Scott Blake Harris to Marlene H. Dortch, IBFS File No. SAT-MOD-20131227-00148 (filed Apr. 28, 2016) (including consideration of sheltering in DAS analysis reduced human casualty rate from 1:4,400 to 1:20,000).

operational inclination, the total risk from the SpaceX system is preliminarily calculated at between 1:17,400 and 1:31,200 – a level that more than satisfies the requirement of 1:10,000 established by NASA and international regulatory authorities.[28]

Here again, OneWeb simply asserts that the Commission should impose a new and unadopted standard, and apply it only to SpaceX and no other applicant in this NGSO processing round. Should the Commission consider recalibrating its risk calculations, the new metrics should be thoroughly considered in a rulemaking proceeding and, if adopted, then made applicable to all NGSO system authorizations. It would be inappropriate to apply an arbitrary and unannounced standard to SpaceX uniquely.

SpaceX fully complies with the requirements set out by NASA, which generally have the effect of ensuring that the aggregate risk of human casualty from naturally occurring space debris is held essentially unchanged, even as more satellites are deployed in any altitude from any source. According to one estimate, more than 1,400 metric tons of space materials have survived re-entry to Earth over the last 50 years, with no reported casualties.[29] On an average day, Earth is struck by between 50 and 240 naturally occurring space objects with masses from 10 grams to greater than 1 kilogram.[30] Compared to the large number of meteorites that strike Earth naturally each year, the proposed SpaceX system adds only negligibly to the overall total on Earth. In fact, the

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28 *See* SpaceX Application, Technical Attachment at 39-59 (discussing DAS analysis). *See also* European Space Agency, *ESA Space Debris Mitigation Compliance Verification Guidelines* at 29 (Feb. 19, 2015) (establishing 1:10,000 human casualty rate standard for ESA missions), *available at* http://www.iadc-online.org/index.cgi?item=documents.

29 *See* Tommaso Sgobba, *Safety Design for Space Operations*, The International Association for the Advancement of Space Safety, at 21 (2013).

30 P.A. Bland et al., *The flux of meteorites to the Earth over the last 50,000 years*, Monthly Notices of the Royal Astronomical Society, 551 (1996); Muriel Gargaud, *Encyclopedia of Astrobiology: Vol I*, 1030 (2011).

gradual turnover and decommissioning of SpaceX satellites over time would likely not even be measurable against natural variation in the impact rate of meteorites and other space objects.

SpaceX continues to refine its spacecraft designs and operational plans, and intends to surpass the very low initial casualty risk indicated in its original application and reduce the per-satellite risk to a level even further below the exposure that occurs from natural sources. When designing its spacecraft, SpaceX has applied a philosophy of using materials that will completely demise during atmospheric re-entry, unless an exception is absolutely necessary to the mission. Its design teams review all relevant subsystems to ensure they are designed to maximize the probability of complete atmospheric demise of the constellation satellites.

In addition, SpaceX expects to even further refine spacecraft component geometries by taking advantage of higher fidelity re-entry analysis from NASA's proprietary ORSAT tool, a more comprehensive model that yields even higher fidelity insight over the standard DAS analysis tool. SpaceX plans to collaborate with NASA and leverage the agency's decades of re-entry experience in order to achieve a design where spacecraft fully demise on orbit with minimal risk to people on the ground. SpaceX will regularly perform this analysis, ensuring that risk estimates capture future spacecraft revisions.

As previously explained,[31] the preliminary casualty risk calculations for the SpaceX system show that it is far superior to all applicable standards. Moreover, SpaceX intends to surpass even this initial very low risk level through continual design improvements and higher-fidelity modeling. SpaceX takes very seriously the importance of mitigating risk. It has dedicated

[31] *See* Letter from William M. Wiltshire to Jose P. Albuquerque, IBFS File No. SAT-LOA-20170301-00027, at 9-11 (filed July 24, 2017) ("SpaceX Supplemental Letter").

significant effort to achieve safety levels well above all U.S. and international norms, and continues to seek additional ways to further exceed these levels with future iterations.

C. SpaceX Has Provided Detailed Information on Orbital Parameters

OneWeb also complains about what it perceives as a shortcoming of the information provided by SpaceX to quantify intra-constellation conjunction distances and how accurately it will maintain its satellites' orbits.[32] To the contrary, SpaceX refers OneWeb to its previous submissions on these matters, including the following detailed information:

> Apogee and perigee will be maintained to within 30 km for the LEO Constellation, and to within 5 km for the VLEO Constellation. For both systems, inclination will be maintained to less than 0.5 degree of the respective target values. The right ascension of the ascending nodes ("RAANs") will precess and span the full range of 0-360 degrees. As the design matures and approaches flight, these values will be refined further.
>
> In addition, SpaceX has designed orbits such that LEO Constellation satellites need only maintain a position with a tolerance no larger than 60 km along-track in the worst case, or even greater distances at earlier stages of the roll-out. It is unlikely this full along-track margin will ever be used, but these highly conservative tolerances further improve the robustness of the SpaceX system. For the VLEO Constellation, under nominal conditions the satellites are separated by at least 55 km in-track, and by 5 km in altitude. In addition, SpaceX will maintain extremely accurate information about the location of each satellite, and make this information available to other operators through its shared ephemeris data.[33]

It is striking that, by contrast, OneWeb has provided no such detailed information with respect to its own proposed NGSO system. Once again, OneWeb would have the Commission hold SpaceX to a higher standard than OneWeb itself has met; here, SpaceX has already surpassed that standard.

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[32] *See* OneWeb Comments at 5.

[33] SpaceX Supplemental Letter at 1-2.

D. SpaceX Has Designed a Highly Reliable NGSO System

OneWeb also asks the Commission to apply a heightened reliability standard to SpaceX's satellites and NGSO system.[34] Notably, OneWeb neither specifies what it believes the current standard to be, nor what additional showings SpaceX should be required to make. At present, there is no consensus on appropriate standards for reliability of satellite design, fabrication, or post-mission disposal. This appears to be another case in which OneWeb proposes that the Commission impose an unfounded new standard uniquely upon SpaceX.

SpaceX has consistently worked to drive the prospect of any individual satellite failure (or failure to de-orbit) as far towards zero as possible, and will continue to do so – both to ensure the continued safety of space and to ensure the continued health of the SpaceX constellation itself. SpaceX will also aggressively monitor the health of each satellite (including through the use of specialized on-board instrumentation) so that it can quickly detect any potential problems, and will have recovery protocols in place should they arise.

SpaceX does not intend to freeze the design process for its spacecraft at the first launch. Rather, it expects to explore new technologies continuously, and then implement upgrades in an iterative process that yields highly capable and highly reliable satellites. This is a necessity not only for maintaining the continued safety of space, but also for ensuring that the space-based infrastructure deployed by SpaceX to deliver high quality broadband service keeps pace with rapidly evolving consumer demand levels and expectations for quality and functionality. SpaceX's substantial experience in continued technological improvement with its Dragon capsule has demonstrated that this ongoing technology review approach lends the opportunity to identify and then rectify any latent issues in system or spacecraft design. SpaceX would then be able to prevent

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[34] *See* OneWeb Comments at 7.

the replication of any problematic spacecraft issues before further deployment and, if needed, opt to de-orbit any already-deployed spacecraft that feature similar issues. As a consequence of these iterative development efforts, the NGSO system proposed by SpaceX can be expected to set the standard for system reliability.

SpaceX recognizes the unprecedented scope of the NGSO system it has proposed and has not made this proposal lightly. The large number of satellites proposed for its constellation is driven by the vast capacity and heightened spectral efficiency required to meet the needs of broadband customers in the U.S. and around the world. As a company, SpaceX depends upon a safe operating environment in space in order to achieve its stated long-term goals, and the NGSO system it has proposed is consistent with its unparalleled commitment to safe space. SpaceX has thoroughly considered and fully addressed the issues raised by OneWeb, and none of them should bar the grant of the application.

V. GRANTING SPACEX'S REQUEST FOR A LIMITED WAIVER OF THE SYSTEM IMPLEMENTATION REQUIREMENT WOULD NOT UNDERMINE THE RULE AND WOULD REFLECT REAL-WORLD CHALLENGES IN DEPLOYING A LARGE NGSO CONSTELLATION

OneWeb voiced concerns that the limited waiver requested by SpaceX for deployment of its constellation would in some way allow SpaceX to warehouse spectrum and orbital resources.[35] Warehousing "refers to the retention of preemptive rights to use spectrum and orbital resources by an entity that does not intend to bear the cost and risk of constructing, launching, and operating an authorized space station, is not fully committed to doing so, or finds out after accepting the license that it is unable to fulfill the associated obligations."[36] It is wholly unclear how the limited waiver requested by SpaceX might purportedly result in, facilitate, or encourage spectrum warehousing.

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35 *See* OneWeb Comments at 2-4.

36 *Comprehensive Review of Licensing and Operating Rules for Satellite Services*, Second Report and Order, 30 FCC Rcd. 14713, ¶ 53 (2015) ("*Part 25 Second R&O*").

SpaceX requested a limited waiver of the deployment requirement in Section 25.164(b) of the Commission's rules that all satellites in an NGSO constellation be launched and begin operations within six years of licensing, such that this requirement would apply to an Initial Deployment of 1,600 satellites. The Commission recently revised its deployment rule so that NGSO licensees must deploy 50 percent of their authorized satellites within six years, and the remainder within three years thereafter.[37] HNS and OneWeb contend that SpaceX's waiver request should be denied, and that instead SpaceX should be required to comply with the new milestone requirement.[38]

Although SpaceX agrees that this revision is a significant improvement and will give NGSO operators much-needed flexibility in determining how best to design and deploy their systems, SpaceX nonetheless continues to believe that a waiver is appropriate in this case. Deploying this many satellites over a six-year period, and the full constellation over a nine-year period, will require an unprecedented launch cadence and volume. SpaceX requested the waiver out of an abundance of caution against such requirements, which are considerable even for a company like SpaceX, which has led the drive to innovate launch and reusability capabilities. Indeed, even as the Commission adopted the revised milestone requirement, Commissioner O'Rielly questioned "whether there are sufficient launch capabilities to get all of these satellites into orbit in time to meet the performance benchmarks," and whether waivers of the rule may be required.[39]

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37 *See NGSO Update Order* ¶¶ 66-67 and new Section 25.164 at 38.

38 *See* HNS Comments at 2-3; OneWeb Comments at 3.

39 *See NGSO Update Order*, Statement of Commissioner Michael O'Rielly.

SpaceX does not need to launch all of the proposed satellites in its system in order to commence delivery of broadband services, nor is it necessary to reach full deployment in order to demonstrate that SpaceX is "fully committed" to utilizing the granted orbital and spectrum resources. Within the time allotted for the Initial Deployment, SpaceX will manufacture, launch, and bring into service more satellites than are currently in operation worldwide. Such significant investment, technological development, and space deployment should more than suffice to demonstrate that the company is "fully committed" to bearing the cost and risk of operating its authorized system.[40] Accordingly, grant of the requested partial waiver would be consistent with the Commission's anti-warehousing policies while recognizing potential implementation constraints and the need for operational flexibility associated with the launch and operation of large NGSO constellations. Moreover, the in-line events sharing regime that the Commission has recently applied to all authorizations issued in this processing round ensures that "[t]here is neither any incentive nor any possibility for non-implemented systems to warehouse allocated spectrum at the expense of operational systems."[41]

HNS argues that granting SpaceX a waiver could result in inefficient use of spectrum and hamper the GSO/NGSO coordination process.[42] However, as indicated in its application, SpaceX expects to begin providing commercial broadband services in the U.S. and globally upon deployment of the first 800 LEO satellites, and to continue to do so as it launches additional satellites and the constellation is replenished and expanded. Thus, it will be able to use spectrum

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40 *See Part 25 Second R&O* ¶ 53.

41 *Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ku-Band*, 17 FCC Rcd. 7841, ¶ 29 (2002).

42 *See* HNS Comments at 2-3.

efficiently at a very early stage of deployment, and increase that efficiency over time as it increases the capacity of its system. With respect to coordination, SpaceX recognizes its obligation to protect GSO systems in the band[43] – an obligation that applies to NGSO systems regardless of their size. In this regard, the uncertainty created by the lack of established rules (such as EPFD limits) is much more likely to complicate GSO/NGSO coordination efforts than any NGSO system's deployment schedule. Yet the timing for adoption and implementation of such critical rules within the U.S. or internationally lies totally outside the control of any NGSO system operator. Moreover, given that all proposed NGSO systems would be deployed in phases and on different timetables, even those that are deployed within a nine-year implementation period, it is hard to see how SpaceX's own plans for phased deployment would introduce qualitatively different issues for GSO/NGSO coordination.

The Commission applies a well-established standard for a waiver, which permits applicants to vary from the Commission's rules for good cause shown, when such deviation would better serve the public interest than would strict adherence to the general rule.[44] For all of the reasons discussed above and in its application, SpaceX's request meets this standard.

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43 *See* ITU Rad. Regs., Art. 22.2.

44 *See* 47 C.F.R. § 1.3; *WAIT Radio v. FCC*, 418 F.2d 1153, 1157 (D.C. Cir. 1969), *cert. denied*, 409 U.S. 1027 (1972); *Northeast Cellular Telephone Co., L.P. v. FCC*, 897 F.2d 1164 (D.C. Cir. 1990).

CONCLUSION

SpaceX has proposed a technologically advanced NGSO system for nationwide and global broadband access, with the capability to make highly efficient use of valuable spectrum resources while sharing them equitably with other licensed users. The system has been designed to meet or exceed all existing requirements for safety of operations in space and upon de-orbit of satellites. None of the concerns raised in the comments filed in response to SpaceX's application should delay the Commission in granting the application so that SpaceX can proceed expeditiously to build the space infrastructure needed to deliver high-capacity, low-latency broadband services in America and around the world.

Respectfully submitted,

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