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

Application of	)	
SPACE EXPLORATION HOLDINGS, LLC	)	Call Signs: S2983 and S3018
For Modification of Authorization for the SpaceX NGSO Satellite System	)	File No. SAT-MOD-_____

APPLICATION FOR MODIFICATION OF AUTHORIZATION
FOR THE SPACEX NGSO SATELLITE SYSTEM

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SUMMARY

With this application, SpaceX seeks to lower the altitude of the rest of its authorized Ku- and Ka- band satellites, continuing its drive to safely and fully deploy a satellite constellation that will deliver high-speed, low-latency, competitively-priced broadband service to the underserved and unserved throughout the United States, in Polar regions, and around the world. This application follows SpaceX's unprecedented deployment of hundreds of satellites within months of the Commission granting SpaceX's first modification, authorizing an initial deployment of 1,584 satellites at the low altitude of 550 km. SpaceX quickly leveraged the experience from its first launch in May of last year to modify its license again to adjust the orbital spacing of its initial deployment. This modest adjustment allowed SpaceX to speed coverage and broaden its geographic reach in the early stages of the constellation's deployment, enabling earlier initiation of service to customers in the middle latitudes and southern-most states, and critically, those often underserved Americans in Hawaii, Puerto Rico, and the U.S. Virgin Islands.

Now, SpaceX takes its next leap forward by seeking authorization to relocate the rest of its satellites to operate in altitudes with the same benefits as those used for its initial deployment. Specifically, SpaceX seeks 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. Because of the increased atmospheric drag at this lower altitude, this relocation will significantly enhance space safety by ensuring that any orbital debris will quickly re-enter and demise in the atmosphere. And because of its closer proximity to consumers on Earth, this modification will allow SpaceX's system to provide low-latency broadband to unserved and underserved Americans that is on par with service previously only available in urban areas.

Finally, this modification will improve service to customers—including Federal users—in otherwise impossible to reach polar areas.

Lower orbit. Maintaining a clean orbital environment is a foundational concern for SpaceX, and the company will continue to take every opportunity to improve its effect on the orbital environment. This commitment was a key driver behind SpaceX's modification last year to lower its initial deployment and its decision to develop and deploy spacecraft with no calculated casualty risk. In this case, SpaceX proposes to double down on the benefits of the lower altitude to even further enhance the already considerable space safety attributes of the constellation by lowering its remaining satellites. Given the atmospheric drag at these lower altitudes, this relocation will ensure that all of SpaceX's satellites will quickly re-enter and demise in the atmosphere when no longer needed for operations.

Slight decrease in satellites. Significantly, SpaceX will improve service while enhancing space safety with no new satellites. To the contrary, through the benefits of the lower altitude and following extensive technological and coordination efforts, SpaceX designed its modification to slightly reduce the number of satellites in its constellation. All of SpaceX's satellites use its proven advanced beam-forming and digital processing technologies to make highly efficient use of spectrum resources while achieving the flexibility to share that spectrum with other licensed satellite and terrestrial users. Moreover, with its satellites closer to Earth, SpaceX will be able to decrease the power levels of its transmissions from and to its satellites. This decrease will also facilitate compliance with applicable EPFD limits designed to promote harmonious operations with GSO satellite systems, while further enhancing SpaceX's ability to protect terrestrial wireless systems. To compliment these technological benefits, SpaceX has commenced extensive coordination efforts to ensure harmonious operation with other spectrum users.

Faster deployment. In keeping with SpaceX's previous modifications, this adjustment will enable SpaceX to accelerate the manufacture and continuing deployment of its cutting-edge satellites. Because of its ability to fully integrate its development, manufacturing, and launch capabilities, SpaceX has been continuously populating its initial deployment even as the company adds features and improves the operation of its satellites. The requested modification would serve the public interest by enabling SpaceX to continue to improve its efficient use of valuable spectrum resources more safely, quickly, and cost-effectively.

Other public interest benefits. SpaceX recognizes that some parties have raised issues that extend beyond radiofrequency interference and even outside the Commission's jurisdiction. SpaceX is taking aggressive steps to address these concerns.

Some small satellite operators have in the past expressed concerns that SpaceX's operations would make it more difficult for them to deploy non-propulsive systems near SpaceX's orbits, given their own limited capability. SpaceX has repeatedly made clear that it intends to conduct active maneuvers to avoid collisions with both debris and other spacecraft throughout the life of its satellites. While SpaceX will use its propulsive capabilities to avoid non-propulsive systems, it also expects other systems to take reasonable steps to avoid collision as well. To help in this effort, SpaceX also provides all of its ephemeris data to other operators via spacetrack.org and it is the first operator to optimize the usefulness of this data by supplementing it with co-variance data, which allows other operators to better predict the trajectories of SpaceX satellites. Moreover, the Commission is addressing these issues as part of an industry-wide proceeding, which is more appropriate than as a license condition applied only to a single operator. This sort of condition could inadvertently create a race to the bottom where operators compete to make their systems as non-maneuverable as possible in an effort to avoid regulatory burdens.

Lastly, while many were excited after SpaceX's first launches, some in the optical astronomy community voiced concern that the light reflected from those satellites could interfere with their space observations. While the Commission does not have jurisdiction over the visibility of satellites, SpaceX is committed to promoting all forms of space exploration, which is why it has already taken a number of proactive steps to ensure it does not materially impact optical astronomy. SpaceX is working with U.S. and international astronomy organizations and observatories to measure scientifically the actual impact of its satellites. Within weeks of receiving results back from these tests—and as a result of SpaceX's unique ability to quickly update, manufacture, and launch its satellites—SpaceX deployed an experimental darkening treatment on one in-orbit satellite to further reduce the visibility on the body of the satellites. Beyond this treatment, SpaceX is developing new mitigation efforts that it plans to test in the coming months. Additionally, SpaceX will make satellite tracking data available so astronomers can better coordinate their observations with our satellites. These measures, along with SpaceX's work with leading astronomy groups, will enable SpaceX to bring the substantial benefits of broadband access to underserved populations around the world without materially impacting views of the night sky.

Despite some claims to the press, operating at higher orbits does not alleviate the need for operators to take additional steps to mitigate their impact on optical astronomy—in fact, higher orbits may worsen the effect in some cases. SpaceX therefore encourages other satellite operators to engage in similar active steps to study their effects on astronomy. Together, the satellite industry and optical astronomers can ensure the public reaps the benefits of satellites operations while mitigating the impact on space exploration.

SpaceX asks the Commission to grant the proposed modification expeditiously so that SpaceX can continue to accelerate its service to underserved and unserved consumers throughout the United States, in Polar regions, and around the world.

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APPLICATION FOR MODIFICATION OF AUTHORIZATION
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In this application, Space Exploration Holdings, LLC ("SpaceX") proposes to build on the success of its earlier modifications in accelerating broadband deployment and increasing space safety by operating the remaining satellites subject to its Ku-/Ka-band non-geostationary orbit ("NGSO") Fixed-Satellite Service ("FSS") license at a lower altitude without increasing interference. This application identifies all changes that SpaceX requests for its Authorization. SpaceX is also filing an FCC Form 312, Schedule S, and updated technical showings to account for the changes proposed. SpaceX certifies that all other information provided in its Ku/Ka-band applications, as modified, remains unchanged.[1]

[1] *See* 47 C.F.R. § 25.117(c). *See also* Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System, IBFS File No. SAT-LOA-20161115-00118 (Nov. 15, 2016); Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System Supplement, IBFS File No. SAT-LOA-20170726-00110 (July 26, 2017); Application for Modification of Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20181108-00083 (Nov. 8, 2018).

DISCUSSION

The Commission authorized SpaceX in 2018 to construct, deploy, and operate an NGSO constellation consisting of 4,425 satellites operating using Ku- and Ka-band spectrum.[2] The Commission granted SpaceX a modification of that authorization in April 2019 to relocate 1,584 satellites previously authorized to operate at an altitude of 1,150 km to an altitude of 550 km. The Commission found that the modification would serve the public interest by improving broadband latency while decreasing the potential for orbital debris.[3]

The Commission granted SpaceX's second modification on December 19, 2019, to allow SpaceX to reconfigure its satellites within the same altitude to place coverage and capacity more evenly and rapidly across more of the U.S.[4] By taking advantage of SpaceX's advanced deployment methods, that modification will accelerate broadband service to middle and southern states, as well as to Hawaii, Puerto Rico, and the U.S. Virgin Islands. Critically, the Commission recognized that because both of these modifications either reduced or maintained the total number of satellites used, they resulted in no material change in interference.[5] The configuration of SpaceX's currently authorized NGSO constellation is summarized in Table 1 below.

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

3 *See Space Exploration Holdings, LLC*, 34 FCC Rcd. 2526 (IB 2019) ("*First Modification*").

4 *See Space Exploration Holdings, LLC*, DA 19-1294 (IB, rel. Dec. 19, 2019) ("*Second Modification*").

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

SpaceX Current Authorization					
Orbital Planes	72	32	8	5	6
Satellites per plane	22	50	50	75	75
Altitude	550 km	1,110 km	1,130 km	1,275 km	1,325 km
Inclination	53°	53.8°	74°	81°	70°

Table 1. Summary of Currently Authorized NGSO Constellation

Based on the success of the deployment of its first 362 satellites and in an effort to even further enhance the already considerable space safety attributes of SpaceX's constellation, SpaceX now proposes a slight further decrease in its total number of satellites and relocation of 2,824 satellites. Specifically, SpaceX proposes to relocate the satellites that are currently authorized to operate at altitudes from 1,110 km to 1,325 km down to altitudes ranging from 540 km to 570 km, as described in Table 2 (with proposed changes identified in green). This move will help ensure that any orbital debris will undergo rapid atmospheric re-entry and demise, even in the unlikely event that a spacecraft fails in orbit. And because of its continued commitment to being a good steward of spectrum, SpaceX has maintained its ability to share spectrum resources fairly and efficiently with other licensed satellite and terrestrial users. Moreover, this modification will ensure SpaceX's system will even further improve the latency it provides all American consumers—critically including those with no other viable high-throughput broadband options in Polar regions such as Alaska.

SpaceX Proposed Modification					
Orbital Planes	72	72	36	6	4
Satellites per plane	22	22	20	58	43
Altitude	550 km	540 km	570 km	560 km	560 km
Inclination	53°	53.2°	70°	97.6°	97.6°

Table 2. Summary of Proposed Modification

Accordingly, grant of the requested modification would serve the public interest by enabling SpaceX to make efficient use of valuable spectrum resources more safely, quickly, and cost-effectively as it begins to offer service to customers worldwide, especially those in areas previously underserved or even totally unserved by other broadband solutions such as those in polar regions.

SpaceX also requests that the Commission grant authority in its modified license for communications during transition phases before and after reaching authorized positions. This would include authority to perform TT&C functions during orbit-raising and de-orbit maneuvers, as is authorized by rule for GSO satellite systems.[6] This would also include authority for testing of the Ku- and Ka-band communications payloads during the orbit-raising process, which would be conducted on a non-protected, non-harmful interference basis. Given that there are over 4,000 satellites in the constellation with a design life of five years, it is likely that SpaceX will be engaged in launch and de-orbit activities on an ongoing basis. Granting the requested authority as part of the space station license would obviate the need for SpaceX to file—and the Commission to process—a never-ending stream of applications for special temporary authority to cover operations as satellites are raised into and de-orbited out of the constellation.[7]

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[6] *See* 47 C.F.R. §§ 25.282, 25.283.

[7] Over the last eight months, SpaceX has been granted eleven space station STAs to cover orbit-raising and de-orbit activities for its constellation. It has received no reports of interference from any other licensed operator.

I. SPACEX CONTINUES TO LEVERAGE ITS UNIQUE INTEGRATED AND ITERATIVE APPROACH TO IMPROVE THE SERVICES IT WILL PROVIDE CONSUMERS AND MAINTAIN A SAFE ORBITAL ENVIRONMENT

Maintaining a clean orbital environment is a fundamental concern for SpaceX's business. For instance, human spaceflight is the core mission of the company. SpaceX is proud that NASA has entrusted the company to safely carry American astronauts in the coming months to and from the International Space Station ("ISS"), a more than $100 billion multinational facility with human beings onboard. Nothing is more important to SpaceX than safely and successfully accomplishing this mission.

While SpaceX's commitment to human spaceflight alone would be sufficient incentive to take all practical measures to ensure that the orbital environment remains safe, the company also depends on a clean environment for its commercial satellite customers for whom SpaceX must safely deliver satellite payloads to their proper orbital altitudes. For other missions, SpaceX must reliably deliver cargo to the ISS. SpaceX is privileged to be trusted by NASA and its International Partners to approach and berth or dock with the ISS—a highly complex operation with stringent safety protocols and virtually no margin for error. SpaceX's operational experience in being one of the world's few "visiting vehicles" to the ISS highlights its capability to maintain safe space operations.

In furtherance of its commitment to minimize the risk to all operating spacecraft and other orbital resources, SpaceX has applied its unique iterative and integrated approach to constantly improve the safety profile of its NGSO satellite system. SpaceX used this same approach to develop its Falcon launch vehicle systems and Dragon spacecraft to great effect, iterating on technologies never thought possible—like reusable rockets—to continuously improve these space systems for performance, reliability, and affordability. SpaceX's integrated and iterative process has allowed it to deploy the largest satellite constellation in history, while exceeding all existing safety standards. Critically, because of the unprecedented pace and urgency with which SpaceX has deployed its system

to this point, it remains on track to deliver high-throughput low-latency broadband to American consumers this year. SpaceX has converted its experience into technological and operational improvements to make its constellation safer, more capable, more efficient, and better able to deliver the broadband services its customers demand. With this proposed modification, SpaceX is poised to take its growing experience operating its system to move to the next stage in its development.

II. GRANT OF THE PROPOSED MODIFICATION WOULD SERVE THE PUBLIC INTEREST BY FURTHER ENSURING A SAFE SPACE ENVIRONMENT WHILE CONTINUING TO LOWER BROADBAND LATENCY FOR AMERICAN CONSUMERS

In granting SpaceX's initial modification, the Commission noted that Section 25.117 governs the modification of space station licenses, and that the rule provides that such applications "will be granted" except in two limited circumstances: either when the modification involves a request for additional bandwidth or when it would not serve the public interest.[8] As in its prior modifications, SpaceX does not request any increase in bandwidth, so the application should be granted so long as it serves the public interest. As discussed below, the modification serves the public interest by improving the safety profile of the system, accelerating deployment of low-latency service to unserved and underserved Americans, and yields a greater degree of broadband competition for more Americans, including in areas requiring polar coverage.

A. The Proposed Modification Would Further Improve the Safety Profile of SpaceX's System while Simultaneously Lowering the Latency of Its Service

The operation of SpaceX's initial satellites at 550 km has proven out several important features of operating at the lower altitude. First and foremost, the natural atmospheric advantage of lower altitude helps reduce the impact of potential debris from other sources. As the Commission has

[8] *See First Modification*, ¶ 7 (citing 47 C.F.R. § 25.117(d)(2)(ii) and (iv)).

recognized, objects de-orbit more quickly below 650 km.[9] At these altitudes, the Earth and its atmosphere sweep the orbit clean—atmospheric drag naturally removes objects from orbit, including loose debris. But while these environmental advantages during nominal operations are substantial, the lower altitude also improves safety during off-nominal events if satellites fail to fully complete their active disposal operations. The passive orbital decay of a satellite at SpaceX's currently authorized altitudes ranging from 1,130 km to 1,325 km can take centuries, but SpaceX satellites at its proposed lower altitudes will take less than five years (even under worst-case assumptions) to de-orbit.

But as SpaceX noted in its initial modification application, moving to a lower altitude also provides an additional benefit—increasing the space between SpaceX's satellites and other proposed large NGSO constellations, such as OneWeb and Telesat. The Commission has authorized those companies to operate NGSO systems at altitudes between 1,000 km and 1,248 km. These satellites will operate in orbits that extend through SpaceX's currently authorized orbit at 1,130 km to 1,325 km. By relocating SpaceX's remaining satellites from those higher altitudes to 540 km to 570 km, the proposed modification not only reduces potential conflict for its own system, it improves the safety profile for those other NGSO operators during nominal operations. Importantly, this modification will also move the satellites authorized to operate in polar orbits, which are similar to the orbits in which other large NGSO constellations hope to operate.

Improved orbital debris mitigation is not the only significant advantage of this modification. Due to the low altitude of its first satellites, SpaceX has already reduced the latency of its transmissions from those satellites to below 50 milliseconds, which is nearly unnoticeable to consumers. This modification will ensure that all of the satellites in SpaceX's system will provide the same low latency services to all Americans, including those in places like Alaska that are served by satellites in polar orbits. Just over half the population living in rural Alaska and no one on Alaskan Tribal Lands has

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

access to fixed broadband service at speeds that meet even the Commission's minimum definition for broadband.[10] And American residential consumers are not the only beneficiaries of this improved service. For many Federal broadband users, satellite service is the only communications option to support critical missions. Improving latency for these users could have significant national security benefits.

Finally, operating at lower altitude has reduced the degree to which satellite beams spread before they reach the Earth. As discussed in the Technical Attachment, SpaceX's ability to use even tighter beams has achieved more efficient re-use of spectrum resources.

Despite these well-known advantages, most other NGSO FSS providers avoid lower orbits because of the difficulty of operating satellites with the amount of drag at these altitudes. The same dynamics that sweep the orbit clean also force satellites to work harder to overcome the higher drag and remain in orbit. Fortunately, SpaceX has demonstrated that its state-of-the-art Hall-effect ion thrusters are more than capable of handling the increased resistance.

Another obstacle that keeps many operators from taking advantage of the lower orbits is that satellites operating at these altitude see less of the Earth, requiring more satellites to serve a given area. To meet this challenge, SpaceX is proposing that it operate its entire constellation at these altitudes to ensure that it has sufficient coverage to serve consumers, no matter where they are on Earth. Overall, based on the experience SpaceX has earned operating its first satellites, it can mitigate the disadvantages of operating at a lower altitude and still reap the well-known and significant benefits.

B. SpaceX Will Achieve These Public Interest Benefits With a Slight Decrease in Satellites

In making its public interest determination, the Commission must weigh the benefits of SpaceX's proposal against any offsetting concerns to see where the balance of interests lies. As

[10] *See Inquiry Concerning Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion*, 34 FCC Rcd. 3857, Appendices 6 and 7 (2019).

discussed above, the modification will lead to a safer space environment, more efficient spectrum use, and better services for American consumers, including otherwise hard to reach polar regions. As discussed below, it will do so without increasing the number of satellites in the constellation.

Section 25.117 of the Commission's rules provides that "applications for modifications of space station authorizations will be granted" unless one of the enumerate exceptions applies.[11] The only two such exceptions that are potentially relevant here are (1) where the applicant seeks to increase the authorized bandwidth of a system authorized pursuant to an NGSO processing round, and (2) where granting the modification would not serve the public interest, convenience and necessity. SpaceX does not seek any additional bandwidth. As for the public interest, the Commission has established criteria for its analysis, recognizing that a modification should be granted where it "does not present any significant interference problems and is otherwise consistent with Commission policies."[12]

In this case, SpaceX invested in an advanced architecture and cutting-edge technology to maintain—or even improve—the interference environment. In particular, SpaceX is taking a number of steps that the Commission has recognized—including when approving SpaceX's first, similar modification—as factors that demonstrate that a modification will not meaningfully increase interference to other NGSO systems. Critically, unlike modifications proposed by others, SpaceX will actually be slightly reducing the total number of satellites in the affected orbital planes, from 4,409 to 4,408. In approving SpaceX's initial modification, the Bureau noted that a reduction in satellites was not a trivial part of its analysis, but rather a "fundamental element

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[11] 47 C.F.R. § 25.117.

[12] *Teledesic LLC*, 14 FCC Rcd. 2261, ¶ 5 (IB 1999) ("*Teledesic*"). *See also The Boeing Co.*, 18 FCC Rcd. 12317, ¶ 7 (IB 2003) ("In recognition of the length of time it takes to construct a satellite system, the rapid pace of technological change, and the goal of promoting more efficient use of the radio spectrum, the [Commission] has granted such requests in cases where the proposed modification presents no significant interference problem and is otherwise consistent with Commission policies." (internal citation omitted)).

in assessing whether there would be significant interference problems as a result of granting the proposed modification."[13] The Bureau properly reasoned that a slight reduction in the number of satellites in the system meant that "the potential for generating interference between SpaceX and any other NGSO FSS system in the same processing round is expected to remain approximately unchanged."[14]

But beyond this reduction, because the satellites will be operating at a lower altitude, fewer of them will be visible from any point in the United States, which is a factor the Commission has recognized as demonstrating that a modification will not increase interference.[15] Finally, because these satellites will be operating at a lower altitude, they will be able to transmit and receive at lower EIRP levels—another factor that reduces the potential for interference. Just as with its first modification, these satellites will operate closer to the Earth, meaning their spot beams can cover less area than constellations at higher altitudes, but map to the same grid. Each of these features alone could reduce the potential for interference, as confirmed by the analysis in the Technical Attachment.

III. SPACEX HAS TAKEN ADDITIONAL STEPS TO PROTECT PHYSICAL OPERATIONS IN SIMILAR ORBITS AND TO REDUCE SATELLITE VISIBILITY FOR ASTRONOMERS

SpaceX recognizes that some parties have in the past raised issues that extend beyond radiofrequency interference. SpaceX is taking aggressive steps to address these concerns, even those that fall outside the Commission's jurisdiction.

A. SpaceX Will Avoid Collisions with Non-Propulsive Small Satellites and Already Employs the Most Aggressive Collision Space Traffic Management in the Industry

Some small satellite operators have in the past expressed concerns that SpaceX's operations would make it more difficult for them to deploy non-propulsive systems near SpaceX's

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13 *First Modification*, ¶ 11.

14 *Id.*

15 *See Teledesic*, ¶ 13.

orbits, given their own limited capability for collision avoidance.[16] SpaceX has made clear that it intends to conduct active maneuvers to avoid collisions with both debris and other spacecraft throughout the life of its satellites, even through the de-orbit phase until the spacecraft enters the atmosphere. As the Commission has recognized, because SpaceX has invested in advanced propulsion capabilities for its satellites, collision risk is considered to be zero (or near zero).[17] In any event, SpaceX is subject to an ongoing obligation to coordinate its physical operations with other NGSO systems (as are the other NGSO operators, including those without propulsive capabilities).[18]

Nonetheless, as an operational matter, SpaceX's propulsive capabilities enable it to avoid non-propulsive systems unilaterally. Yet these types of voluntary steps would be a poor basis for license conditions. This sort of condition would put an additional regulatory burden on the system that invested in more maneuverable satellites, which could inadvertently create a race to the bottom where operators make their systems as non-maneuverable as possible in an effort to avoid regulatory obligations. The Commission is instead properly considering as part of its larger proceeding on orbital debris an industry-wide approach to create incentives that would drive more operators to follow SpaceX's lead in investing in more maneuverable systems.

In addition to its voluntary steps to autonomously avoid non-propulsive systems, SpaceX has taken a number of additional steps to ensure a safe space environment. For instance, SpaceX provides all of its ephemeris data to other operators via spacetrack.org. SpaceX is also the first operator to optimize the usefulness of this data by supplementing it with co-variance data, which

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[16] *See* Comments and Petition to Defer ("CSSMA Comments"); Petition to Defer ("Astro Digital Petition"); Petition to Defer ("Planet Labs Petition); and Petition to Defer ("Spire Petition"). All these filings were submitted in IBFS File No. SAT-MOD-20181108-00083 on January 29, 2019.

[17] *See, e.g., First Modification*, ¶ 22.

[18] *See id.*

allows other operators to better predict the trajectories of SpaceX satellites. Going forward, SpaceX encourages all operators to follow these same practices.

B. SpaceX is Working with Astronomers to Ensure its Operations Have No Material Impact on Views of the Night Sky

Lastly, while many were excited after SpaceX's first launches, some in the optical astronomy community voiced concern that the light reflected from those satellites could interfere with their space observations.[19] SpaceX is committed to promoting all forms of space exploration, which is why it was the first NGSO licensee in its processing round to reach an agreement with radio astronomers to ensure its service does not interfere with radio observatories.[20]

While the Commission does not have jurisdiction over the visibility of satellites, SpaceX nonetheless would like to take this opportunity to explain its efforts to address the concerns of optical astronomers. In fact, SpaceX has already taken a number of proactive steps to ensure it does not materially impact optical astronomy. While no established guidelines or standards exist for acceptable levels of reflection from spacecraft, SpaceX is working with U.S. and international astronomy organizations and observatories to measure scientifically the actual impact of its satellites. SpaceX is studying the brightness of its satellites both during deployment and during on-orbit configuration, with the goal of finding potential avenues for amelioration if appropriate.[21] SpaceX has already determined that during the orbit-raising phase of its operations, the satellites are closely clustered and their solar arrays are in a special low-drag configuration, making them more visible from the ground. Once the satellites reach their operational altitude and begin on-

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[19] *See, e.g.,* Shannon Hall, "After SpaceX Starlink Launch, a Fear of Satellites That Outnumber All Visible Stars," NEW YORK TIMES (June 1, 2019), https://www nytimes.com/2019/06/01/science/starlink-spacex-astronomers html.

[20] *See* National Science Foundation, Press Statement 19-005, "Statement on NSF and SpaceX Radio Spectrum Coordination Agreement" (June 4, 2019), https://www nsf.gov/news/news_summ.jsp?cntn_id=298678.

[21] As noted by SpaceX founder and CEO Elon Musk (@elonmusk), TWITTER (May 27, 2019, 3:11 AM), "…we'll make sure Starlink has no material effect on discoveries in astronomy. We care a great deal about science."

station service—where the satellites spend the vast majority of their lifetime—their orientation changes and the satellites become significantly less visible from the ground. To decrease visibility during this phase of operations, SpaceX is testing an experimental darkening treatment on one in-orbit satellite to further reduce the visibility (albedo) on the body of the satellites. Initial results indicate that this treatment made the satellite invisible to the naked eye, making it a successful first step in our work with the community.[22] Additionally, SpaceX will make satellite tracking data available so astronomers can better coordinate their observations with our satellites. These measures along with our work with leading astronomy groups will enable SpaceX to bring the substantial benefits of broadband access to underserved populations around the world without materially impacting views of the night sky.

In addition to the benefits to space safety mentioned above, the altitude decreases will decrease the period of time during which any individual satellite is visible and decrease the total number of satellites simultaneously visible from a single location. These modifications will also give the lowered satellites a similar brightness profile to those recently launched. For these reasons, we also believe that this modification will have a positive impact on satellite albedo overall.

SpaceX's operations at a lower altitude will not have an overall negative affect on astronomy because brightness is not simply a function of altitude. Critically, contrary to unsupported statements made to the press, operating at higher orbits does not alleviate the need for operators to take additional steps to mitigate their impact on optical astronomy. Based on SpaceX's research and work with astronomers, the actual situation is much more complicated.

[22] *See* J. Tregloan-Reed, A. Otarola, E. Ortiz, V. Molina, J. Anais, R. González, J. P. Colque, and E. Unda-Sanzana,, "First Observations and Magnitude Measurement of SpaceX's Darksat," Astronomy and Astrophysics (Apr. 16, 2020), https://arxiv.org/pdf/2003.07251.pdf.

While satellites operating at a higher altitude will tend to be less bright, they will also be subject to a number of other factors that will actually increase their potential to harm astronomical observations. For instance, the satellites will have longer overall exposure time as they will be outside the Earth's shadow for a more prolonged period. Furthermore, just as a higher orbit could increase the potential for in-line interference because more satellites will be operating above the horizon, more satellites will also be visible to astronomers at any given site for longer. Given these complexities, SpaceX encourages other satellite operators to work with astronomers to study the actual harm caused by their constellations. Together, the satellite industry and optical astronomers can find concrete ways supported by empirical data to mitigate their impact on space exploration.

CONCLUSION

By authorizing the changes outlined in this application, including lowering 2,824 satellites to altitudes ranging from 540 km to 570 km, the Commission can improve the orbital environment, improve latency for American consumers, and accelerate the initiation of broadband service in Polar regions, including in areas with no viable high-speed broadband alternative. Moreover, it can achieve this result without any material impact on other spectrum users. For the foregoing reasons, and for the reasons set forth in the accompanying materials, SpaceX requests that the Commission find that granting the requested modification would serve the public interest, and issue such grant expeditiously.

Respectfully submitted,

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