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

Application of	)	
SPACE EXPLORATION HOLDINGS, LLC	)	Call Sign:
For Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System	)	File No. __________________

APPLICATION FOR APPROVAL FOR ORBITAL DEPLOYMENT AND OPERATING AUTHORITY FOR THE SPACEX NGSO SATELLITE SYSTEM

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TABLE OF CONTENTS

Page

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Space Exploration Holdings, LLC, a wholly owned subsidiary of Space Exploration Technologies Corp. (collectively, "SpaceX"), requests operating authority (that is, approval for orbital deployment and a station license) for use of V-band frequencies with a non-geostationary orbit ("NGSO") satellite system in the Fixed-Satellite Service ("FSS"). A completed Form 312, accompanying Schedule S, Technical Attachment, and Waiver Request are associated with this application, consistent with the information required by the Commission's rules in support of the requested authorization.

The requested authorization of V-band capability augments an NGSO system SpaceX previously proposed for operation in Ku-band and Ka-band frequencies,[1] enabling the combined NGSO system to provide a broader range of services, higher capacity, and enhanced operational flexibility. Specifically, SpaceX seeks authority to operate using V-band spectrum to expand its Ka/Ku-band NGSO constellation in two ways:

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[1] *See* IBFS File No. SAT-LOA-20161115-00018 ("Ka/Ku Application").

- First, utilizing the same number of satellites as originally proposed (4,425) in the Ku and Ka bands, this enhancement would create additional spectrum diversity by enabling use of both Ku- and V-band spectrum for user links and both Ka- and V-band spectrum for gateway links and tracking, telemetry and control ("TT&C") functions. As before, the system would operate in 83 orbital planes (at altitudes ranging from 1,110 km to 1,325 km), along with associated ground control facilities, gateway earth stations and end user earth stations.[2] These V-band assets, referred to herein as the "LEO Constellation," would provide high-speed broadband service in the United States and around the world, including in remote and rural locations currently unserved by other providers.
- Second, SpaceX would add a very-low-Earth orbit NGSO constellation, consisting of 7,518 satellites operating at altitudes from 335 km to 346 km, using V-band spectrum for all links to and from associated earth stations. These assets, referred to herein as the "VLEO Constellation," would enhance capacity where it may be needed most, enabling the provision of high speed, high bandwidth, low latency broadband services that are truly competitive with terrestrial alternatives.

When combined into a single, coordinated system (the "SpaceX System"), the LEO and VLEO Constellations would provide both diverse geographic coverage and the capacity to support a wide range of broadband and communications services for residential, commercial, institutional, governmental and professional users in the United States and globally.

SpaceX has designed its V-band system to provide efficient, high-capacity connectivity, to include connectivity for rural, remote, and hard-to-reach end-users. Operating at an altitude of 1,110 km or more, satellites in the LEO Constellation will have a relatively larger footprint, which

[2] To the extent necessary, SpaceX hereby incorporates by reference relevant portions of the Ka/Ku Application.

will enable them to deploy narrow spot beams over a fairly broad coverage area. Because the VLEO Constellation operates at approximately one-third the altitude of the LEO Constellation, it benefits from commensurately smaller spot beam sizes on the surface of the Earth. This, of course, necessitates the deployment of a larger number of satellites, but would allow substantially greater spectrum reuse capability, enabling the VLEO Constellation to deliver more bandwidth, more satellite diversity options for serving customers,[3] or a combination of the two.

The V-band operations of the LEO and VLEO Constellations would enhance the operations of the Ka/Ku-band system previously proposed in several ways. First, the increase in capacity and frequency reuse increases the number of customers who could be served. Second, the increase in bandwidth available per user improves the quality of service. Third, the combination of satellites with narrow, steerable spot beams in higher and lower orbits creates opportunities to optimize spectrum use, which will reduce interference both within the SpaceX System and in coordination with other NGSO, GSO, and terrestrial wireless systems.

The same advanced beam-forming and digital processing technologies within the satellites previously proposed in the Ka/Ku-band application will ensure that the entire system makes highly efficient use of V-band resources and has the flexibility to share that spectrum with other licensed satellite and terrestrial users. Likewise, gateway earth stations will apply advanced phased array technologies to generate high-gain steered beams to communicate with multiple NGSO satellites from a single gateway site. User terminals operating with the SpaceX System will use similar phased array technologies to allow for highly directive, steered antenna beams that track the

[3] As explained by the Commission, "[w]ith satellite diversity, NGSO FSS systems can avoid an in-line interference event by selecting another visible satellite within their system constellation (performing a hand-over process) whenever the current satellite approaches the in-line event with a satellite operating in another NGSO FSS system constellation." *Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ka-Band*, 18 FCC Rcd. 14708, ¶ 44 (2003).

system's satellites. The system will employ optical inter-satellite links for seamless network management on-orbit and continuity of service, while also aiding compliance with emission constraints designed to facilitate spectrum sharing with other space-based and terrestrial systems.

As with the proposed Ka/Ku-band system, SpaceX anticipates that the first 800 LEO satellites deployed will enable the system to provide initial U.S. and international coverage for broadband services. Deployment of the remainder of that constellation will complete coverage and add capacity around the world. The VLEO Constellation will add enhanced capacity where demand may be greatest, and satellite enhancements derived from lower power demand and more compact spot size will add user value without increasing system costs. Once fully optimized through deployment of all satellites, the system would be able to provide high bandwidth, low latency broadband services.

Consistent with the principles of good spectrum stewardship, the SpaceX System has been designed to maximize the efficient use of spectrum and to ensure protection of other satellite and terrestrial systems by mitigating harmful interference to such systems. The system will be designed for high degrees of adaptability, making it more flexible to accommodate evolutions in broadband service demand and better able to coordinate with existing and future space and terrestrial systems. SpaceX is also committed to meeting or exceeding best practices and international norms to ensure the safety of space. Here, SpaceX will employ advanced space-situational awareness techniques and other methods to mitigate the potential creation of additional orbital debris. To this end, SpaceX will implement an operations plan for the orderly de-orbit of satellites nearing the end of their useful lives (roughly five to seven years) at a rate far faster than is required under international standards. Satellites in the LEO Constellation will de-orbit by propulsively moving to a disposal orbit from which they will reenter the Earth's atmosphere within approximately one year after completion of their mission. Because the VLEO Constellation operates at an altitude where atmospheric drag necessitates constant station keeping in order to remain in orbit, its satellites would naturally de-orbit within a matter of weeks at the end of their useful lives. At this very-low operational altitude, other space debris also naturally re-enters the atmosphere, resulting in a safer environment for space operations.

I. BACKGROUND AND SYSTEM PARAMETERS

A. SpaceX Background

SpaceX is a private company founded in 2002 by Chief Executive Officer and Lead Designer Elon Musk to revolutionize space technologies, with the ultimate goal of enabling humanity to become a multi-planetary species. The company designs, manufactures, and launches advanced rockets and spacecraft. It has approximately 5,000 employees based in the United States at the company's headquarters in Hawthorne, California; launch facilities at Cape Canaveral Air Force Station and Kennedy Space Center, Florida, and Vandenberg Air Force Base, California; a private launch facility under construction in Brownsville, Texas; and offices in the Washington, D.C. and Seattle, Washington areas.

Since its founding in 2002, SpaceX has achieved a series of historic milestones. In December 2010, SpaceX became the first private company ever to successfully launch and return a spacecraft (Dragon) from low-Earth orbit. In May 2012, the company again made history when Dragon berthed with the International Space Station ("ISS"), delivered cargo, and returned safely to Earth – a technically challenging feat previously accomplished only by nations. In December 2015, SpaceX successfully returned a first stage rocket booster to land after carrying a payload to space, and has now successfully landed its first stage booster seven times on land and upon droneships at sea. SpaceX will reuse these flight-proven boosters for various missions, including the upcoming launch of a high-value commercial satellite.

SpaceX's current and planned space-based activities illustrate and underscore its commitment to space safety. The company is highly experienced with space-based operations and debris mitigation practices. SpaceX maintains deep ties with the domestic and international institutions tasked with ensuring the continued safety of space operations, which facilitates aggressive and effective space-debris mitigation practices. SpaceX brings this commitment and experience to all aspects of its space-based operations.

B. The SpaceX System

The SpaceX System consists of a constellation of low- and very-low-Earth orbit satellites and ground-based technologies. The system is highly spectrum-efficient, sharing Ku-, Ka-, and V-band spectrum with conventional GSO satellite and terrestrial networks without causing harmful interference. SpaceX will submit to the Commission network filings for submission to the International Telecommunication Union ("ITU") on its behalf for the V-band components of its system.

SpaceX has designed its system to achieve the following objectives:

- High capacity: By combining the umbrella coverage of the LEO Constellation with the more intensive coverage from the VLEO Constellation, the SpaceX System will be able to provide high volume broadband capacity over a wide area. SpaceX will periodically improve the satellites over the course of the multi-year deployment of the system, which may further increase capacity.

- High adaptability: The system leverages phased array technology to dynamically steer a large pool of narrow beams to focus capacity where it is needed. Optical inter-satellite links permit flexible routing of traffic on-orbit. Further, the constellation ensures that a variety of frequencies can be reused effectively across different satellites operating at different altitudes and in different planes to enhance the flexibility, capacity, and robustness of the overall system.

- Expansive coverage: With deployment of the first 800 satellites of the LEO Constellation, the system will be able to provide initial U.S. and international broadband connectivity; when fully deployed, the system will add capacity and availability at the equator and poles.

- Efficiency: SpaceX is designing the overall system from the ground up with cost-effectiveness and reliability in mind, from the design and manufacturing of the space and ground-based elements, to the launch and deployment of the system using SpaceX launch services, development of the user terminals, and end-user subscription rates.

The various space and ground facilities composing the SpaceX System are described below and in more detail in Schedule S and the Technical Attachment (Attachment A) accompanying this application.

1. Space Segment

The SpaceX System will consist of a total of 4,425 satellites in the LEO Constellation and 7,518 satellites in the VLEO Constellation. When combined, these constellations would enable SpaceX to provide full and continuous coverage of the Earth utilizing a minimum elevation angle of 35 degrees. The LEO Constellation is configured as follows:

SpaceX System LEO Constellation					
Parameter	**Initial Deployment (1,600 satellites)**	**Final Deployment (2,825 satellites)**			
Orbital Planes	32	32	8	5	6
Satellites per Plane	50	50	50	75	75
Altitude	1,150 km	1,110 km	1,130 km	1,275 km	1,325 km
Inclination	53º	53.8º	74º	81º	70º

The VLEO Constellation will be deployed over a range of three altitudes and three angles of inclination. The satellites are distributed approximately equally across those altitudes and inclinations, with the precise number in each chosen to maximize the spacing between satellites and thereby preclude the risk of conjunction, while still providing even coverage on the ground.

However, each satellite will occupy a unique orbital plane in very low Earth orbit, as detailed in the materials submitted with this application. The constellation can be summarized as follows:

SpaceX System VLEO Constellation			
Satellites per Altitude	2,547	2,478	2,493
Altitude	345.6 km	340.8 km	335.9 km
Inclination	53º	48º	42º

SpaceX will be able to provide early beta service with limited coverage at certain high latitudes with deployment of as few as 100 satellites in the LEO Constellation (using 4 of the 32 planes at 53º inclination). As each additional satellite is launched and brought into operation, it will be integrated into the system and used to enhance the overall broadband service offerings.

Deployment of the first 800 satellites in the LEO Constellation (32 planes with an initial 25 satellites per plane) will permit widespread U.S. and international coverage sufficient to offer commercial broadband service. Completion of the 53º inclination orbit will add capacity throughout the system and provide robust broadband connectivity around the globe, with service concentrated in the area between 60 degrees North Latitude and 60 degrees South Latitude. Launch of the final 2,825 satellites of the LEO Constellation will complete this aspect of the overall system, further increasing available capacity and extending geographic coverage to polar and high-latitude regions above 60 degrees North Latitude and below 60 degrees South Latitude. Addition of satellites in the VLEO Constellation would enhance overall system capacity where demand is highest.

The SpaceX System will use V-band spectrum for communications between satellites and user terminals, gateway earth stations, and TT&C facilities.[4] SpaceX requests authority to operate on the following frequencies:

Type of Link and Transmission Direction	**Frequency Ranges**
Downlink Channels Satellite to User Terminal or Satellite to Gateway	37.5 – 42.5 GHz
Uplink Channels User Terminal to Satellite or Gateway to Satellite	47.2 – 50.2 GHz 50.4 – 52.4 GHz
TT&C Downlink Beacon	37.5 – 37.75 GHz
TT&C Uplink	47.2 – 47.45 GHz

A more precise description of the frequency and channelization plan for the V-band operations of the SpaceX System is included in Schedule S and the Technical Attachment accompanying this application.

2. Ground Segment

The SpaceX System includes three broad categories of V-band earth stations: TT&C stations; gateway earth stations; and user terminals. There will be relatively few TT&C stations

4 The system will also employ optical inter-satellite links for communications directly between SpaceX satellites. As the Commission has previously found, "[b]ecause optical ISLs do not involve wire or radio frequency transmissions, the Commission does not have jurisdiction over the use of optical ISLs." *Teledesic LLC*, 14 FCC Rcd. 2261, ¶ 14 (IB 1999). Moreover, to the extent that the use of optical ISLs alleviates congestion in radio frequency bands, it is to be encouraged. *Id.*

(*e.g.*, primary and back-up TT&C locations in the United States, with further locations distributed internationally). The gateway earth stations will use phased array antenna technology, with several hundred locations anticipated within the U.S., co-located with or sited near major Internet peering points to provide the required Internet connectivity to the satellite constellation. The user terminals will also utilize phased array antenna technology.

At the appropriate time, SpaceX will submit applications to the Commission requesting individual licenses for any TT&C stations and gateway earth stations, and a blanket license for user terminals to be located in the United States, pursuant to Sections 25.115 and 25.130 of the Commission's rules.[5]

II. GRANT OF THIS APPLICATION WOULD SERVE THE PUBLIC INTEREST

Worldwide demand for broadband services and Internet connectivity continues to evolve, with ever-escalating requirements for speed, capacity, and reliability. The volume of traffic flowing over the world's networks continues to grow, with one report estimating annual global Internet protocol ("IP") traffic surpassed the zettabyte threshold in 2016 – meaning over 1,000 billion gigabytes of data exchanged worldwide.[6] By 2020, that figure is projected to more than double (reaching a level nearly 100 times greater than the global IP traffic in 2005), global fixed broadband speeds will nearly double, and the number of devices connected to IP networks will be three times the global population.[7]

To meet this booming, rapidly evolving broadband demand, diverse technology platforms

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5 *See* 47 C.F.R. §§ 25.115, 25.130.

6 *See* Cisco Visual Networking Index: Forecast and Methodology, 2015-2020, at 1 (June 6, 2016), *available at* http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf.

7 *Id.* at 1-2.

will be required, from terrestrial fiber and cable systems to mobile broadband networks and space-based systems, along with innovative new alternatives currently under development. Customers in urban areas of the developed world enjoy many options for connectivity, which has become a basic part of everyday life. In these areas, broadband providers face the challenge of devising strategies to keep up with growing demand that threatens to overwhelm their systems.

Yet the Commission's data analysis concludes that advanced telecommunications capability is not being deployed to all Americans in a reasonable and timely fashion.

> Despite the increase in the number of Americans that are able to obtain advanced telecommunications capability, these advances are not occurring broadly enough or quickly enough to achieve our statutory objective. Nationwide, one in ten Americans lacks access to 25 Mbps/3 Mbps broadband. As importantly, there continues to be a significant disparity of access to advanced telecommunications capability across America with more than 39 percent of Americans living in rural areas lacking access to advanced telecommunications capability, as compared to 4 percent of Americans living in urban areas, and approximately 41 percent of Americans living on Tribal lands lacking access to advanced telecommunications capability. We note that small businesses tend to subscribe to mass market broadband service. Thus, the rural-urban disparity in deployment of these broadband services also disproportionately impacts the ability of small businesses operating in rural areas to successfully compete in the 21st century economy.[8]

Internationally, the disparities between broadband access and absence are even greater. As the U.N. Broadband Commission for Sustainable Development recently noted:

> Today, 4.2 billion people (or 57% of the world's population) are offline for a wide range of reasons, but often also because the necessary connectivity is not present or not affordable. Information and Communication Technologies (ICTs) are vital enablers of the three pillars of sustainable development – economic development, social development and environmental protection. . . . In developing countries, broadband can help meet the basic needs of food, water and energy, as well as access to health services and education.[9]

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[8] *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*, 31 FCC Rcd. 699, ¶ 4 (2016).

[9] Broadband Commission for Sustainable Development, "Open Statement from the Broadband Commission for Sustainable Development to the UN High-Level Political Forum (HLPF)" (July 11, 2016), *available at* http://broadbandcommission.org/Documents/publications/HLPF-July2016.pdf.

The resulting digital divide has very real economic consequences. As reported by the Congressional Research Service,

> disparities in broadband access across American society could have adverse consequences on those left behind, and . . . advanced telecommunications applications critical for businesses and consumers to engage in e-commerce are increasingly dependent on high-speed broadband connections to the Internet. Thus, some say, communities and individuals without access to broadband could be at risk to the extent that connectivity becomes a critical factor in determining future economic development and prosperity.[10]

Satellite technology has long helped to alleviate the inequities in availability of communications services, in part due to its geographic reach. Historically, satellites first revolutionized the availability of international telephony, then pioneered global distribution of video content. More recently, satellite systems have introduced broadband connectivity for mobile platforms, such as aircraft and ships.

The combined SpaceX System will address both the need to bring new broadband capability to the U.S. and international markets and the need to accommodate growing demands in more developed areas. The LEO Constellation, operating at relatively higher altitudes, will be able to achieve greater coverage with fewer satellites, initiating widespread commercial service after launch of 800 satellites, and extending high-speed broadband coverage to additional underserved areas as the rest of the constellation is deployed. The VLEO Constellation, operating at lower altitudes that enable even smaller spot beams and greater satellite diversity, will be able

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[10] Congressional Research Service, "Broadband Internet Access and the Digital Divide: Federal Assistance Programs," at 8 (Dec. 28, 2016), *available at* https://www.everycrsreport.com/files/20161228_RL30719_a6c4d95cdf832cb7a13f8b75140dccb7bb38d8b4.pdf. *See also* Broadband Commission for Sustainable Development, "The State of Broadband 2015," at 8 (Sep. 2015), *available at* http://www.broadbandcommission.org/Documents/reports/bb-annualreport2015.pdf ("A large body of evidence has now been amassed that affordable and effective broadband connectivity is a vital enabler of economic growth, social inclusion and environmental protection." (footnotes omitted)).

to achieve a higher degree of frequency reuse and thereby significantly enhance the capacity that can be made available in areas of high demand around the world.

Both constellations apply cutting-edge technologies designed to maximize spectrum efficiency and broadband capacity, while leveraging lower orbits for lower latencies and safe space operations. The combination of multiple frequencies in the LEO Constellation (Ku, Ka, and V bands) and multiple satellites in view from a given point on the ground will give the SpaceX System great flexibility in delivering robust service despite a crowded spectrum environment.

The SpaceX System was designed to ensure protection of existing satellite and terrestrial systems from harmful interference while maximizing its efficient use of spectrum. As demonstrated in the Technical Attachment, Waiver Requests, and Schedule S accompanying this application, the system will not create harmful interference to other satellite and terrestrial systems. The system will comply with all international downlink power limitations applicable to the bands in which it will operate, which were designed to safeguard terrestrial operations. Analyses confirm that the SpaceX NGSO system will have a *de minimis* effect on terrestrial fixed and mobile networks in these bands. In frequency bands where the Commission has not yet adopted service rules or licensed other operators, SpaceX is confident that the variety of its system's attributes that facilitate spectrum sharing, including narrow, steerable spot beams, operations at high elevation angles, and the ability to provide service from multiple satellites with overlapping coverage contours, can be used individually or in combination as necessary to address any coordination issues that may arise.

The ability to share available spectrum in an efficient manner among NGSO systems will be a prerequisite to optimizing broadband speeds and increasing broadband availability for customers in the U.S. and around the world. SpaceX will seek in every case to reach coordination agreements that optimize spectrum efficiency and allow for the greatest operational flexibility possible among the systems. In this regard, the ability to choose among both Ku-band and V-band frequencies for communications with user terminals will enhance the SpaceX System's ability to accommodate other systems as necessary while still providing a high level of service to its own customers.

In addition, although the VLEO Constellation adds more spacecraft to those previously proposed, it also enjoys built-in advantages with respect to stewardship of space. While SpaceX has designed its system so that normal operations should not generate any debris, to the extent any related to the VLEO Component arises, atmospheric drag will ensure that such debris will quickly disintegrate in the atmosphere and pose no further danger to space operations. Thus, these additional spacecraft will contribute a great deal of capacity to the SpaceX System without imposing undue risk to safety in space.

A. Eligibility and Operational Requirements

To the extent necessary, SpaceX confirms that (1) it has no right that would run afoul of the prohibition in Section 25.142(d) of the Commission's rules as applied to its system,[11] nor will it acquire any such right in the future; (2) it will post a surety bond as required under Section 25.165 of the Commission's rules;[12] (3) it will comply with the Commission's milestone

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[11] *See* 47 C.F.R. § 25.142(d) ("No license shall be granted to any applicant for a non-voice, non-geostationary mobile-satellite service system if that applicant, or any companies controlling or controlled by the applicant, shall acquire or enjoy any right, for purposes of handling traffic to or from the United States, its territories or possession, to construct or operate space segment or earth stations in the non-voice, non-geosynchronous mobile-satellite service, or to interchange traffic, which is denied to any other United States company by reason of any concession, contract, understanding, or working arrangement to which the licensee or any persons or companies controlling or controlled by the licensee are parties."). This provision is made applicable to this application by virtue of the default service rules in Section 25.217(b)(1).

[12] *See id.* § 25.165(a)(1).

requirements, subject to its request for a limited waiver;[13] and (4) it does not have any other application for an NGSO-like satellite system license on file with the Commission, or any licensed-but-unbuilt NGSO-like system, in any frequency band involved in this application.[14]

III. ITU COST RECOVERY

SpaceX is aware that, as a result of the actions taken at the 1998 Plenipotentiary Conference, as modified by the ITU Council in 2005, the ITU now charges processing fees for satellite network filings. As a consequence, Commission applicants are responsible for any and all fees charged by the ITU. SpaceX confirms that it is aware of this requirement and accepts responsibility to pay any ITU cost recovery fees associated with this application. Invoices for such fees may be sent to the contact representative listed in the accompanying FCC Form 312.

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13 *See id.* § 25.164(b). In its Waiver Request, SpaceX seeks relief from the implementation milestone in recognition of the practical challenge of launching and beginning operations of thousands of satellites within six years of licensing and the operational capability to initiate commercial broadband service provision upon the launch of an initial 800 satellites.

14 *See id.* § 25.159(b).

IV. CONCLUSION

For the foregoing reasons, and for the reasons set forth in the accompanying materials, SpaceX requests that the Commission find that granting approval for orbital deployment and a station license (*i.e.*, operating authority) for the V-band components of the SpaceX System would serve the public interest, and issue such grant expeditiously.

Respectfully submitted,

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