STATEMENT OF
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BEFORE THE
COMMITTEE ON COMMERCE, SCIENCE & TECHNOLOGY
UNITED STATES SENATE

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Mr. Chairman, Ranking Member Nelson, and Members of the Committee:

Thank you for the opportunity to participate in today's hearing. We appreciate the Committee's interest in exploring how advanced satellite technologies can expand broadband access within the United States and the policies that would foster that capability. SpaceX also appreciates that the Committee recognizes the potential of a new generation of U.S.-based low-Earth orbit ("LEO") or non-geostationary satellite orbit ("NGSO") satellite broadband system as an integral part of any strategy to augment high-speed Internet connectivity nationwide. NGSO satellite constellations intend to leverage emerging technologies in space and on the ground to provide reliable, high-speed, and affordable broadband service to customers throughout the United States and abroad.

SpaceX was founded in 2002 with the express goal of dramatically improving the reliability, safety, and affordability of space transportation. Today, SpaceX today is the world's largest launch services provider, measured by missions under contract and cadence of launch, with 42 successful Falcon 9 launches, including 15 in 2017 alone.

SpaceX has deployed over 65 commercial communications satellites since 2010. In addition to commercial satellite operators, SpaceX supports a diverse and growing set of satellite and space customers, including NASA, the Department of Defense, and allied international governments. We have signed contracts for nearly 70 missions on manifest, representing more than $10 billion. Under one of the most successful public-private programs ever undertaken with NASA, SpaceX also supports the Nation's civil space program through routine cargo resupply missions with our Dragon spacecraft to the International Space Station (ISS). Next year, we will have the awesome responsibility of launching NASA astronauts to space from U.S. soil for the first time since the Space Shuttle was retired in 2011. SpaceX is also a certified provider to the Department of Defense for national security space launch.

Leveraging our experience in space launch system and spacecraft design, development, production, and on-orbit operations, SpaceX is developing an innovative NGSO constellation. Our system is designed to reach directly to end users, and provide global broadband services at speeds, latencies and prices on par with terrestrial alternatives available in metropolitan communities. Accordingly, we filed applications with the Federal Communications Commission ("FCC") in November 2016 and April 2017 that detail those plans.

My testimony today will describe SpaceX's planned satellite constellation, including our capabilities and timelines, as well as offer a number of recommendations for the Committee's consideration to streamline regulatory processes, maximize planned government investment to accelerate broadband deployment, and ensure a safe, collaborative operating environment in space. Specifically, my testimony today will focus on the following areas:

(1) **Launch.** The importance of low cost launch enabled by rapid reusability and robust launch

infrastructure to making large-scale, space-based broadband internet services more viable today than ever before, and recommendations to improve the launch licensing regulatory framework both at the FCC and the Federal Aviation Administration (FAA);

(2) **Spectrum Efficiency.** Recommendations to ensure the efficient use of spectrum, including potential regulatory incentives for systems that invest in technologies that effectively share spectrum. The Committee should take proactive steps to encourage and reward companies that utilize and advance technologies that result in maximum spectrum sharing and efficiency.

(3) **Technology-Neutral Programs.** The need to update eligibility requirements for nationwide broadband infrastructure initiatives to ensure they are truly technology neutral, and do not needlessly preclude satellite systems with equivalent or better service from competing against more traditional broadband providers. This hearing is an important forum to review how satellite broadband has improved and can contribute to the Nation's connectivity goals, and how to incorporate such services into any national infrastructure initiative.

(4) **Space Safety.** The importance of ensuring that large satellite constellations will employ robust orbital debris and space safety protocols, including high reliability for individual spacecraft; the speedy, planned deorbit of satellites at the end of the useful life; the ability to implement active collision avoidance throughout a satellite's life; and transparency and information sharing.

I. Vertically Integrated Approach to Manufacturing & Extensive Space Operations Experience

As the leading domestic commercial space launch provider, SpaceX has restored the U.S. as a leader in global commercial satellite launch by percentage of market share. In developing its fleet of highly-reliable, affordable, and innovative launch vehicle systems, SpaceX has invested billions of private capital in sophisticated manufacturing processes, engineering and design know-how for space and launch systems, the infrastructure needed to launch satellite payloads into orbit, and technologies to make launch more affordable. These manufacturing, engineering and design capabilities are trusted by the U.S. civil and national security space community, commercial satellite operators, and international governments.

Looking forward, SpaceX intends to leverage its fifteen years of experience in space to develop and deploy a cost-effective and sophisticated broadband satellite constellation. Our vertically-integrated approach to this initiative—linking design, development, production, launch, and operations—lends a unique capability to address the challenges that stymied past generations that have considered low-earth orbiting communications constellations from space.

SpaceX's proven core competency is the manufacturing of complex space systems with increased efficiency, scale, and affordability. Here, SpaceX has a vertically-integrated approach to manufacturing uncommon within the aerospace industry. For Falcon, SpaceX manufactures over 70 percent of the value of the Falcon 9 in-house, including the first- and second-stage propulsion systems (Merlin 1D and MVacD), the tanks, composite structures, payload fairings, avionics, etc. Similarly, SpaceX produces the autonomous Dragon spacecraft in house, including the on-board propulsion systems (Draco and SuperDraco), pressure vessel, avionics, and all other major subsystems and components. SpaceX also has extensive test facilities at our Rocket Development facility in McGregor, Texas.

SpaceX will carry this vertical approach to design, manufacturing, and test into our satellite broadband constellation. SpaceX expects to manufacture in-house the majority of each spacecraft, leveraging the experience we have gained with Falcon and Dragon in manufacturing and specific systems, such as propulsion systems, avionics, and solar arrays, among others. We are uniquely positioned to apply these

proven methods of reliability and cost-effectiveness to our planned broadband satellite constellation.

SpaceX's satellite constellation will also benefit from the company's extensive space operations experience, drawn from the Falcon 9 launch vehicle's 42 successful flights, 18 successful fist-stage re-entries and landings, and over 13 Dragon flights to and from the International Space Station (ISS). SpaceX can build upon the optimized guidance, navigation, and control ("GNC") systems that allow us to land our first-stage boosters on land and at sea with pinpoint accuracy. Similarly, our deep experience with orderly and safe de-orbit through routine Dragon missions to the ISS has informed and enriched careful and detailed on-orbit operations and de-orbit planning for the satellite constellation. SpaceX is also drawing on the operational experience it has built with every Federal agency working on space-related issues—including FCC, FAA, NASA and DOD—to prepare and coordinate for the satellite constellation undertaking. This unique manufacturing, operational, and cross-agency engagement will advance the planning and operations of the satellite broadband constellation.

II. Expanding Broadband Access and Bridging the Digital Divide

SpaceX sees a robust market of continuously-growing demand for high-speed broadband both in the United States and worldwide. Connected consumers continue to increase requirements for speed, capacity, and reliability. And the volume of traffic flowing over the world's networks continues to skyrocket, with one vendor estimating that annual global Internet Protocol ("IP") traffic surpassed the zettabyte threshold in 2016—meaning that over 1,000 billion gigabytes of data was exchanged worldwide last year.[1] 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 as high as the global population.[2]

However, as the Committee is aware, millions of Americans outside of limited urban areas lack basic, reliable access to broadband—even as worldwide demand for data skyrockets. We note a few important facts about the availability and quality of broadband access in the United States and worldwide:

- According to the FCC, 34 million Americans lack access to 25 megabits per second ("Mbps") broadband service, and 47 percent of the Nation's students lack the connectivity to meet the FCC's short-term goal of 100 Mbps per 1,000 students and staff. [3]

- The FCC has further noted that "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."[4]

- Connectivity levels are even lower for tribal communities, with "approximately 41 percent of Americans living on Tribal lands lacking access to advanced telecommunications capability."[5]

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[1] 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; *see also* http://blogs.cisco.com/sp/happy-zettabyte-day-2016. To fathom the volume of a zettabyte, if one byte is a litter, then a zettabyte is the equivalent of 7080 Pacific Oceans. *See id*.

[2] Ibid.

[3] Federal Communications Commission, *2016 Broadband Progress Report,* (January 28, 2016), GN Docket No. 15-191, available at https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-6A1.pdf..

[4] Ibid.

[5] Ibid.

- In addition, nearly 10 million Americans living in non-rural areas also lack basic access to high-speed internet service. As a general matter, the U.S. continues to lag behind other developed nations in both its broadband speed and in price competitiveness.

- Even in urban areas of the United States, a majority of Americans lacks more than a single fixed broadband provider from which to choose and may seek additional competitive options for high-speed service.[6] According to the FCC, "only 38 percent of Americans have more than one choice of providers for fixed advanced telecommunications capability," with only "13 percent of Americans living in rural areas having more than one choice of providers of these services compared to 44 percent of Americans living in urban areas."[7]

- Beyond the United States, the United Nations Broadband Commission for Sustainable Development recently noted that 4.2 billion people, or 57 percent of the world's population, are simply "offline" for a wide range of reasons—but predominately because the necessary connectivity is not present or not affordable.[8]

III. NGSO Satellite Constellations Offer Unique Advantages in Expanding Broadband Access

Satellites have traditionally served at the forefront of remote and rural connectivity, and often have helped to alleviate inequities in the availability of communications services, in part due to 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—establishing and supporting new markets and enhancing those businesses and their customer experience.

New constellations of sophisticated satellites operating close to the Earth add important prospects for remote connectivity, particularly where latency is critical. In adopting new rules for such NGSO systems and moving briskly on NGSO applications for U.S. market access and systems licenses, the Commission has underscored the vital role that NGSO systems can have for the broadband landscape of the future, and that this future is coming imminently.[9]

At its Open Meeting on September 26, 2017, the Commission adopted a Report and Order and Further Notice of Proposed Rulemaking removing "regulatory obstacles for companies proposing to provide [broadband] services via large, ambitious, non-geostationary-satellite orbit (NGSO), fixed satellite service (FSS) systems."[10] SpaceX supports the Commission's actions in this proceeding that update outdated NGSO rules, create greater regulatory certainty and add flexibility for next-generation NGSO systems that hold the promise of truly nationwide satellite broadband coverage at speeds and latencies comparable to

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[6] FCC, *2016 Broadband Progress Report.*
[7] Ibid.
[8] 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.
[9] *Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, IB Docket No. 16-408, Report and Order and Further Notice of Proposed Rulemaking, FCC 17-122 (rel. Sept. 27, 2017) ("NGSO Report & Order").
[10] Id., Statement of Chairman Ajit Pai (stating that he has circulated to the Commissioners orders granting U.S. market access to two more NGSO systems).

terrestrial fiber-optics. Chairman Pai recognized the importance of NGSO systems, stating that "[a]s we strive to close the digital divide, we must be open to any and every technology that could connect consumers across the country. . . . The rules we adopt will promote the next generation of NGSO systems, which could expand broadband access where it's needed most."[11] Commissioner Clyburn similarly stated that "[t]oday, we take yet another step to close those gaping divides by updating and streamlining rules to facilitate the deployment of NGSO FSS systems, which have the potential to provide ubiquitous broadband services to all of our communities."[12]

SpaceX is unique in designing its system specifically to link consumers directly with high-speed, low-latency broadband connectivity. On orbit, SpaceX is employing advanced operational techniques and spacecraft technologies in order to maximize the capacity it can employ for high-speed broadband services, including high-degrees of re-use of valuable spectrum, and flexibility in interference mitigation, allowing our system to co-exist with other space- and ground-based systems. On the ground, affordable, easy-to-install end-user terminals can obviate the costs, environmental regulations, property rights issues, and other regulatory obstacles, that have precluded many unconnected end-users in smaller communities, or remote locations from comparable quality Internet access. Once the satellite capability is deployed on-orbit, the incremental costs of delivering broadband access to each new customer become agnostic to urban, suburban, or rural locations, in contrast to traditional terrestrial broadband networks.

SpaceX's constellation is designed fulfill its primary service objective of providing high-speed broadband directly to end users globally, both widely-dispersed locations and also more concentrated population areas with higher capacity demands. With many satellites in view, the constellation offers a diversity of path for reliability and also access for any given customer location, even those blocked from traditional satellite services by buildings, mountains, or other physical obstacles. Phased-array technology on-orbit and on-ground gateways and end-user terminals permit 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. The same phased array technology allows for dynamic beam formation, shaping, and direction, both to tailor capacity by demand profile and also to mitigate interference to space- and ground-systems. Spectrum sharing prospects with terrestrial systems sharing the same frequency bands are enhanced by the use of high-elevation angles for communications with earth stations and highly directional space station and earth station beams.

The combination of unique vertically-integrated manufacturing and design capabilities, proven production and operations experience, and highly-adaptable, leading-edge technology in space and on the ground gives promise for the SpaceX constellation to help close the digital divide, and bridge the current disparity in service between well-covered metropolitan consumers and their counterparts in rural or other "hard-to-reach" areas. Importantly, that urban-rural parity can also be sustained over future generational upgrades over the NGSO constellation, without requiring additional costly last-mile infrastructure upgrades.

This lag was noted by the Government Accountability Office ("GAO"):

> Access to affordable broadband telecommunications is vital to economic growth and improved quality of life across the country. In rural areas in particular, broadband can serve to reduce the isolation of remote communities and individuals. The provision of broadband Internet infrastructure and services in the United States is generally privately financed. However, rural areas can have attributes that increase the cost of broadband deployment,

[11] *NGSO Report and Order*, Statement of Chairman Ajit Pai.
[12] *Id.,* Statement of Commissioner Mignon L. Clyburn.

> such as remote areas with challenging terrain, or make it difficult to recoup deployment costs, such as relatively low population densities or incomes. These attributes can decrease the likelihood that a broadband service provider will build out or maintain a network in a rural area. For these reasons, some rural areas lag behind urban and suburban areas in broadband deployment or service speed.[13]

Next-generation satellite systems operating in orbits close to the Earth, powered by innovative technologies to provide rapid data rates and minimal latency, can offer a way around this gap in broadband access in the United States.

IV. SpaceX's Proposed Satellite Constellation Architecture

As noted, SpaceX plans to leverage its unique space-based design, manufacturing, launch, and space operations experience for the planned NGSO constellation.

In particular, SpaceX aims to apply our experience in designing and manufacturing cutting-edge space to apply technology advancements like dynamic beam forming and phased array antennas in space and on the ground. These will ensure both unparalleled frequency re-use and spectral efficiency, as well as redundant and high-capacity infrastructure. The satellites' optical inter-satellite links will establish a "mesh network" in space through which the satellites will communicate with each other, further enhancing the capacity levels and network flexibility for faster and reliable broadband satellite service.

SpaceX's consumer focus sets it apart from most other proposed NGSO system. 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 goal demands far more on-orbit capacity, which in turn drives the larger number of satellites in the design and the focus on spectrum re-use efficiency. Initially, the SpaceX system will consist of 4,425 satellites operating in 83 orbital planes (at altitudes ranging from 1,110 km to 1,325 km). This system will also require associated ground control facilities, gateway earth stations, and end user earth stations.[14] Using Ka- and Ku-Band spectrum, the initial system is designed to provide a wide range of broadband and communications services for residential, commercial, institutional, governmental, and professional users worldwide. SpaceX has separately filed for authority to operate in the V-Band, where we have proposed an additional constellation of 7,500 satellites even closer to Earth, our Very Low Earth Orbit, or "VLEO," system. In the future, these satellites will provide additional broadband capacity to the SpaceX system and further reduce latency where populations are heavily concentrated.[15]

To implement the system, SpaceX will utilize powerful computing and software capabilities, which will enable SpaceX to allocate broadband resources in real time, placing capacity where it is most needed and directing energy away from areas where it might cause interference to other systems, either in space or on the ground. Because the satellites will beam directly to gateways or user terminals, the infrastructure needed on the ground—particularly in rural or remote areas—is substantially reduced, essentially addressing the

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[13] U.S. Government Accountability Office, *Rural Broadband Deployment: Improved Consistency with Leading Practices Could Enhance Management of Loan and Grant Programs,* (April 2017), GAO-17-301, available at http://www.gao.gov/assets/690/684093.pdf.

[14] Space Exploration Holdings, LLC, *Application for Approval for Orbital Deployment and Operation Authority for the SpaceX NGSO Satellite System* (November 15, 2016), Before the Federal Communications Commission, IBFS File No. SAT-LOA-20161115-00118.

[15] Space Exploration Holdings, LLC, *Application for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System* (March 1, 2017), Before the Federal Communications Commission, IBFS File No. SAT-LOA-20170301-00027.

"last mile" challenge and helping to close the digital divide. In other words, the common challenges associated with siting, digging trenches, laying fiber, and dealing with property rights are materially alleviated through a space-based broadband network.

SpaceX intends to continually iterate and improve the technology in the system, something that our satellite manufacturing cost profile and in-house launch capability uniquely enables. The ability to modify service as necessary, as well as refresh the technology of the satellite system through iterative spacecraft design changes and phased, continuous deployment, is critical to meet rapidly changing customer demands and responsibly utilize spectrum. This approach will ensure that the system remains adaptable to existing and future customer demands.

For the end consumer, SpaceX user terminals—essentially, a small flat panel, roughly the size of a laptop—will use similar phased array technologies to allow for highly directive, steered antenna beams that track the system's low-Earth orbit satellites. In space, the satellites will communicate with each other using optical inter-satellite links, in effect creating a "mesh network" flying overhead that will enable seamless network management and continuity of service. The inter-satellite links will further help SpaceX comply with national and international rules associated with spectrum sharing, which distinguishes our system from some of the other proposed NGSO constellations.

Overall, SpaceX has designed our system to achieve the following key objectives:

(1) **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.

(2) **Adaptability.** The system leverages phased array technology to steer dynamically a large pool of beams to focus capacity where it is needed. As noted, optical inter-satellite links will permit flexible routing of traffic on-orbit. Further, the constellation ensures that a variety of frequencies can be reused effectively across different satellites to enhance the flexibility, capacity and robustness of the overall system.

(3) **Broadband Services.** The system will be able to provide broadband service at fiber-like speeds, the system's use of low-Earth orbits will allow it to target latencies comparable to terrestrial alternatives. SpaceX intends to market different packages of data at different price points, accommodating a variety of consumer demands.

(4) **Efficiency.** SpaceX is designing the 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.

SpaceX soon will begin the process of testing the satellites themselves, with the first two prototypes launching within the next several months. Following the successful demonstration of our space and ground technology, SpaceX intends to begin the operational satellite launch campaign in 2019. The remaining satellites in the constellation will be launched in phases through 2024, when the system will reach full capacity with the Ka- and Ku-Band satellites. The constellation will be operational well in advance of full deployment, and we expect to begin offering services commercially as early as deployment of 800 satellites.

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.

SpaceX has designed its satellite constellation to meet or exceed all existing requirements for safety of operations in space and upon de-orbit of satellites, and SpaceX is deeply committed both to maintaining a debris-free environment in space and to disposing of orbital assets in a responsible and safe manner.

V. Overcoming the Cost of Large Constellation Deployment: Launch and Reusable Rockets

While rights of way and the high costs of terrestrial connectivity for rural remote areas historically has limited the reach of broadband, the cost of space launch has been the major obstacle to the deployment of large-scale broadband satellite constellations. Affordable access to space effectively limited the size of satellite constellations operating close to the earth, where shorter signal paths could lower overall end-to-end latency to levels comparable to modern mobile or fixed broadband.

By rethinking the launch vehicles design and production, SpaceX has driven down launch costs. Our work to recover and reuse rockets will enable truly revolutionary reductions in the speed and cost of space access. Every other launch vehicle provider in the world discards its rocket hardware after each launch. This practice is akin to throwing away an airplane after every leg of a trip. However, SpaceX has invested considerable internal resources to develop and implement reusability into the Falcon 9. Most of a launch vehicle's cost is concentrated in its first stage. SpaceX has incorporated advanced technologies that uniquely enable the Falcon 9 first stage to return to either a ground-based landing platform or an off-shore autonomous spaceport droneship after nearly every mission.

This year, SpaceX proved out this concept with the successful launch and landing of three flight-proven Falcon 9 boosters, placing high-value telecommunications satellites into orbit for commercial satellite operators. Each Falcon 9 first stage will soon be capable of at least 10 flights with no refurbishment and many more flights after minimal refurbishment, resulting in significant cost reductions.

Dramatically lower launch costs and the demonstrated capability to launch nearly every two weeks (or less) allows SpaceX affordably to deploy larger numbers of satellites for its own NGSO constellation at a pace not previously possible. Moreover, affordable access to space also allows SpaceX to refresh the constellation technology over time, driving down the cost of producing each satellite and making it easier to add capability to meet consumer demand and dynamically react to an evolving market.

VI. Policy Recommendations to Facilitate the Deployment of Space-Based Broadband Systems Safely and Efficiently

As the Committee considers policies that could facilitate the expansion of broadband access in the U.S., SpaceX offers the following recommendations:

(1) FAA Commercial Launch License Regulations Require Modernization. As noted, launch is the key enabling capability for the deployment of NGSO constellations, as well as other satellite platforms that are critical to expanding broadband access. As such, SpaceX recommends that existing FAA launch statutes and regulations be modernized and streamlined to adapt to higher numbers of launches at a more rapid cadence. The current FAA regulations were promulgated in a time when commercial spaces launches were rare, and launch was primarily the domain of the U.S. Government. However, as the industry transitions from a pace of a few commercial launches per year to a launch per week, or more, in the near future, and new U.S. launch providers consider entering the market, it is essential that FAA regulations be updated to avoid obstructing industry growth and innovation in the U.S. domestic commercial space launch industry.

(2) FCC Commercial Launch Spectrum Licensing Process Should be Streamlined. The FCC licenses the radio frequencies used by commercial launch operators during launch and reentry operations. Because launches originally were assumed to be by and for the government, there is no allocation for the spectrum used for commercial launchers. As a result, the FCC must use its experimental licensing rules through a cumbersome Special Temporary Authorizations (STA) process. This process is time-consuming for the applicant and the FCC, as each launch mission may have multiple STAs for launch, landing, and various short-range communications with the payload. Each STA is limited in validity to a maximum of six months; and is approved on a non-interference basis, with "special conditions" that ensure frequency coordination with other federal users in the spectrum bands. In September 20, 2013, the FCC issued a Notice of Proposed Rulemaking (NPRM) addressing spectrum for non-federal space launch, in which it noted that the STA process is suboptimal as commercial space launches and other commercial operations in orbit grow in volume and frequency.

The FCC's NPRM would remedy this problem by establishing co-primary, interference-protected allocation status for commercial space launch companies and would streamline the authorization process through standard, clearly-defined application and coordination processes. The growth of the U.S. commercial space launch industry necessitates the development of a streamlined, predictable spectrum licensing process to ensure the continued growth of the industry and the effective, efficient, and prudent use of radio frequencies.

This NPRM, now pending for more than four years, proposes a specific allocation for non-federal space launch that would allocate specific frequencies commercial space launch companies. It would streamline the authorization process and allow for a single, five-year license for multiple like-missions (for example, all missions for the same customer to the same orbital plane). The allocation would be secondary to the federal users already in the band, requiring the same coordination processes undertaken now to de-conflict any interference prior to each mission. Importantly, federal agencies have agreed to this change, and the agency that represents federal users of radio frequencies, the Department of Commerce's National Telecommunications & Information Administration ("NTIA") sent a letter to the FCC in September 2016 stating that federal users of the frequency bands under discussion "strongly agree" with the proposed new rules.

SpaceX recommends that the Committee encourage the FCC to act now to adopt the proposed rules and then move quickly to develop implementing regulations that can allow frequency authorizations to cover multiple like launches. This long overdue action would save time and money, and it would help with long-term planning for both the FCC and industry.

(3) Systems and Technology that Achieve Spectrum Efficiency Should be Rewarded. The new generation of broadband NGSO constellations holds incredible potential to bring affordable, fiber-like broadband services to underserved and unserved areas of the United States. Investment in advanced technologies that provide spectral efficiency and operational flexibility are necessary for NGSO systems to increase access to reliable, high-speed broadband connectivity. How they share the valuable spectrum resources will be important to their operational efficiency and their ability to deliver quality broadband services. Unfortunately, not all aspiring operators have chosen to make the investment necessary to include many of these technologies in their proposed systems. As a result, some systems would not only make inefficient use of the spectrum they seek to use, but also may prevent other NGSO systems from efficiently sharing the available spectrum.

As such, the Committee should ensure that their rules do not unduly burden more flexible, adaptable systems with the responsibility of spectrum sharing with other less sophisticated systems. Any

such outcome would impose an asymmetrical burden that is counter to the overall FCC goals of incentivizing efficient spectrum sharing. Spectrum sharing policies should ensure that all systems have equitable access to spectrum, avoid any warehousing of spectrum by non-operating systems, and incorporate sufficient flexibility to promote and accommodate spectrum coordination among operating systems. Given the advent of new space-based and ground technologies, spectrum sharing is most efficiently managed by using highly intelligent and flexible satellites, as this expands the range of potential sharing strategies available to the operators involved.

(4) Spectrum Use Policy in the Ka- and V-Bands Should be Revised. When drafted, FCC policies governing the use of spectrum by NGSO constellations—specifically in Ka- and V-bands—did not envision the potential of very large constellations operating in LEO. As a result, NGSO constellations are unduly restricted from using important segments of spectrum as compared to ground-based fixed systems. While the agency has granted waivers for NGSO systems to operate in parts of this spectrum on an unprotected, non-interference basis, this approach is not sustainable over the long-term, especially as these new NGSO systems come online.

Clear and reasonable rules must be developed to govern how multiple companies will share spectrum among NGSO systems. These rules are essential to the development and deployment of potential NGSO systems. Companies have proposed widely varying space architectures, ranging from highly-elliptical orbit systems operating from 8,000-43,500 km that focus on Arctic coverage to small constellations at medium Earth orbit at around 10,000 km above the Earth to several larger constellations operating in LEO at 1,000-3,000 km from the Earth.

The FCC recently issued a Report and Order to update rules for NGSO satellite systems, including deployment milestones, geographic coverage, and allocations of radio-frequency bands. The new rules also discussed how multiple NGSO operators should share valuable spectrum, specifying that the preferred method to address interference between two NGSO systems is operator-to-operator negotiations. Where operator-to-operator negotiations fail, the FCC recommended parameters to determine where operators could interoperate and where they would be required to simply divide frequency bands ("splitting spectrum").

Every NGSO applicant agreed that spectrum splitting is the least desirable and most inefficient approach to sharing frequencies, because it reduces capacity and services made available to consumers. The parameters that the FCC identified work well when sharing spectrum for downlinking from space, because downlinks already have power limits to protect other services so all NGSO systems operate at similar downlink power levels. However, when applied to uplinks to spacecraft in widely varying space architectures, the rules actually yield far more instances of mandated spectrum splitting because no comparable power limits exist. The wide disparity in uplink power levels often yield situations that defy coordination.

The Committee should encourage the Commission to open a further inquiry on how to best optimize spectrum use among non-homogeneous NGSO systems to elicit further technical input and regulatory consideration. This should include review of the uplink transmissions needed to traverse across higher NGSO orbits in a manner that does not create broad-based interference to other lower-situated NGSO systems. The FCC's inquiry should also examine the effect of beam-size on interference mitigation, since large geographic beams of some higher-altitude systems will operate without flexibility, and essentially nullify the flexibility of other NGSO systems. These technical inquiries should presume that the public interest is served by multiple successful NGSO systems, providing services to American consumers and using valuable spectral resources effectively.

(5) Satellite Ground Station Siting Rules Must be Modified. As part of its Spectrum Frontiers rulemaking, the FCC is reviewing the rules it set out for the siting of satellite gateways using the 28 GHz range (Ka-band) frequencies, including gateways supporting both geostationary and upcoming NGSO constellations. The current earth station siting rules are a complex mix of numerical caps of gateways per county, and geographic avoidance of population centers and arterial roadways. These rules were designed to balance the need to protect terrestrial operations with satellite operators' need to deploy satellite gateways in locations with access to Internet points of presence and backhaul facilities. However, the metrics defined for gateway siting are overly complex and difficult to interpret, and also may actually have the unintended effect of deterring satellite deployment in certain rural areas. Several satellite operators have suggested new metrics that would remove the per-county limit and recalibrate the siting rules.

The FCC should streamline the Ka-band satellite gateway siting rules to reflect reasonable real-world deployment scenarios for both existing and next-generation satellite gateway technologies and their terrestrial mobile broadband counterparts. The FCC should also exempt from its siting rules those satellite gateway earth stations that operate under the limit set to protect mobile broadband networks, including both any per-county cap and population coverage limits.

These clarifications will maintain reasonable interference protection for evolving terrestrial mobile networks while permitting the development of ground infrastructure needed to support NGSO satellite systems. Given that NGSO constellations could help provide broadband access to millions of previously unserved or underserved Americans, the FCC should adopt spectrum sharing rules that do not unduly constrain deployment of Ka-band satellite ground station facilities to support the delivery of innovative satellite services.

(6) Maintaining a Safe Space Environment. Any policy environment concerning orbital debris should minimize risk to space systems without imposing an unnecessary burden on responsible actors. Recent concern in this arena has been driven by the proliferation of small experimental satellites (micro-, nano-, and cubesats) that are not maneuverable; by recent debris collisions and end-of-life disassembly problems with aging geostationary satellites; and, to some extent, by the potential deployment of large NGSO constellations.

To reduce conjunction risks, policies should be pursued that encourage responsible and reliable satellite design and operation from launch to disposal. Future policies should balance a satellite's deorbit reliability with the risk of a premature failure when considering whether to extend the satellite's use after it reaches its design lifetime. Regulations can encourage and reward manufacturing designs that allow for easier tracking (e.g., tracking reflectors) and are fault-tolerant and safe, particularly with respect to battery and propulsion systems. Such designs would utilize materials that diminish the risk of generating new debris from internal faults, impacts with untracked debris, or planned de-orbit reentries. Additionally, current international policy guidelines mandate satellites have the capability for disposal within 25 years; this timeframe should be shortened. Given the diverse federal agencies employed with space regulation and policy matters, SpaceX welcomes the establishment of the National Space Council and encourages robust inter-agency dialogue to root agency policies in common objectives and premises, even if the diverse agency authorities and space missions under each agency's oversight results in distinct specific regulations.

SpaceX also supports broad sharing arrangements among space operators to increase the accuracy of ephemeris data and mitigate potential conjunction events, even while space activities expand. Expanded data sharing will augment reliance on the space surveillance network for positional information and reduce positional uncertainty, reducing unnecessary on-orbit maneuvers. In

addition to increased data sharing among operators, the United States should consider investments in orbital object tracking radars and other systems to enhance the amount and quality of space surveillance data.

(7) Satellite Broadband Technology Should Not Be Excluded from FCC Broadband Incentives. The FCC is currently in the process of reviewing rules for and structuring the second phase of the Connect America Fund (CAF II). This program, with awards determined through a reverse auction, would support up to $1.98 billion in funding over ten years to support broadband expansion to areas of need across the country. The Commission has adopted rules providing different bidding weights to different tiers of speed, usage, and latency applicants might select. This is a reasonable means by which to ensure the best service receives the most favorable score in the bidding process, which is inherently in the interest of the American consumer.

However, current rules preclude all satellite systems from meaningful participation, simply because current-day geostationary satellite offerings do not meet the FCC's high-speed, low-latency criteria. Even if next-generation NGSO satellite providers could provide equivalent or better services than the top tiers outlined in the rules, these systems are still precluded for participating. This creates a false presumption that all satellite technologies are now and forever unsuitable for consumer broadband, and therefore ineligible for support in areas where NGSO systems are uniquely designed to serve customers competitively and cost-effectively. Conflating NGSO systems and traditional geostationary systems would be the same as the FCC prohibiting fiber systems from bidding because dial-up is not fast enough: just because both systems are hard wired does not mean that they are equivalent.

The original CAF rules also require a stand-alone voice telephony service, meaning that bidders for the fund cannot offer only internet-based Voice over IP ("VOIP") services like Skype or Vonage but must bundle a land-line-type service. This adds inefficiency and cost, and creates another bias against non-wireline bidders.

The FCC should remove constraints on any qualifying technology to participate, and update or eliminate the existing general preclusion for satellite bidders. By doing so, the FCC will demonstrate a clear commitment to results-based regulation, with a CAF II auction that supports broadband in the areas that need it in the most cost effective, administratively efficient way. Moreover, the Commission will achieve this goal while ensuring that every bidder – no matter what technology it might use – has a meaningful opportunity to participate. In addition, the Commission should remove the unnecessary requirement to provide standalone voice service rather than simply make voice-over-IP capabilities.

(8) Next Generation Satellite Systems are Broadband Infrastructure and Should Be Included in Any Infrastructure Legislation. The expansion of satellite broadband through U.S.-based constellations is, fundamentally, a national infrastructure project, even though many components of the infrastructure will be in space. In prior investment rounds and through funds like the Universal Service Fund ("USF"), satellite broadband was often an afterthought. For example, of the $6.9 billion awarded for broadband infrastructure through National Telecommunications and Information Administration's ("NTIA") Broadband Technology Opportunities Program ("BTOP") and the U.S. Department of Agriculture's Rural Utilities Service ("RUS"), only approximately $100 million went to satellite systems, or less than 1.5 percent of all funds appropriated.[16] In many

[16] National Telecommunications and Information Administration, U.S. Department of Commerce, Broadband Technology Opportunities Program (BTOP) Quarterly Program Status Report (March 2017), available at https://www.ntia.doc.gov/files/ntia/publications/ntia_btop_31st_qtrly_report.pdf; and U.S. Department of

ways, this was the result of limitations at the time on satellite capacity, high latency rates due to satellite distance from the Earth, and relatively slow data rates compared to terrestrial and mobile networks. It was also related to a general failure of imagination to make investment and subsidy structures applicable to satellite infrastructure and consumer hardware, since satellite systems have few "shovels in the ground."

However, as satellite-based broadband achieves speeds, latencies, and pricing equivalent to terrestrial and 5G wireless technologies, it becomes especially critical for Congress and federal agencies to reconsider how these systems can participate in national infrastructure investment programs and other federal initiatives to close the digital divide. Infrastructure associated with a satellite broadband system includes launch facilities, consumer terminals that are placed on homes or businesses, gateways that will be placed at potentially hundreds of internet points of presence ("PoPs") throughout the United States that are used to route traffic, large antennas to track and control the satellites in space, and satellite operations centers. The satellites themselves are essentially infrastructure in the sky, a network that is not dissimilar to cell towers or underground fiber.

As such, SpaceX encourages the Committee to take steps to ensure that satellite-based broadband infrastructure is duly captured in any federal infrastructure, incentive, or tax policy legislation undertaken to expand broadband access in the United States. Such an approach will not only ensure that Congress and regulatory agencies maintain a technology-neutral approach, but it will also ensure the U.S. Government and American consumers are positioned to benefit from the significant innovations and great promise of that satellite systems are poised to bring.

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Mr. Chairman, I appreciate your invitation to testify before the Committee today. SpaceX looks forward to being part of the solution to expand access to high-speed, reliable, and affordable broadband internet connectivity in the United States and worldwide.

Agriculture, Rural Utilities Service, Broadband Initiatives Program Final Report (December 2016), available at https://www.rd.usda.gov/files/reports/RUS_BIP_Status_FinalReportDec_2016.pdf.pdf.