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

In the Matter of	)	
WORLDVU SATELLITES LIMITED	)	Call Sign: S2963
Petition for a Declaratory Ruling Granting Access to the U.S. Market For the OneWeb NGSO System	)	File No. SAT-LOI-20160428-00041

COMMENTS OF SPACE EXPLORATION TECHNOLOGIES CORP.

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SUMMARY

Space Exploration Technologies Corp. ("SpaceX") hereby comments on the Petition for a Declaratory Ruling filed by WorldVu Satellites Limited, d/b/a OneWeb ("OneWeb"), requesting authority to provide Fixed-Satellite Service ("FSS") in the United States using a proposed non-geostationary satellite orbit ("NGSO") constellation authorized by the United Kingdom.[1] This is likely to be only one of several NGSO systems seeking to serve the U.S. using Ku- and Ka-band frequencies. Each of these NGSO/FSS systems will need to use the same limited bands of spectrum, and each has the potential to add hundreds or thousands of new satellites to those already in orbit. Consequently, both efficient spectrum sharing and sophisticated collision avoidance/end-of-life disposal techniques will be critical to the success of all such constellations and their ability to deliver advanced broadband services in the United States and around the world.

New technologies are now available that allow satellites to narrow their beam widths and shape their beam contours for greater capacity, throughput, and spectrum efficiency. These capabilities, if effectively employed by NGSO constellations, can address some of the challenges that stymied the NGSO/FSS broadband systems proposed in the past. Unfortunately, OneWeb has chosen not to include many of these technologies in its proposed system. As a result, OneWeb's system would not only make inefficient use of the spectrum it seeks to use, but may also prevent *other* NGSO/FSS systems from efficiently sharing the available spectrum. The Commission must carefully consider these issues to determine whether granting market access under these circumstances would serve the public interest.

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[1] *WorldVu Satellites Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the OneWeb System*, IBFS File No. SAT-LOI-20160428-00041 (filed April 28, 2016) ("OneWeb Petition").

As is made clear in its filing, OneWeb has declined to make core design decisions that leverage available adaptive technologies that allow for efficient spectrum usage. For example, OneWeb's proposed system would serve customers using ultra-wide downlink beams rather than narrower spot beams that could have both increased capacity through greater frequency reuse and provided more options for spectrum sharing. Further, because the beams from one satellite in the proposed system generally do not overlap with beams from others, OneWeb cannot switch a customer to an alternative satellite when necessary to avoid interference from and to other NGSO/FSS systems. Such choices fail to make efficient use of spectrum, and result in a higher likelihood of interference with and lower flexibility to share spectrum among all proposed NGSO/FSS systems. Further, it appears that the OneWeb system, once launched, cannot be expanded by adding satellites to expand capacity or upgraded to improve coexistence with other NGSO systems. The end result would compromise the Commission's dual goals of promoting efficient usage of spectrum and maximizing broadband service to the public.

Historically, when NGSO/FSS systems were not able to coordinate shared use of spectrum, the Commission divided the available bands into segments, with each operator assigned a portion of the spectrum. OneWeb has asked the Commission instead to apply a regime based on avoidance of in-line interference events and coordination. However, this more efficient approach of in-line avoidance will put a high premium on successful spectrum coordination among NGSO/FSS systems, a goal made more difficult to achieve given the limited technology implemented in OneWeb's design.

OneWeb states in its Petition that "it is likely that the constellation might not get completed at all" if it is limited to operating with just a portion of the spectrum it seeks (even if a Commission

decision to segment bands were applied only while operating over the United States).[2] In essence, by electing to design its proposed NGSO/FSS system with limited technical capabilities, OneWeb signals that it may have made its own business model untenable. Further, OneWeb is requesting that the Commission authorize its own system at the expense of other prospective NGSO/FSS constellations. Because its system is not designed to coordinate readily with other NGSO/FSS systems, such an authorization would sacrifice the benefits of a competitive NGSO environment for broadband service diversity in the U.S.

Separate from spectrum efficiency, OneWeb has not provided any information on its plans for mitigating orbital debris and disposing of satellites at end-of-life. OneWeb seeks an exception to the general requirement to provide such information because it will be subject to regulatory oversight in the United Kingdom. But the Commission has made clear that this exception only applies where the non-U.S. licensing authority has reviewed and affirmatively approved the operator's specific debris mitigation plan.[3] OneWeb has provided no evidence that it has submitted such a plan to the U.K., much less received approval of that plan. Given the size of OneWeb's proposed constellation, the issues of orbital debris and post-mission disposal are too important to overall space safety for the Commission to defer to another country's regulator. Rather, the Commission should require OneWeb to submit this information, and give all interested parties an opportunity to review and comment upon it, before taking any further action in this proceeding.

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2 *See* OneWeb Petition at 19.

3 *See, e.g., John K. Hane, Esq.*, 26 FCC Rcd. 7996 (IB 2011) (dismissing satellite application where operator failed to state whether the foreign regulator had "reviewed and affirmatively approved the specific debris mitigation plans" for the satellite).

The Commission's has indicated that it intends to update its rules for NGSO systems, which were put in place over a decade ago and were adopted based on satellite technology and system designs proposed nearly a decade before that. The Commission has indicated that it will soon commence a rulemaking proceeding to update those rules.[4] That upcoming proceeding will provide an opportunity to implement a regime better suited to an environment in which constellations of hundreds or thousands of satellites employing sophisticated technologies must share limited spectrum resources and safeguard the space environment for all who seek to make productive use of it. At a minimum, the Commission should apply any eventual updated rules to this application, consistent with precedent in prior NGSO/FSS processing rounds.

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[4] *See* Matt Daneman, "Satellite/5G Sharing of 28 GHz Band Seen As Inevitable," COMMUNICATIONS DAILY (Mar. 3, 2016).

TABLE OF CONTENTS

Page

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SpaceX hereby comments on the Petition for a Declaratory Ruling filed by OneWeb requesting authority to provide FSS in the United States using a proposed NGSO constellation authorized by the United Kingdom.[5]

OneWeb's proposed system is likely to be only one of several NGSO systems seeking to serve the United States using Ku- and Ka-band frequencies. Each of these systems will need to use the same limited bands of spectrum, and each has the potential to add hundreds or thousands of new satellites to those already in orbit. Consequently, both efficient spectrum sharing and sophisticated collision avoidance/end-of-life disposal techniques will be critical to the success of all such constellations and their ability to provide advanced broadband services in the United States and around the world.

New technologies are now available that, if effectively employed by NGSO constellations, can address the challenges that stymied the NGSO/FSS broadband systems proposed in the past.

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[5] OneWeb Petition.

Unfortunately, however, OneWeb has chosen not to include many of these technologies in its proposed system. As a result, OneWeb's system would not only make inefficient use of the spectrum it seeks to use, but may also prevent *other* NGSO systems from efficiently sharing the available spectrum. The Commission must carefully consider these issues to determine whether granting market access under these circumstances would serve the public interest.

In addition, the record in this proceeding does not include any information on OneWeb's orbital debris mitigation plans, or any indication that another licensing authority has assessed and approved such plans. The Commission must require OneWeb to submit this information, and give all interested parties an opportunity to review and comment upon it, before taking any further action in this proceeding.

The Commission's rules for NGSO systems were emplaced more than a decade ago, and were adopted based on satellite technology and system designs proposed nearly a decade before that. The Commission has announced that it will soon commence a rulemaking proceeding to update those rules.[6] That upcoming proceeding will provide an opportunity to implement a regime better suited to an environment in which constellations of hundreds or thousands of satellites employing sophisticated technologies must share limited spectrum resources and safeguard the space environment for all who seek to make productive use of it. Any action in this proceeding should explicitly incorporate the outcome of the rulemaking, consistent with Commission practice

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[6] *See* Matt Daneman, "Satellite/5G Sharing of 28 GHz Band Seen As Inevitable," COMMUNICATIONS DAILY (Mar. 3, 2016).

in prior NGSO/FSS processing rounds.[7] This will ensure that the Commission's rules do not inadvertently saddle modern NGSO/FSS systems with an outdated regulatory framework that may no longer be tailored to best serve the public interest.

DISCUSSION

A. AFTER SEVERAL FALSE STARTS, THE TIME FOR NGSO BROADBAND SYSTEMS HAS ARRIVED

Since the early 1990s, the concept of using a constellation of NGSO/FSS satellites to provide affordable, ubiquitous, low-latency communications connectivity to all areas of the world has been a tantalizing possibility. Systems such as those proposed by Teledesic[8] and SkyBridge[9] had promised to bring connectivity to users in previously underserved or unserved areas. Using Ka- and Ku-band spectrum and satellite constellations that were considered to be large at the time, the proposed NGSO systems aspired to create a truly connected world. However, these first-generation proposals never came to fruition, as they could not overcome a combination of technical and financial challenges.

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[7] *See, e.g.*, *Teledesic Corp.*, 12 FCC Rcd. 3154, ¶ 36 (IB 1997) ("*Teledesic Authorization Order*") (conditioning Ka-band NGSO/FSS authorization on compliance with service rules to be adopted in a then-pending rulemaking); *Amendment of the Commission's Space Station Licensing Rules and Policies*, 18 FCC Rcd. 10760, ¶ 275 (2003) ("*Space Station Licensing Revision Order*") (stating that newly-adopted rules would be applied to then-pending applications in NGSO/FSS processing round).

[8] *See Teledesic Authorization Order*, *supra* (authorizing launch and operation of Ka-band NGSO/FSS constellation of 840 satellites); *Teledesic LLC*, 14 FCC Rcd. 2261 (IB 1999) (reducing constellation to 288 satellites). Teledesic later sought to reduce its constellation to 30 satellites (*see* Public Notice, Rep. No. SAT-00101 (Feb. 14, 2002)), but surrendered its authorization in 2003 while that application was still pending.

[9] *See SkyBridge L.L.C.*, 20 FCC Rcd. 12389 (Int'l Bur. 2005) (authorizing launch and operation of a Ku-band NGSO/FSS constellation of 80 satellites). SkyBridge declined to accept this authorization, which was issued more than eight years after it filed its initial application in 1997.

Today, a new generation of technology, coupled with near-insatiable demand for broadband, as well as innovation in satellite, ground systems, and launch technologies, has spurred a host of newly proposed NGSO/FSS systems to provide global broadband connectivity. For example, phased array antennas and adaptive beam-forming strategies allow satellites to target narrow coverage areas more precisely while enabling Earth stations to track satellites moving through the sky and then seamlessly transition to the next one appearing over the horizon. More powerful computing and software capabilities enable operators to allocate resources in real time, so that capacity can be placed where it is most needed and energy can be directed away from areas where it might cause interference to other spectrum users. This on-orbit flexibility not only facilitates spectrum sharing among satellite systems (both GSO and NGSO), but also gives a system operator the ability to modify its service as necessary to meet rapidly changing customer demands. In addition, increased satellite launch capacity, coupled with a faster cadence of launch activity at lower costs than when earlier NGSO systems were conceived, makes the deployment and replenishment of certain systems more feasible.

B. ONEWEB IS LIKELY TO BE ONLY ONE OF SEVERAL NGSO SYSTEMS, AND MUST BE CAPABLE OF SHARING VALUABLE SPECTRUM RESOURCES EFFICIENTLY

Although OneWeb's Petition precipitated a processing round for those proposing NGSO-like operations in the Ku- and Ka-bands,[10] it is not the only current-generation operator to apply for the right to provide broadband NGSO/FSS service in the U.S. using this spectrum. O3b is already authorized to provide such service—and is actually doing so—using a medium Earth orbit

[10] *See* Public Notice, "OneWeb Petition Accepted for Filing," DA 16-804 (rel. July 15, 2016).

("MEO") constellation of twelve Ka-band satellites.[11] Moreover, in the past twenty-four months alone, administrations around the world have submitted to the ITU requests for coordination for more than twenty-five NGSO systems operating in the Ku- and/or Ka-bands.

Given this wave of interest in NGSO/FSS constellations, the Commission must anticipate that several operators may apply to participate in the upcoming NGSO/FSS processing round. Competition among broadband satellite NGSO/FSS systems will drive innovation in space systems and ground equipment technology and operations, resulting in better broadband services at lower cost for consumers.[12] The ability to share available spectrum in an efficient manner among NGSO system applicants will be a crucial prerequisite to optimizing broadband speeds and increasing broadband availability for customers in the U.S. and around the world. In addition, large NGSO/FSS constellations will add hundreds or thousands of satellites in orbit, placing an even higher premium on effective orbital debris mitigation plans, space awareness capabilities, and end-of-life disposal procedures.

OneWeb's Petition must be evaluated in the larger context of the public interest in maximizing the productive use of valuable public resources by multiple systems, as well as the Commission's other rules and policies. Unfortunately, as discussed below, OneWeb's chosen system design is inconsistent with efficient spectrum use and spectrum sharing, and its Petition

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[11] *See* Grant Stamp, IBFS File Nos. SAT-LOI-20141029-00118 and SAT-AMD-20150115-00004 (Jan. 22, 2015). O3b has also filed a petition to increase the number of satellites in its system authorized to access the U.S. market to a total of 20. *See* IBFS File No. SAT-MOD-20160624-00060.

[12] *See, e.g.*, *Connecting America: The National Broadband Plan*, at 36, § 4.1 (2010) ("Competition is crucial for promoting consumer welfare and spurring innovation and investment in broadband access networks. Competition provides consumers the benefits of choice, better service and lower prices."), *available at* https://transition fcc.gov/national-broadband-plan/national-broadband-plan.pdf.

does not allow the Commission or other interested parties to evaluate the physical risk its system presents to other systems in space.

1. Spectrum for NGSO Satellite Operations Is an Extremely Scarce and Valuable Resource

OneWeb proposes to use spectrum in the Ku- and Ka-bands that has been allocated internationally for FSS operations, including some portions that have been specifically designated for use by NGSO systems. This resource is finite, and its usefulness should be maximized.

Commission policy has long recognized that "[m]echanisms to ensure spectrum efficiency are a high regulatory priority."[13] The Commission has found that, "[b]ecause the radio spectrum is a limited resource, as a general principle, all Commission licensees should use spectrum in the most efficient manner possible. This is particularly true where different services share the same radio spectrum resource and inefficient use by one service could foreclose or severely limit use by another service."[14] Applying this policy, the Commission consistently pays special attention to spectral efficiency when considering new rules, license applications, and other regulatory decisions. For example, in 2003, while noting that "new satellites are capable of generating multiple narrow-beam spot beams" and that "such space stations reuse frequencies in spatially independent beams rather than by using orthogonally polarized signals within a single beam," the

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[13] *A Re-Examination of Tech. Regulations*, 99 F.C.C.2d 903, ¶ 27 (1984).

[14] *FWCC Request for Declaratory Ruling on Partial-Band Licensing of Earth Stations*, 15 FCC Rcd. 23127, ¶ 26 (2000). *See also Spectrum Policy Task Force Seeks Public Comment on Issues Related to Commission's Spectrum Policies*, 17 FCC Rcd. 10560, ¶ 16 (2002) ("Due to the ever increasing spectrum demand, increased spectral efficiency will be needed to accommodate future growth. To this end, it is important that spectrum policies create positive incentives to make 'efficient' use of the spectrum resource and to continue the development of spectrally efficient technologies.").

Commission revised its frequency reuse rules to account for such beams in order to "encourage deployment of new, technologically innovative spot-beam satellites."[15]

This approach is a necessary response to the simple fact that spectrum is a finite and highly valuable resource, but it is also compelled by the Communications Act. As the Commission has observed, considering an application "without regard to the efficiency of the applicant's proposed use of the spectrum, has the potential to produce anomalous results that would seem to contravene the original statutory mandate of section 307(b) 'to provide a fair, efficient, and equitable distribution of radio service.'"[16] Similarly, the Commission has held that the public interest, the lodestar of all Commission decision-making, is best served "by making efficient use of finite spectrum and orbital resources."[17]

In the context of NGSO processing rounds, the Commission has recognized that spectrum sharing policies should ensure that all applicants have equal access to spectrum, avoid any spectrum warehousing by non-implemented NGSO/FSS systems at the expense of operational systems, and incorporate sufficient flexibility to promote and accommodate spectrum coordination among operating systems.[18] Given the advent of new space-based and ground technologies, spectrum sharing is most efficiently managed through the use of highly intelligent and flexible

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15 *Space Station Licensing Revision Order*, ¶ 262.

16 *Applications of Faye & Richard Tuck, Inc., et al.*, 3 FCC Rcd. 5374, ¶ 4 (1988).

17 *Amendment of Part 25 of the Commission's Rules to Establish Rules & Policies Pertaining to the Second Processing Round of the Non-Voice, Non-Geostationary Mobile Satellite Serv.*, 13 FCC Rcd. 9111, ¶ 136 (1997).

18 *Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ku-Band*, 17 FCC Rcd. 7841, ¶¶ 9, 27 (2002) ("*Ku-band NGSO Sharing Order*").

satellites, as this expands the range of potential sharing strategies available to the operators involved.

2. OneWeb's System Design Does Not Include Advanced Capabilities Necessary to Facilitate Efficient Spectrum Sharing

OneWeb has made specific design choices that limit the spectral efficiency and flexibility of its system. Its system lacks currently available technology that could have enabled more effective frequency re-use and therefore provide more capacity to more customers, as well as create more options for coordinating with other NGSO systems. The decision not to invest in such advanced technology not only limits OneWeb's ability to deliver on the full potential of NGSO/FSS broadband service, but also imposes harmful and unnecessary burdens on other NGSO/FSS systems. There are several examples of technologies now available, but not incorporated by OneWeb, that would constrain both spectral efficiency and operational flexibility.

a. Large satellite downlink beams limit frequency reuse

The ability to reuse a frequency as many times as possible across a given service area is critical to achieving spectral efficiency. With a very limited amount of spectrum allocated for use by all FSS systems and numerous current-generation NGSO systems proposing to share that spectrum, spectral efficiency will depend on the ability to reuse downlink spectrum by packing more beams into the same service area.

In the simple case illustrated in Figure 1, satellite systems reuse spectrum by alternating the frequencies used for downlink beams so that no two adjacent beams are using the same frequencies, with each color indicating a beam using a different block of spectrum. As with terrestrial systems, this strategy of dividing and reusing the frequencies not only increases spectrum efficiency within a given service area, it also yields a commensurate increase in system

capacity, allowing more customers to be served, faster throughput speeds, or both. Analogous to the generational improvements in terrestrial cellular technology, the more an NGSO/FSS system operator can narrow the size of its beams and develop more sophisticated reuse patterns, the greater the spectral efficiency and corresponding enhancement of service capability.

NGSO systems have an inherent advantage over traditional GSO satellites in these spectral reuse dynamics because they are tens of thousands of miles closer to the Earth than GSO satellites,[19] and their beams have less distance over which they would spread before they reach the Earth. Thus, one would expect that a low-Earth orbiting NGSO system operating at an altitude of only 1,200 km, such as that proposed by OneWeb, would use quite small downlink beams that could be densely packed to maximize capacity over a given service area. That is not the case. While each OneWeb satellite has 16 downlink beams serving customers,[20] they are large beams that fail to optimize the capacity of OneWeb's proposed system. Rather than tightly-packed narrow beams, each OneWeb beam covers approximately 70 km by 1,140 km,[21] for a total area of approximately 80,000 km^2 or

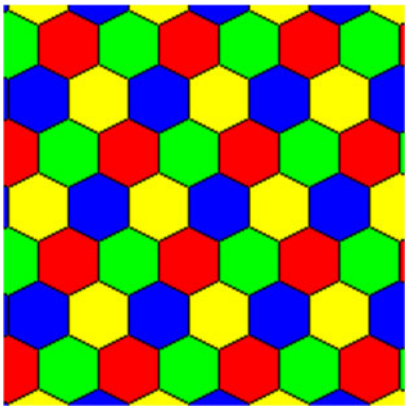

Figure 1. Sample 4x Frequency Reuse Pattern

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[19] GSO satellites operate at an altitude of approximately 36,000 km (or 22,350 miles). OneWeb proposes to operate at an altitude of just 1,200 km (or 745 miles).

[20] *See* OneWeb Petition, Technical Appendix at 7.

[21] *See id.* at 12 (Figure A.3-1 shows downlink beams projected onto Earth covering approximately three degrees by 50 degrees, corresponding to a spot size of approximately 70 km by 1140 km for a satellite at an altitude of 1,200 km).

roughly the size of South Carolina.[22] This footprint is two or more times the size of the beams used by GSO broadband satellites operated by ViaSat and EchoStar, which are located over 20,000 miles higher in space.[23]

Such wide beam design significantly constrains the service capability of the proposed OneWeb system. Using information from the OneWeb Petition and reasonable estimates for operating parameters, link budget calculations indicate an approximate total throughput for each OneWeb downlink beam of just 422 Mbps.[24] Applying a moderate estimate of average usage per customer of 1 Mbps,[25] at this throughput level, each beam would support service to just 422 active users in an area the size of South Carolina. In that state alone, over 850,000 people (or 18% of the

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[22] *See* U.S. Census Bureau, "Land and Water Area of States and Other Entities: 2008" (showing South Carolina has a land area of 77,881 km^2), *available at* https://view.officeapps.live.com/op/view.aspx?src=http%3A%2F%2Fwww2.census.gov%2Flibrary%2Fpublications%2F2011%2Fcompendia%2Fstatab%2F131ed%2Ftables%2F12s0358.xls.

[23] *See* Letter from John P. Janka to Marlene H. Dortch, GN Docket No. 14-177 et al., Attachment 1, Table 2 (Apr. 21, 2016) (showing beam areas of 31,000 km^2 for ViaSat's second and third generation satellites and 35640 km^2 for EchoStar's Jupiter 97 satellite).

[24] *See* Exhibit 1 attached hereto. While not all of the parameters used in this exhibit may precisely conform to OneWeb's intended operations, they represent a reasonable approximation of the throughput of a Ku-band downlink beam.

[25] The necessary capacity per user depends on a number of factors including peak utilization per user, and appropriate margins for spare capacity, which can vary depending on system and user characteristics, including connection speed. But 1 Mbps is likely a conservative figure. *See, e.g.*, White Paper, "Defining Broadband Speeds: Deriving Required Capacity in Access Networks," ADTRAN (Jan. 4, 2010) at 18-19 and Table 6 (projecting per household capacity requirement of 2.4 Mbps in 2015), *available at* www ntia.doc.gov/files/ntia/broadbandgrants/comments/rfi2/WP_Defining_Broadband_Speeds_Attach%20to%20RFI%20Letter%20Final.doc; Report, "Forecast of Residential Fixed Broadband and Subscription Video Requirements," ACG Research (Dec. 4, 2014) at 12 (estimating per household capacity requirements of 2.5 Mbps in 2014), *available at* http://acgcc.com/wp-content/uploads/2014/12/Forecast-of-Residential-Fixed-Broadband-Requirements-2014.pdf.

population) lack access to adequate fixed broadband service.[26] Extending this analysis nationwide, OneWeb's proposed system would be able to support fewer than 47,000 active users across the 8 million square kilometers contained in the contiguous United States.[27] Over time, as users demand even greater broadband capacity, the number of U.S. consumers that OneWeb could serve would diminish as well. An NGSO system with such limited capacity would barely make a dent in serving the nearly 34 million Americans that represent the Digital Divide.[28]

Designing and constructing a satellite with a large number of narrow up- and downlink beams may be more challenging or expensive than building one with a much smaller number of much larger beams, but that investment is necessary to maximize the broadband service that can be provided using a very limited amount of FSS spectrum. Just as OneWeb's choice to employ a lower-capacity beam configuration will limit its ability to serve substantial numbers of customers, it also will constrain its ability to share spectrum with the additional NGSO/FSS systems expected to share the same spectrum. Operators with more beams available maximize their flexibility in determining where to provide service, aiding spectrum sharing among NGSO/FSS systems. For

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[26] *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, Appendix D (2016) ("*2016 Broadband Deployment Report*").

[27] *See* United States Census Bureau, *State Area Measurements and Internal Point Coordinates* (2012), https://www.census.gov/geo/reference/state-area.html. Assuming five percent overlap of adjacent beams at the Eastern and Western edges (*i.e.*, a reduction of the beam size by a total of ten percent), the calculation would be the area of CONUS (8,000,000 km^2) divided by the area of each OneWeb downlink beam after reduction to account for slight overlapping (0.9 times 80,000 km^2) multiplied by 422 users per beam, for a total of 46,889 active users on average. For purposes of this calculation, we did not attempt to offset the number of users supported in a beam in the areas of overlap, though that would tend to reduce the total.

[28] *See 2016 Broadband Deployment Report,* ¶ 4 and Appendix D (finding that one in ten Americans lacks access to 25 Mbps/3 Mbps broadband, including more than 39 percent of Americans living in rural areas lacking access to advanced telecommunications capability).

example, two operators with smaller beams could coordinate their spectrum usage during times when their satellites pass in close proximity to one another by having one utilize only the beams oriented to the West and the other using only the beams oriented to the East. By comparison, a system with one larger beam preempts the use of all frequencies used in that beam over its entire footprint at all times. Accordingly, failing to use smaller beams is not only inefficient at the system level, but imposes inefficiencies that extend to all other NGSO/FSS systems sharing the band.

b. Beams that cannot be steered or shaped further limit operational flexibility

Although OneWeb expects to use phased array technology for the antennas on its user terminals,[29] its spacecraft rely upon older "bent pipe" technology that does not permit formation of its service beams. In addition, OneWeb has not included the ability to steer those beams over a range of locations.[30] Both are well-known, tested satellite technologies and were features of NGSO/FSS systems proposed more than 20 years ago.[31] As a result, the Ku-band downlink beams remain essentially static. Indeed, it is this lack of ability to move or reshape individual beams that necessitates OneWeb's proposed "progressive pitch" maneuver, in which the entire satellite is reoriented as it nears the equator in order to protect Ku-band GSO satellites from interference by

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[29] *See, e.g.,* OneWeb Petition, Technical Appendix at 10 ("user terminals will employ mechanically steerable parabolic reflector antennas, electronically steerable phased array antennas or other beam steering technology").

[30] Notably, OneWeb included steering capability for the Ka-band downlink beams used to communicate with its gateway Earth stations, but for some reason chose not to do the same with respect to its Ku-band service links.

[31] Mark A. Sturza, Teledesic Corporation, *The Teledesic Satellite System: Overview and Design Trades*, at 7, http://www.3csysco.com/pubs/the%20teledesic%20satellite%20system%20-%20overview%20and%20design%20trades.pdf.

creating a more favorable angle with the geostationary arc and complying with the Commission's limits on equivalent power flux-density.[32]

This lack of operational flexibility further limits the proposed system's ability to share spectrum with other NGSO/FSS constellations. The proposed system cannot, for example, reorient its beams in a way that would allow geographic separation from the beam of another NGSO system's spacecraft as it passes nearby. Moreover, the proposed OneWeb satellites lack overlapping beams—or beams that can be steered so that they overlap—which are important in avoiding potential interference during "in-line events" with other NGSO systems.[33] A system design that allows a customer to be served by more than one satellite at a time (a concept called "satellite diversity") enables the operator to determine which specific satellite to use based on whether it would cause or receive interference from a satellite of another system. 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."[34] But it appears that OneWeb's Ku-band downlink beams from satellites in the same and adjacent orbital planes typically overlap only at the

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[32] *See* OneWeb Petition, Technical Appendix at 30-32.

[33] An in-line event occurs when satellites from two different constellations physically align with an Earth station communicating with one of those systems within a certain minimal level of angular separation.

[34] *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) ("*Ka-band NGSO Sharing Order*").

outermost Eastern and Western edges of those beams.[35] This lack of satellite diversity significantly limits the options available for avoiding potential interference to and from other NGSO/FSS systems.

c. Poor design wastes valuable spectrum

OneWeb also has elected not to invest in advanced processing power and filtering capabilities for its satellite system. In doing so, the OneWeb system leaves valuable FSS spectrum underutilized. For example, its Ka-band downlink beams only utilize 125 MHz of spectrum, but actually occupy 155 MHz "to allow for on-board frequency translation and associated filter implementations."[36] As shown in the illustration below, this arrangement also leaves a total of 60 MHz of spectrum at the upper edges of the bands unused.

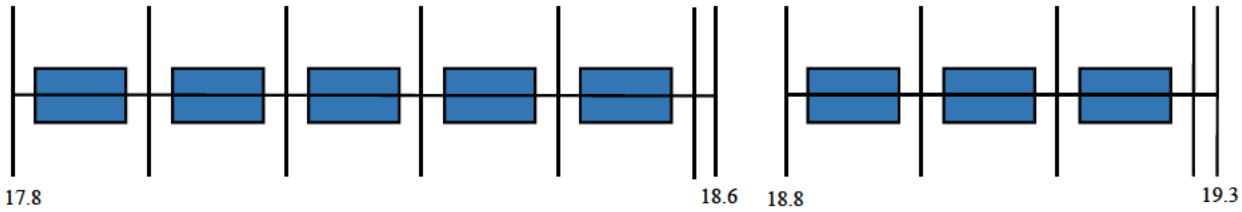

Figure 2. OneWeb Ka-band Downlink Channels

In other words, in order to simplify and reduce the cost of its satellites, OneWeb's system will leave fallow approximately 20 percent of this valuable FSS downlink spectrum.

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[35] *See* OneWeb Petition, Technical Appendix at 15-16 (discussion and illustration of downlink beams). *See also id.*, Annex 1, at A1-14 (discussing an EPFD model parameter setting that captures the "[r]are situation when operational satellites have overlapping service areas and overlapping frequencies"). The one exception is when satellites approach the equator, and the "progressive pitch" technique is used to reorient the entire satellite and create a slight overlap to allow an Earth station to communicate with a satellite less in line with the GSO arc. *See* Letter from Kalpak S. Gude to Marlene H. Dortch, IBFS File No. SAT-LOI-20160428-00041, OneWeb Response at 3-4 (June 24, 2016). Even then, OneWeb apparently will turn off overlapping beams in order to comply with applicable EPFD limits. *Id.*

[36] *See* OneWeb Petition, Technical Appendix at 7 n.6.

3. By Limiting Spectrum Sharing Options, OneWeb Will Increase the Likelihood of Band Segmentation—to the Detriment of all NGSO/FSS Operators and OneWeb Itself

In the absence of coordination agreements among NGSO/FSS operators, the Commission has applied two approaches to spectrum sharing in the Ku- and Ka-bands. One involves simply splitting the spectrum among the eligible NGSO systems—an approach commonly referred to as band segmentation.[37] Alternatively, the Commission may apply an approach based upon avoidance of in-line interference events, in which NGSO systems are allowed to use all authorized spectrum except when their satellites and Earth stations align in a specified manner—at which point they revert by default to band segmentation in the absence of a coordinated arrangement.[38]

SpaceX agrees with OneWeb that the Commission should not reflexively impose the automatic band segmentation approach upon the current generation of participants in the upcoming NGSO processing round, and should instead proceed with a regime based on avoidance of in-line interference events.[39] Yet this more efficient approach will put a high premium on successful spectrum coordination among NGSO/FSS systems, a goal made more difficult to achieve given OneWeb's proposed limited design. When the Commission adopted its current avoidance of in-line interference approach, it anticipated that in-line events would not be a problem "90% or more

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[37] *See, e.g.*, 47 C.F.R. § 25.157(e) (establishing certain band segmentation procedures if there is not sufficient spectrum available to accommodate all qualified NGSO applicants).

[38] *See, e.g.*, 47 C.F.R. § 25.261 (Ka-band spectrum); *Ku-band NGSO Sharing Order*, ¶¶ 52-55; *Ka-band NGSO Sharing Order*, ¶¶ 18-21.

[39] *See* OneWeb Petition at 17-19.

of the possible operating time"[40] or at least a "majority of the time."[41] These analyses were made in the context of first-generation NGSO/FSS systems with constellations of just tens of satellites apiece.[42] However, with numerous current-generation NGSO/FSS constellations each proposing to deploy hundreds or even thousands of satellites, in-line events are likely to be the norm rather than the exception. In-line interference is an even greater risk for a system designed like OneWeb's that uses static beams that generally cannot serve customers from more than one satellite. Further, it appears that the OneWeb system, once launched, cannot be expanded by adding satellites for increased capacity or upgraded to improve coexistence with other NGSO systems. OneWeb's system and technology design choices may cause all NGSO/FSS systems to be relegated to the less-efficient band segmentation approach some or all of the time.

Yet OneWeb's own Petition makes clear that it does not have a business case to support its system if it is granted access to only a segment of the spectrum it seeks.

> OneWeb cannot maintain a high-speed broadband service across the entire globe if it is limited (even if only for the United States) to operating its satellite constellation in just one-third (or less) of the full Ku-band spectrum that it needs for viable operations. . . . [W]ere such a segmentation requirement to be imposed on OneWeb, ***it is likely that the constellation might not get completed at all***.[43]

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[40] *Ka-band NGSO Sharing Order*, ¶ 19.

[41] *Ku-band NGSO Sharing Order*, ¶ 30.

[42] *See, e.g., Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ku-Band*, 16 FCC Rcd. 9680, Appendix D (2001) (discussing seven proposed Ku-band NGSO systems with from 13 to 80 satellites in the constellation); *Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ka-Band*, 17 FCC Rcd. 2807, Appendix D (2002) (discussing five proposed Ka-band NGSO systems with 15 to 96 satellites in the constellation).

[43] OneWeb Petition at 19 (emphasis added).

In essence, by electing to design its proposed NGSO system with limited technical capabilities, OneWeb signals that it may have made its own business model untenable. More importantly, it also would needlessly have made operation with additional NGSO/FSS systems more challenging, further compromising efficient spectrum sharing for an entire class of proposed NGSO/FSS systems. In effect, OneWeb is requesting that the Commission authorize its own limited proposed system at the expense of other prospective NGSO/FSS constellations that do employ technologies that are efficient and sacrifice the benefits of a competitive NGSO/FSS environment for broadband service diversity in the U.S.

C. THE COMMISSION SHOULD REQUIRE ONEWEB TO SUBMIT COMPLETE INFORMATION ON ORBITAL DEBRIS MITIGATION AND END-OF-LIFE DISPOSAL PLANS BEFORE ACTING ON THE PETITION

The OneWeb Petition raises orbital debris and space operational safety concerns. The danger posed by orbital debris can be thought of "fundamentally as a long-term environmental problem" as well as "potentially affecting U.S. security interests, especially in its ability to interfere with consistent satellite support to U.S. military and intelligence organizations."[44] As the Commission has found, "orbital debris poses a potential risk to the continued reliable use of these orbital regimes for space-based services and operations, as well as to the continued safety of persons and property in space and on the surface of the Earth."[45] One mishap or unforeseen problem in space can have ramifications for the broader space environment lasting decades. Thus, orbital debris mitigation and post-mission disposal are issues of great significance to the entire

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[44] Congressional Research Service, "Threats to U.S. National Security Interests in Space: Orbital Debris Mitigation and Removal," at 13 (Jan. 8, 2014), *available at* https://www fas.org/sgp/crs/natsec/R43353.pdf.

[45] *Mitigation of Orbital Debris*, 19 FCC Rcd 11567, ¶ 4 (2004) ("*Orbital Debris Order*").

space sector, including the governmental and commercial satellite systems of all nations operating at virtually all orbits, as well as satellite launch providers and the U.S. and international customers who depend upon their services.

When the Commission adopted orbital debris mitigation rules, it concluded that the public interest is served by requiring those seeking access to the U.S. market "to submit the same information concerning the orbital debris mitigation plans of the non-U.S-licensed space station as that submitted by U.S.-licensed space stations."[46] It found that some consideration of this issue is appropriate, "regardless of the licensing Administration, in order to ensure that the satellite communications activity that we authorize does not involve substantial safety concerns or activities that may be detrimental to space operations."[47] Accordingly, the Commission's rules generally require those seeking access to the U.S. market to provide a comprehensive description of the design and operational strategies they intend to use to mitigate orbital debris, including post-mission disposal plans for space stations at the end of life.[48]

OneWeb has not submitted such information with its Petition. Instead, it argued that it is subject to an exception to the general rule (codified in Section 25.114(d)(14)(v) of the Commission's rules) because its system "is subject to direct and effective regulatory oversight by the United Kingdom's regulatory authorities, including particularly the U.K. Space Agency, with

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[46] *Id.*, ¶ 93.

[47] *Id.*

[48] *See* 47 C.F.R. §§ 25.114(d)(14) (discussing required orbital debris showing), 25.137(b) (requiring non-U.S. systems to provide the legal and technical information called for under Section 25.114).

respect to orbital debris mitigation plans."[49] In support of this assertion, OneWeb cited the Commission's finding that the U.K. would provide such direct and effective regulatory oversight with respect to the NGSO system operated by O3b.[50]

When the Commission initially adopted this exception, it stated that a petitioner could make the required showing of direct and effective regulatory oversight by submitting an English language version of the debris mitigation rules or regulations of the national licensing authority and indicating the current status of the national licensing authority's review of its debris mitigation plans.[51] The OneWeb Petition includes neither of these items. In response to a request by the International Bureau staff for any publicly available materials discussing the criteria applied by the United Kingdom to assess the debris mitigation plans of NGSO satellite systems, OneWeb provided a "Guidance for Applicants" document that outlines the license application and approval process for the United Kingdom, including provisions applicable to orbital debris mitigation.[52] While OneWeb anticipates that the U.K. will issue Space Activity Licenses for its system before the initial launch of its satellites,[53] there is no indication that OneWeb has filed any application for such licenses or any related information on orbital debris mitigation.

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[49] *See* OneWeb Petition at 16 (citing 47 C.F.R. § 25.114(d)(14)(v)).

[50] *Id.*, n.50 (citing Petition for Declaratory Ruling of O3b Limited Granting Access to the U.S. Market for the O3b MEO Satellite System, IBFS File No. SAT-AMD-20150115-00004, Radio Station Authorization, at 3, Condition 15 (granted Jan. 22, 2015)).

[51] *Orbital Debris Order*, ¶ 95.

[52] *See* Letter from Kalpak S. Gude to Marlene H. Dortch, IBFS File No. SAT-LOI-20160428-00041, Response to Question 6 (June 24, 2016) ("OneWeb Supplemental Response").

[53] *See* OneWeb Petition at 16, n.49.

In applying the exception in Section 25.114(d)(14)(v), the Commission has made clear that the mere prospect of regulatory review by another administration at some point in the future is not sufficient. Thus, for example, the Commission dismissed as defective a petition by New Skies Satellites, B.V. ("New Skies") to serve the U.S. market using the SES-4 satellite, authorized by the Netherlands, due to deficiencies in its orbital debris mitigation showing. In addition to failing to provide the Netherlands' debris mitigation guidelines, New Skies did not provide "the current status of the Netherlands' review of the specific debris mitigation plans for the SES-4 space station."[54] The Commission advised that, in order to provide the information necessary to determine whether granting market access would serve the public interest, "New Skies must state whether the licensing administration for SES-4 has ***reviewed and affirmatively approved the specific debris mitigation plans*** for the SES-4 space station set forth in New Skies' application."[55]

By construing Section 25.114 in this way, the Commission ensures that the exception only applies in cases where another licensing administration with a robust debris mitigation regime has received complete information from the licensee, thoroughly evaluated it, and actually concluded that the proposed plan will promote the safe use of space. Deferring to another regulator in such circumstances may be considered a reasonable application of international comity. By comparison, deferring where no regulator has yet received such information (much less approved it) would be an abdication of the Commission's responsibilities.

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[54] *John K. Hane, Esq.*, 26 FCC Rcd. 7996, 7997 (IB 2011).

[55] *Id.* (emphasis added). *See also Carlos M. Nalda*, 28 FCC Rcd. 1050, 1051 (IB 2013) (dismissing an application to modify a blanket license for communications with non-U.S. licensed satellites where the applicant failed to provide "an indication as to whether the licensing authority has reviewed and affirmatively approved specific debris mitigation plans for the spacecraft").

According to the information submitted by OneWeb, the U.K. regulator does not require submission of any information on orbital debris mitigation and post-mission disposal until six months before launch or operation.[56] OneWeb has not indicated that it has provided the U.K. authorities any such information to consider, or that its specific debris mitigation plans have been reviewed and approved. It is asking the Commission to grant the Petition up to four years *before* OneWeb may be required to submit any such information to the U.K. authorities.[57] By contrast, the Commission's authorization to O3b cited by OneWeb was issued at a time when O3b's system was already in commercial operation[58]—*i.e.*, *after* the U.K. had already fully considered O3b's application and issued licenses for its system.

Given the scope of OneWeb's proposed constellation—40 satellites in each of 18 orbital planes—safe operation and disposal of these space objects will be crucial. Granting such a system access to the U.S. market before *any* administration has received orbital debris information would create a serious risk to all space-based systems, as there would be no assurance that the operator had thoroughly evaluated strategies for minimizing or eliminating orbital debris and for safely and efficiently disposing of spacecraft at the end of their useful lives. Such an outcome would not

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[56] *See* OneWeb Supplemental Response, Attachment "Revised Guidance for Applicants—Outer Space Act 1986," at 2 ("Applications should be submitted at least six months in advance of any plans for launch or operation.").

[57] The Petition indicates that OneWeb plans to launch its entire constellation within six years of gaining access to the U.S. market, with principal launch activities performed over an 18 month period. *See* OneWeb Petition, Technical Appendix at 6. Under this schedule, OneWeb would not have to provide any information on orbital debris mitigation to the U.K. licensing authorities until up to four years after Commission action — with no requirement to share that information with the Commission or other interested parties.

[58] O3b launched its first four satellites in June 2013, and began providing service on a limited basis soon thereafter. *See* Press Release, "O3b Takes Control of First Satellites, as In-Orbit Testing Successfully Completed," O3b Networks (July 30, 2013), *available at* http://www.o3bnetworks.com/o3b-takes-control-first-satellites-orbit-testing-successfully-completed/. O3b filed a Letter of Intent seeking U.S. market access for its NGSO system in October 2014. *See* IBFS File No. SAT-LOI-20141029-00118.

serve the public interest, and can easily be avoided by enforcing the Commission's rules that require submission and evaluation of this information before a U.S. authorization can be issued.[59]

CONCLUSION

The new generation of NGSO/FSS constellations holds incredible potential to bring affordable, advanced broadband services to underserved and unserved areas of the United States and around the world. Investment in advanced technologies that provide spectral efficiency and operational flexibility are necessary for NGSO/FSS systems to successfully increase access to reliable, high-speed broadband connectivity. Because OneWeb has chosen not to make that investment in certain available technologies, its system would waste valuable spectrum and inhibit effective spectrum sharing, creating obstacles for both its own operations and those of other systems. In effect, OneWeb is requesting that the Commission authorize its own limited proposed system at the potential expense of other prospective NGSO/FSS constellations and sacrifice the benefits of a competitive NGSO/FSS environment for broadband service diversity in the U.S. Further, OneWeb's silence on its orbital debris mitigation and end-of-life disposal plans denies the Commission and other interested parties crucial data that goes to the heart of safe space operations.

The Commission must therefore assess whether granting market access to such a system would serve the public interest. In particular, it must decide whether rewarding a system design that fails to incorporate available technology to enhance spectrum capacity and make spectrum sharing more feasible would achieve the long-recognized public interest goal of greater spectrum efficiency. It must also consider whether any grant should be conditioned in a way that would

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[59] In addition, because virtually all of the required information relates to considerations incorporated into the design and anticipated operation of the system, OneWeb should have little difficulty assembling and presenting it to the Commission for consideration.

offset the impact of OneWeb's design choices. This should include making any authorization subject to whatever rules are adopted in the upcoming rulemaking on NGSO/FSS issues. In making this determination, the Commission should not allow OneWeb to impose an unfair and disproportionate burden on other NGSO/FSS systems.

Given that the Commission intends to initiate a rulemaking to update its rules for NGSO/FSS systems in the near future, the issues raised here should be addressed first through rule revisions that establish proper incentives to design systems that achieve their full potential for broadband connectivity and spectrum efficiency. At a minimum, the Commission should apply any eventual updated rules to this application, consistent with precedent in prior NGSO/FSS processing rounds. It should also require OneWeb to submit complete information on orbital debris mitigation plans and satellite disposal at end-of-life for consideration by the Commission and all interested parties.

Respectfully submitted,

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August 15, 2016

EXHIBIT 1 Illustrative Link Budget for OneWeb Ku-band Downlink Beam		
Parameter	**Value**	**Notes**
Reference temperature [K]	293	
K [J/K]	1.38E-23	Boltzmann
Frequency [GHz]	11.7	Downlink: 10.7 - 12.7 GHz
EIRP [dBW]	34.60	Per OneWeb Tech Narrative
altitude [km]	1200	Per OneWeb Tech Narrative
Space loss, user at nadir [dB]	175.39	
distance to spot edge [km]	1352.43	25° away from boresight (50° beamwidth)
Space loss user at spot edge [dB]	176.43	
Clear sky attenuation [dB]	0.30	
Rx antenna directional error [dB]	0.10	
Polarization loss [dB]	0.30	
Rain fade [dB]	0.30	
Margin for Adaptive Coding and Modulation [dB]	0.75	Margin to run ACM
Implementation loss, RF and modem [dB]	1.50	
ES Antenna Gain [dB] - estimated	33.00	~50cm "average" ES antenna (30-75cm, per OneWeb Tech Narrative)
Symbol rate [Msym/sec]	250	
Necessary Bandwidth [MHz]	250	
Antenna temperature [K]	60	
ES Noise Figure of LNB [dB]	2.0	
ES LNB noise temperature [K]	171.37	
ES Receiver noise temperature [K]	231.37	
ES Effective G/T [dB/K]	9.36	
C/N for ES @ spot edge [dB]	5.90	
PHY rate in 250MHz @ spot edge [Mbps]	417	Based on using modcods that are 1dB worse than DVB-S2X codes, ideal EsNo, AWGN Lin Ch
C/N for ES @ spot center [dB]	9.94	
PHY rate in 250MHz @ spot center [Mbps]	639	
Average PHY Rate [Mbps]	528	Averaging between spot center and spot edge
MAC efficiency [%]	80%	
Average Thru per beam [Mbps]	**422**	IP throughput

ENGINEERING CERTIFICATION

The undersigned hereby certifies to the Federal Communications Commission as follows:

(i) I am the technically qualified person responsible for the engineering information contained in the foregoing Comments,

(ii) I am familiar with Part 25 of the Commission's Rules, and

(iii) I have either prepared or reviewed the engineering information contained in the foregoing Comments, and it is complete and accurate to the best of my knowledge and belief.

Signed:

/s/ Mihai Albulet

Mihai Albulet, PhD
Principal RF Engineer
SPACE EXPLORATION TECHNOLOGIES CORP.

August 15, 2016

Date

CERTIFICATE OF SERVICE

I hereby certify that, on this 15th day of August, 2016, a copy of the foregoing Comments was served via First Class mail upon:

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