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November 17, 2017

File Number: 48HH-246229

VIA IBFS

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street S.W.
Washington, D.C. 20554

Re: **Ex Parte Presentation Concerning Application of Space Exploration Holdings, IBFS File No. SAT-LOA-20170301-00027, Call Sign S2992**

Dear Ms. Dortch:

WorldVu Satellites Limited, d/b/a OneWeb ("OneWeb"), files this *ex parte* presentation to address the failure of Space Exploration Holdings, LLC ("Space Exploration Holdings" or "SEH") to account for the serious safety issues raised by its proposed non-geostationary orbit ("NGSO") system.[1]

As the Commission is aware, OneWeb, since 2012, has made a significant investment in the development of its own NGSO system, construction of which is already underway, and with which SEH's later-in-time proposed system would compete. OneWeb's investment in its system stands to bring dramatic benefits to American citizens, businesses, and the federal government. As the SEH Application proposes an overlapping NGSO system which creates significant safety

[1] Space Exploration Holdings, LLC, *Application For Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System*, IBFS File No. SAT-LOA-20170301-00027 (Call Sign S2992) (filed March 1, 2017) (the "SEH Application").

risks to OneWeb's system – risks SEH has not adequately accounted for – OneWeb has serious concerns that the SEH Application has been interposed for the purposes of delaying and frustrating a competitor.

OneWeb agrees with SEH that regulators should "encourage responsible and reliable satellite design and operation from launch to disposal," as SEH's representative stated before the Senate Committee on Commerce, Science & Technology.[2] SEH, however, has failed to adequately address the safety issues that arise from its application. OneWeb is most troubled by SEH's puzzling proposal to place its constellation in dangerously close proximity to (and interwoven with) OneWeb's pre-existing constellation, as well as other proposed constellations. Indeed, SEH's proposed system is so enormous and so complicated that it introduces danger from orbital debris greater than the Commission has ever witnessed – danger that flies in the face of the recommendation of the Inter-Agency Space Debris Coordination Committee (the "IADC") to maintain "sufficient altitude separation between all parts of the constellation and with respect to other large constellations and crowded orbits in order to minimise the potential collision risk."[3]

The safety issues presented by SEH's proposed constellation have become a significant public issue. They have now become the subject of Senate hearings and letters from multiple

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[2] *The Commercial Satellite Industry: What's Up and What's on the Horizon: Hearing Before the Committee on Commerce, Science & Transportation*, 115th Cong. 11 (2017) (Statement of Patricia Cooper, Vice President, Satellite Government Affairs, Space Exploration Technologies Corp.), *available at* https://www.commerce.senate.gov/public/_cache/files/0f1ac5f8-bfac-42e4-af28-985c9ffc06d0/34EE5201515C44F6E342E25E1E5DCCF9.cooper-testimony.pdf.

[3] Inter-Agency Space Debris Coordination Committee, *IADC Statement on Large Constellations of Satellites in Low Earth Orbit*, IADC-15-03 (Sept. 2017), *available at* http://www.iadc-online.org/index.cgi?item=docs_pub, at § 4.2.1 ("IADC Guidance").

space agencies, including NASA.[4] SEH thus far has provided few answers in response to OneWeb's comments regarding "issues related to the safety of [SEH's] proposed NGSO system,"[5] or to the Commission's own questions.[6] For instance, it has yet to explain how a collision between any two of its own satellites would affect other constellations with which it has proposed to interleave its NGSO system, or how those collision risks could be reduced if SEH instead placed its system in a non-overlapping altitude. The Commission must insist on satisfactory answers to these questions before moving forward on the SEH Application.[7]

I. SEH Must Account for the Safety Risks of Operating in Such Close Orbital Proximity to OneWeb and Other Systems.

As OneWeb explained in its Comments on SEH's V-band application, "[t]he selected orbit locations of Space Exploration Holdings ignore the large number of satellites from multiple operators that are in such close proximity that they will overlap due to orbital perturbations and/or failed satellites."[8] SEH has still failed to account adequately for these risks, which would

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[4] *See, e.g.*, Letter from Anne E. Sweet, NASA Representative on the Commercial Space Transportation Interagency Group, to Marlene Dortch, Secretary, Federal Communications Commission, Re: DA 17-524 Report No. SPB-271 Applications Accepted for Filing, Specifically Space Exploration Holdings, LLC (SAT-LOA-20161115-00118) and Theia Holdings A, Inc. (SAT-LOA-20161115-00121) (June 26, 2017).

[5] Space Exploration Holdings, LLC, *Consolidated Response to Comments*, IBFS File No. SAT-LOA-20170301-00027, at iv (Call Sign S2992) (filed Oct. 10, 2017) ("Consolidated Response").

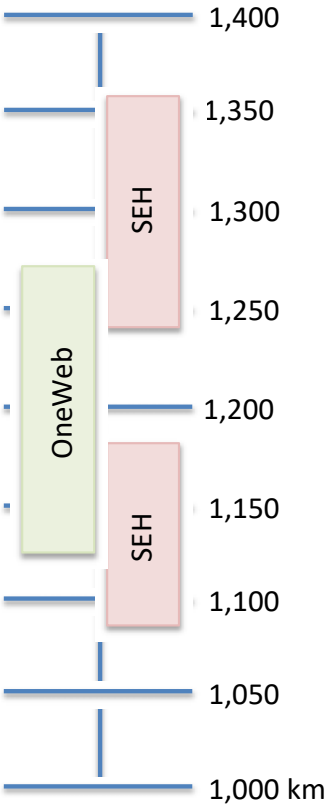
[6] *See* Letter from Jose Albuquerque, Chief, Satellite Division, to William Wiltshire, Counsel for Space Exploration Holdings, Re: Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20170301-00027, Call Sign S2992 (June 22, 2017) ("FCC Letter").

[7] The safety concerns raised by OneWeb in this ex parte presentation apply equally to Space Exploration Holdings' application for an NGSO FSS system operating in the Ku- and Ka-bands. *See Application of Space Exploration Holdings for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System*, IBFS File No. SAT-LOA-20161115-00118 (Call Sign S2983) (filed Nov. 15, 2016).

[8] Comments of WorldVu Satellites Limited, *In re Space Exploration Holdings Application for Approval for Orbital Deployment and Operating Authority for the Space Exploration Holdings NGSO Satellite System*, at 5 (Sept. 25, 2017) ("OneWeb Comments").

jeopardize the physical integrity of OneWeb's system, create unacceptable financial risks for all the systems involved, and destroy use of these altitudes for future space ventures.

Specifically, SEH is requesting to place 3,600 satellites between 1080 and 1180 km, another 375 satellites between 1245 and 1305 km, and yet another 450 satellites between 1295 and 1355 km.[9] Notwithstanding SEH's claims regarding the maneuvering capability of its satellites when they are functioning properly, they will all need a wide berth—which even Space Exploration Holdings' own technical submissions estimate at ±30km.[10] This altitude variance, known by all, occurs because even satellites in "circular" orbits vary in altitude with natural orbital perturbations. SEH, however, has inexplicably chosen to place its proposed satellites into orbits that overlap in altitude with the constellation OneWeb is launching, and about which SEH has known for years, as well as with the orbital altitudes of other proposed large constellations. SEH's choices complicate the operations of other providers operating in the same altitudes and elevate the risk of collisions.



Thus far, SEH has failed to answer basic questions raised by the Commission and by OneWeb:

[9] *See* Space Exploration Holdings Application Technical Attachment; Letter from William Wiltshire, Counsel to Space Exploration Holdings, to Jose Albuquerque, Chief, Satellite Division, Re: Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20170301-00027 (July 24, 2017) ("SEH Response Letter").

[10] SEH Response Letter at 1.

1) What happens to the existing and proposed systems of other providers, including OneWeb, if SEH's satellites experience certain failure rates (specifically 1%, 5% or 10%)? The Commission asked SEH to answer this question, and asked for studies in support of SEH's response, on June 22, 2017.[11] To date, however, SEH has done no more than provide estimates of the likelihood of collisions, rather than studies as requested by the Commission. And even SEH's estimates failed to completely answer the questions presented: the collision estimates provided account only for the possibility of collisions between SEH's failed satellites and the existing catalog of space objects—neglecting entirely the additional risks of SEH's failed satellites colliding with one another, or with satellites in other proposed constellations, such as OneWeb's.

2) In a recent Senate hearing, SEH itself acknowledged that the debris clouds when satellites collide create a "sandstorm in space" threatening other orbital installations.[12] Indeed, SEH has claimed that space debris is the reason it has avoided other altitudes, confirming that collisions can ruin entire altitudes for all operators. Yet despite acknowledging these risks, SEH has yet to produce any impact studies related to the additional collision risks created by operating

[11] FCC Letter at 1.

[12] *The Commercial Satellite Industry: What's Up and What's on the Horizon: Hearing Before the Committee on Commerce, Science & Transportation*, 115th Cong. (2017) (response to Senator Peters' question by Patricia Cooper, Vice President, Satellite Government Affairs, Space Exploration Technologies Corp.), *available at* https://www.commerce.senate.gov/public/index.cfm/hearings?ID=C77B42B7-8EB3-4BD1-B309-0AC311639DAB at 1:48:30-1:51.

> in such close proximity to OneWeb's constellation, the new "sandstorms" that an SEH satellite collision would create, or the consequences such an event would have on its own or other nearby satellites.[13]

Instead of producing *studies* like the Commission requested, SEH has broadly and generically emphasized the maneuverability of its satellites as a talisman to ward off collisions.[14] The fact that SEH's proposal depends to such a great degree on the "maneuverability" of its satellites only emphasizes how precarious and unsustainable SEH's constellation design and location are. Satellites can only maneuver to avoid collisions if they are operational to begin with. Perhaps none of SEH's thousands of satellites will fail. But as SEH knows from its own launch failures, even carefully watched things can break, and other providers operating at overlapping altitudes—such as OneWeb—should not have to bear those risks before SEH has even been able to quantify or explain them.

SEH is well aware that the results of a collision within its constellation could be devastating to operators at nearby altitudes. In fact, SEH acknowledges that a single satellite collision can cause a shrapnel cloud or sandstorm so large that even SEH, having designed satellites with full maneuvering capabilities, would consider the affected region to be too

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[13] Satellite collisions, moreover, can cascade with disastrous effects, as each collision creates new debris fragments that increase the risk of further collisions. *See* Donald J. Kessler & Burton G. Cour-Palais, *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, 83 J. GEOPHYSICAL RES. 2637 (1978).

[14] Space Exploration Holdings has emphasized that it "*designed its spacecraft with the capability to avoid potential collisions, a capability it will use as necessary to ensure safe operating distances among its own spacecraft and with respect to other orbiting objects.*" Consolidated Response at 10.

inhospitable for its constellation.[15] SEH has been unable to produce any studies showing that its overlapping constellation concepts will not create this precise risk.

The 700-900 km region of low-Earth orbit ("LEO") has already experienced two such events in recent history. On February 10, 2009, the Iridium 33 satellite and the Cosmos 2251 satellite collided at an altitude of 770 km over Siberia, significantly increasing the amount of lethal debris in this heavily-used region of LEO.[16] Scientists estimate that this debris may remain in orbit *for a century*.[17] Two years earlier, a Chinese missile destroyed a defunct weather satellite at 850 km altitude in a 2007 test of China's anti-satellite capabilities. This also produced a space sandstorm, which experts estimate to include 40,000 fragments larger than one centimeter.[18]

These events demonstrate that the orbital environment is extremely fragile and that even a single collision can have serious and long-lasting consequences. For instance, the following plot, created using NASA's Standard Breakup Model, illustrates the distribution of fragments that would result if two 500 kg satellites, in circular orbits at 1,100 km altitude, were to collide. The figure plots both apogee and perigee altitudes of the resulting fragments against their average orbit altitudes. Moreover, the figure depicts only the trackable fragments larger than 10 cm, even though thousands of fragments smaller than 10 cm, each of which can cripple a

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[15] Indeed, Space Exploration Holdings has been clear that it chose its proposed altitudes because there is (currently) less orbital debris there than at other altitudes. Consolidated Response at 12.

[16] David Wright, Union of Concerned Scientists, *Colliding Satellites: Consequences and Implications* at 1 (Feb. 26, 2009), *available at* http://www.ucsusa.org/sites/default/files/legacy/assets/documents/nwgs/SatelliteCollision-2-12-09.pdf.

[17] Brian Weeden, Secure World Foundation, "2009 Iridium-Cosmos Collision Fact Sheet," (Nov. 10, 2010), *available at* https://swfound.org/media/6575/swf_iridium_cosmos_collision_fact_sheet_updated_2012.pdf.

[18] Press Release, Union of Concerned Scientists, UCS Statement on Chinese Anti-Satellite Test (Jan. 18, 2007).

satellite, would also result. The plot illustrates that the consequences of such an incident would be far-reaching, with most fragments continuously oscillating up and down around the collision altitude for thousands of years, creating obvious risks for any other satellites in that altitude range:

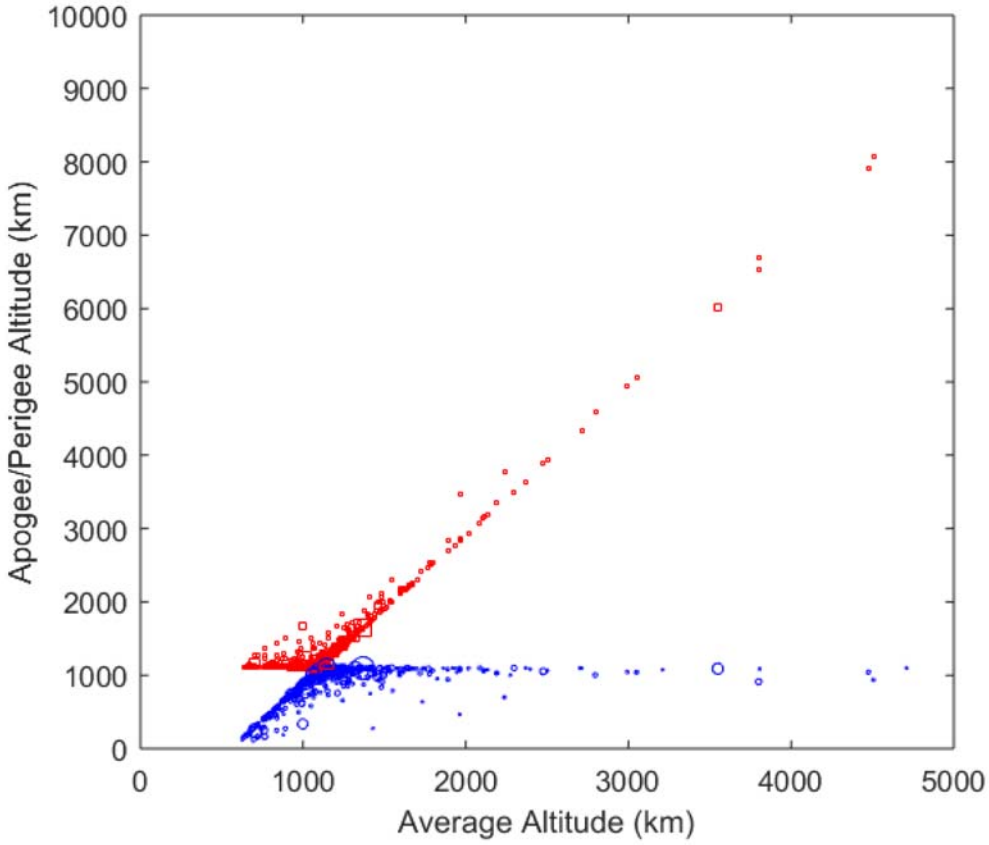

Fig. 1: Altitude distribution of fragments ≥10 cm generated in a collision involving two, 500 kg satellites in 1,100 km circular orbits.

Figure 2 below summarizes this same data by showing the percentage (and number) of these same fragments (10 cm and larger) as a function of maximum altitude those fragments will attain. Although no separation distance would assure complete safety in the wake of a collision (particularly given the many thousands of <10 cm fragments not represented on the graph), these

data show the risks are materially reduced at a distance of 125-150 km or greater, making it reasonable to require large constellation centers to be separated by at least this amount.[19]

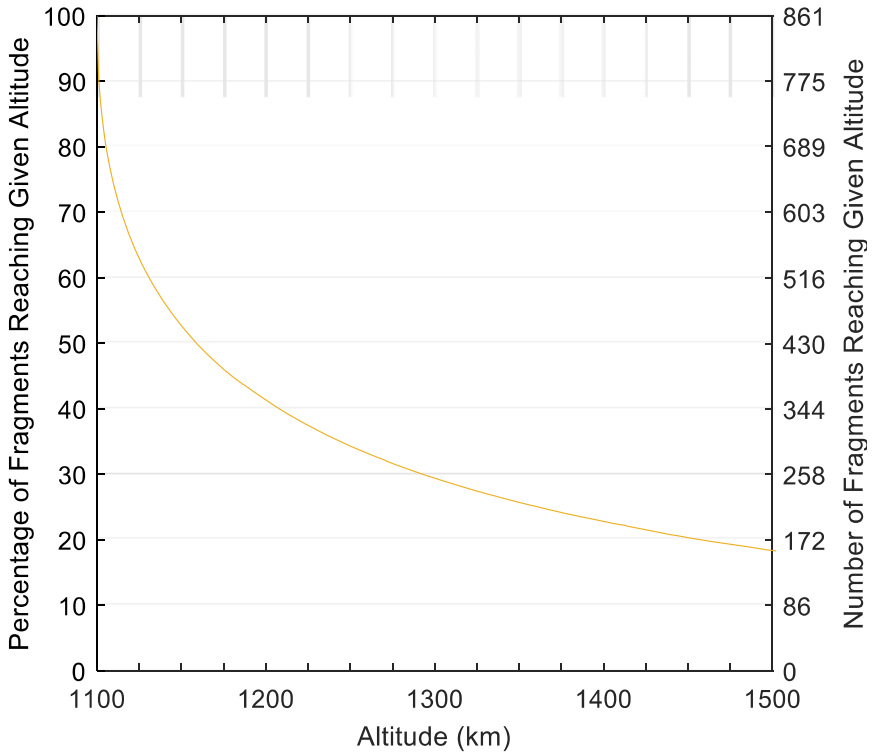

Fig. 2: Percentage (and number) of fragments reaching altitudes above the event altitude.

To further investigate the risk of collocating large constellations, OneWeb has engaged Dr. Hugh Lewis at the University of Southampton to conduct a parametric study of the dependence of long-term environmental risk on constellation separation distance. For purposes of this analysis, Dr. Lewis modeled the OneWeb and SEH constellations as each being at single altitudes, and ran a long-term (80 years) simulation to estimate the collision probability between uncontrollable satellites in the two constellations. Dr. Lewis's analysis excluded collisions

[19] Half of the large fragment population can be avoided at a distance of 50 km, and the OneWeb constellation remains within 75 km of its mean constellation altitude.

involving operational spacecraft, as well as intra-constellation collisions, in order to isolate the risks created by the interleaving of the constellations itself.

Dr. Lewis's results clearly demonstrate the reduction of risk afforded by adequate separation of large constellations. First, his simulations show that the possibility of failed spacecraft in one constellation colliding with those of the other is virtually eliminated if adequate open space is maintained between the outer extents of the two constellations. In this case, the centers of the SEH and OneWeb constellations would need to be at least 125 km apart.[20]

Second, Dr. Lewis quantifies the benefit of increased separation in reducing the risk posed to OneWeb by a hypothesized collision within the SEH constellation.[21] While the absolute number of expected collisions depends substantially on some of the input assumptions, the effect of proximity is clear. The risk to OneWeb from large fragments generated in a single collision between two SEH satellites drops by nearly an order of magnitude when the constellations are separated by at least 125 km.

[20] Space Exploration Holdings states that its satellites will span +/-30 km from the constellation center altitude, and OneWeb will extend up to 75 km from its center altitude. To account for long-term perturbations, 20 km of open space is proposed (30 + 75 + 20 = 125). It is notable that SEH, upon further review of its own constellation, may consider less overlap and more separation within its own constellation to reduce the likelihood of intra-constellation collisions, but such studies are outside of the scope of OneWeb's examination.

[21] University of Southampton study, performed by Dr. Hugh Lewis under contract to OneWeb, 2017. The results to date are so important that OneWeb was compelled to file this *ex parte* now with the expectation of filing a more complete report by Dr. Lewis once it has been finalized.

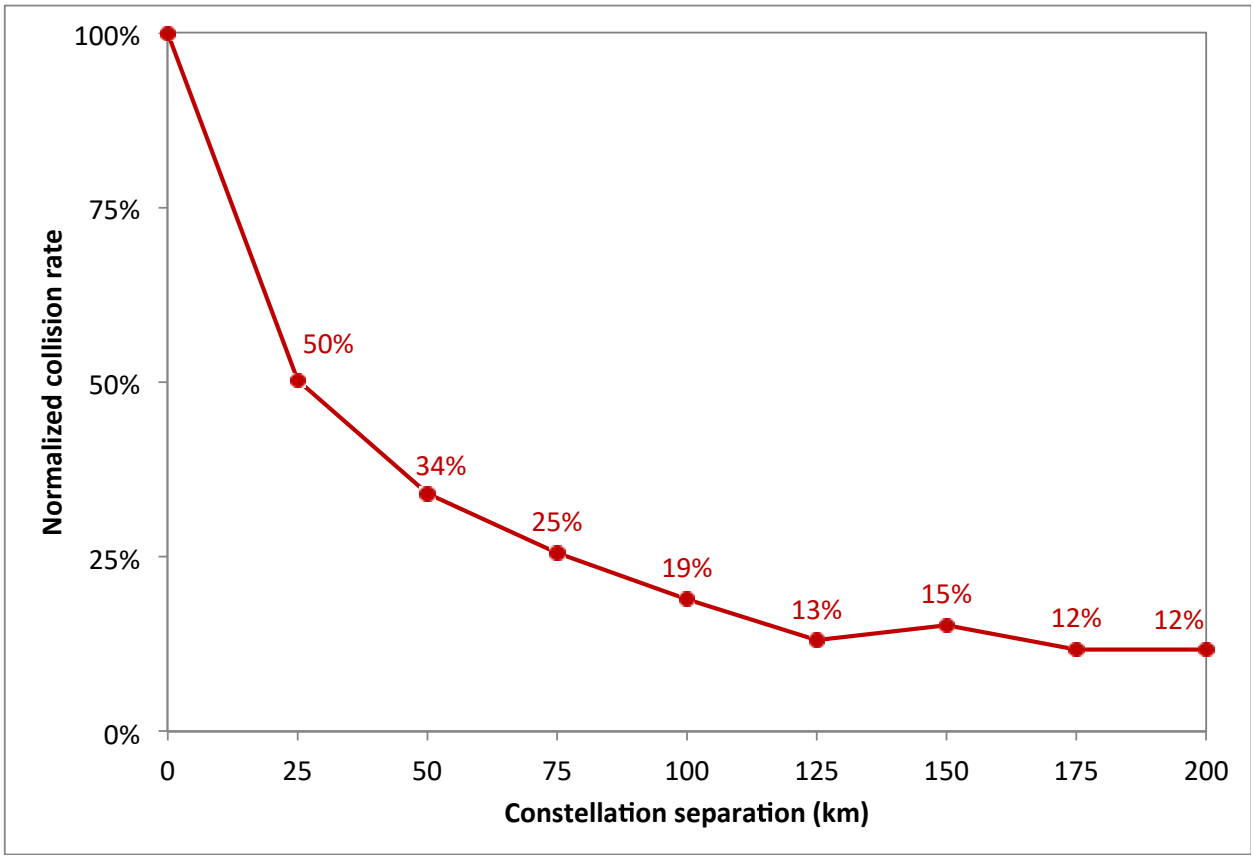

Fig. 3: The benefit of constellation separation on risk reduction for collisions between OneWeb satellites and fragments from a hypothesized collision within the SEH constellation.

Separate findings and recommendations were recently published by the IADC in its newly-updated guidance on deployment of large constellations in LEO. The IADC, which comprises thirteen space agencies including NASA, produced this guidance because, "[w]ith the anticipated number of orbital objects required to establish, maintain and refresh the new architectures, the greatest impact, at least in the short term will be on the constellations

themselves, in terms of possible close approaches, and the consequent potential burden in terms of conjunction assessment."[22] The IADC's first suggestion on Constellation Design states:

> "It is recommended to consider sufficient altitude separation . . . with respect to other large constellations and crowded orbits in order to minimise the potential collision risk."[23]

Section 25.114(d)(14)(iii) of the Commission's rules requires SEH to "ascertain the likelihood of successful coordination of physical operations with" OneWeb,[24] which SEH has yet to initiate. Given the environmental risks of collocating two large constellations at overlapping altitudes, the Commission should not approve the SEH Application unless and until SEH has provided studies answering the key safety questions its proposal raises.

II. Space Exploration Holdings Has Not Adequately Accounted for the Safe Disposal of Its System.

Beyond the risks to its own NGSO system, OneWeb continues to be concerned by the volume of hazardous debris that could strike the Earth from SEH's proposed very low Earth orbit ("VLEO") and LEO constellations. In total, SEH is asking to drop more than 63,000 objects from space over the stated 5-7 year lifespan of the constellations. Each of these heavy objects will impact the Earth with more than 60 times the kinetic energy needed to cause loss of life. SEH has downplayed this risk by comparing the new debris from its proposed constellation to the *total* amount of mass that de-orbits in a typical year.[25] However, SEH's comparison is misleading. The total mass that de-orbits each year includes numerous items that pose no

[22] IADC Guidance at § 3.

[23] *Id*. at § 4.2.1.

[24] 47 C.F.R. § 25.114(d)(14)(iii).

[25] Consolidated Response at 17-18.

material risk to persons and facilities on the ground, including the controlled re-entries of large satellites and the re-entry of dust-like particles with too little energy (*i.e.*, below the 15 Joule casualty threshold) to pose a significant risk. The new debris created by SEH, by contrast, would re-enter the atmosphere in the form of tens of thousands of 1.5 kg chunks of material.[26] SEH is requesting to de-orbit nearly 12,000 satellites over a 5-7 year period, with each satellite generating 5 or 6 potentially lethal objects that will reach the ground—creating risks for which it has failed to adequately account.

Further, SEH's focus on the reentry of any *single* satellite fails to address the *aggregate* risks created by its proposed system of nearly 12,000 satellites—or even by its VLEO system of over 7,500 satellites. OneWeb has previously pointed out that even though any *individual* SEH satellite might fall below NASA's per-satellite casualty risk threshold of 1:10,000, SEH's *aggregate* system, based on SEH's own numbers, has a 1:3 chance of causing a casualty when satellite components fall to Earth.[27] The IADC has recognized this aggregate risk posed by large LEO constellations.[28] To mitigate this risk, the IADC suggests that operators "consider spacecraft design options that reduces [*sic*] the number/size of harmful fragments impacting [the] ground."[29]

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[26] *See* SEH Application Technical Attachment at 50.

[27] OneWeb Comments at 8. When NASA drafted its human casualty risk standards focusing on individual satellites in isolation, it was not contemplating massive constellations like the one proposed by SEH. *See* NASA Standard 8719.14A, "Process for Limiting Orbital Debris," § 4.7.2.1 (2012), *available at* http://www.iadc-online.org/References/Docu/NASA-STD%208719-14%20Rev%20A%20Change%201%20-%20Approved.pdf (establishing thresholds for risk of human casualty for NASA space programs that use atmospheric re-entry as a means of disposal).

[28] IADC Guidance at § 4.3.3 ("During the operation of one or more large constellations, several hundred uncontrolled re-entries can be expected per year.").

[29] *Id.*

SEH's documents gloss over this risk, pointing the Commission to a potential, but not guaranteed, better design, as SEH has "plans to collaborate with NASA and leverage the agency's decades of re-entry experience in order to achieve a design where spacecraft fully demise on orbit with minimal risk to people on the ground."[30] In the meantime, SEH states its re-entry casualty risks are unavoidable because it wants to use materials "critical to the design and function of [the] parent assembly."[31] These are carefully chosen words. The fact still remains that the inter-satellite link "parent assembly" uses materials which create a significant safety issue.

SEH should consider the IADC recommendations and limit the number of potentially lethal objects produced by each of its satellites. Although SEH has stated that it "expects to even further refine spacecraft component geometries,"[32] it should be required—at minimum—to complete and publish the outcomes of such collaboration and refinements before the Commission takes action on the SEH Application.[33]

III. Conclusion

Space is a natural resource that must be protected for the benefit of current and future generations. The SEH Application proposes a massive constellation that would operate in dangerously close proximity to, and even be interwoven with, OneWeb's system. SEH has

[30] Consolidated Response at 18.

[31] SEH Response Letter at 9.

[32] *Id*.

[33] Members of the Senate Committee on Commerce, Science & Transportation have also come out in support of using a coordinated and publicized inter-agency approach to mitigate the increased risks of orbital debris arising out of the large LEO constellations proposed for deployment in the near future. *See* Letter from Sens. Cory Booker and Dan Sullivan, Committee on Commerce, Science & Transportation, to Ajit Pai, Chairman, Federal Communications Commission (Sept. 29, 2017), *available at* https://www.booker.senate.gov/?p=press_release&id=668.

failed to account for the new risks this arrangement could create to OneWeb's system, to other proposed constellations, and to long-term future uses of the space environment at and around the affected altitudes. Nor has SEH adequately accounted for the new risks of falling debris that its proposal would create to persons and facilities on the ground. Whatever theoretical benefits SEH might glean from such close operation to OneWeb's system (relative to designing a more efficient, non-overlapping constellation), it has not shown that the benefits to the public of its proposal outweigh these new risks. In fact, it has not even answered basic questions from the Commission about the safety of its proposal. The Commission should, at a minimum, require SEH to complete these studies, and to maintain an appropriate safety buffer from other current and proposed constellations, prior to taking any further action on the SEH Application.

Please do not hesitate to contact the undersigned with any questions.

Very truly yours,

/s/ Brian D. Weimer

Brian D. Weimer
for SHEPPARD, MULLIN, RICHTER & HAMPTON LLP

COUNSEL TO ONEWEB

CERTIFICATION OF PERSON RESPONSIBLE FOR REVIEWING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for reviewing the engineering information contained in this ex parte presentation, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this presentation, and that it is complete and accurate to the best of my knowledge and belief.

Dated: November 17, 2017

/s/ Marc Dupuis

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