Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
New Spectrum Satellite, Ltd	)	File No. SAT-PDR-20170726-00111
Petition for Declaratory Ruling Seeking U.S. Market Access for the New Satellite Spectrum, Ltd. Non-Geostationary Satellite System	)	Call Sign S3019

OPPOSITION OF NEW SPECTRUM SATELLITE, LTD

New Spectrum Satellite, Ltd ("New Spectrum Satellite"), pursuant to Section 25.154(c) of the Commission's Rules, hereby opposes the Petition to Dismiss or Defer of SES Americom, Inc. ("SES") and O3b Limited ("O3b"). No other parties commented on the New Spectrum Satellite Application. As explained below, SES and O3b in their Petition raise two objections, neither of which warrants denial or deferral of the New Spectrum Satellite Application: (i) a nonconforming use of the 17.8-18.3 GHz band without adequately demonstrating that New Spectrum Satellite can successfully operate in this band without causing interference; and (ii) a failure to show how New Spectrum Satellite will manage the physical operations of its satellites to limit the potential for collisions with O3b spacecraft.

In its Application, New Spectrum Satellite had not addressed the non-conforming use of the 17.8-18.3 GHz band for the simple reason that it was not a non-conforming use at the time the Application was filed.[1] However, as New Spectrum Satellite explained in its July 16, 2018 response to a question from the Commission:

> When it submitted its Letter of Intent application in July 2017, NSS had optimized its design to accommodate the use of the 17.3-18.3 GHz band in the Earth-to-space direction, before the Commission adopted its rules in September of that same year. To the extent a waiver is required, NSS requests it based on the fact that no interference is expected to and from other licensed systems operating in the Space-to-Earth direction as per the following explanation: NSS will use the 17.8-18.3 GHZ band for feeder links uplinks from Gateways. The Virtual Geo system gateways use large 6 meter antennas at 18 GHz that are highly directive to its satellites, which in turn during operation have very large separation angles from the geostationary arc (more than 40 degrees). NSS will also as needed, employ sites furnishing adequate separation and terrain shielding from any known or projected sites using this band in a downlink direction or for terrestrial microwave reception. NSS accordingly requests a waiver for this application. Please let us know if you need more data in support of the waiver request.

New Spectrum Satellite remains confident that it can operate the proposed feeder link uplinks without causing any interference into O3b transceivers for a number of reasons.

Other services in this band use the band either for satellite downlinks or for terrestrial links. In either case, the vulnerable receivers in such services are located on the surface of the earth. New Spectrum Satellite will be using this band for feeder link uplinks from a very limited number of gateway stations in the United States. This means that the New Spectrum Satellite transmitters, or hypothesized interference sources, are also located on the surface of the earth. For harmful interference to occur, the path taken by an interfering signal must therefore traverse the surface of the earth successfully from source to victim. New Spectrum Satellite will take steps to deny any such propagation paths.

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[1] The New Spectrum Satellite Application was filed on July 26, 2017, but the Commission decision specifying that band as Space-to-Earth was not adopted until September 27, 2017. *Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, 32 FCC Rcd 7809 (2017).

New Spectrum Satellite anticipates deployment of no more than ten (10) feeder link earth stations in the United States. In addition, acknowledging the need to limit potential interference because of the non-conforming use, New Spectrum Satellite will choose sites that are located in isolated areas with available terrain shielding (*e.g.* as due to high surrounding terrain) to limit the signals propagation in a horizontal direction, taking into account any known terrestrial usage of this band. It is quite possible to find such private sites to ensure adequate protection. In short, we will ensure that no line of sight or near-line-of-sight exists between a New Spectrum Satellite gateway site and one of another receive site in this band in another network.[2] Moreover, the gateway stations will use antennas with a narrow beamwidth (0.2 degrees), and they will only be operating at a high elevation angle (above 20 degrees minimum elevation angle), when communicating with the satellites in their active arc. In addition, supplemental shielding can also be implemented on the earth stations themselves if needed to further limit the horizontal propagation of the signals so as to avoid potential interference to terrestrial receivers if new operations in this band are deployed near the New Spectrum satellite gateways. All of these factors combined will minimize any risk of potential interference as a result of New Spectrum Satellite's non-conforming use of this band.

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[2] The requirements for non-line-of-sight troposcatter links to establish connectivity exemplify the isolation available here. Troposcatter links typically operate on the order of hundreds of miles, but require kilowatts of RF power into a large directive antenna pointed to the horizon within 1 or 2 degrees to get adequate signal at the receiver. In the case of Virtual Geo gateways, the large directive antennas are directed away from the horizon by a minimum of 20 degrees, and the links employ less than one watt per 18 MHz channel, a direction and power level wholly inadequate for over-the-horizon connectivity.

New Spectrum Satellite therefore undertakes that it will choose ground entry sites and operate its transmitters using this band so as to protect other FS and downlink FSS services operating in the band by using terrain shielding to isolate its sites and elevation angles at 20 degrees or above to minimize horizon-oriented emissions. New Spectrum Satellite also acknowledges that it will accept any interference from these primary, conforming services.

SES/O3b also challenged the New Spectrum Satellite Application on the grounds that it failed to include an assessment of the risk of a collision with the O3b satellites.[3] The Commission's Rules specify when NGSO applications must include such an analysis: "Where a space station will be launched into a low-Earth orbit that ***is identical, or very similar, to an orbit used by other space stations***, the statement must include an analysis of the potential risk of collision and a description of what measures the space station operator plans to take to avoid in-orbit collisions."[4] In this case, the proposed Virtual Geo constellation is not identical or very similar to the O3b orbit.

O3b currently operates in an equatorial circular orbit of zero inclination at 8062 kilometers altitude.[5] The Virtual Geo satellites as reflected in the Schedule S filed in July 2017 operate in an elliptical orbit inclined at 63.4 degrees, a semi-major axis of 20,281 kilometers, eccentricity of 0.605, and an argument of perigee of 270 degrees. As a consequence of this design, Virtual Geo satellites in their nominal orbit have only one specific altitude for any given latitude. Virtual Geo satellites are at 6,482 kilometers altitude in the nominal orbit, both when

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3 SES/O3b Petition at pp. 5-6.

4 47 C.F.R. § 25.114(d)(14)(iii)(emphasis added).

5 SES/O3b Petition at p. 6.

ascending and descending, as they pass through 0 degrees latitude where O3b satellites operate. This is some 1,580 kilometers below the O3b orbit. Even were a large relaxation in tolerances to result in a drift of the argument of perigee by as much as 2 degrees, Virtual Geo satellites would pass the equator no higher than 6,760 kilometers in altitude (at the higher node), still some 1,302 kilometers below the O3b orbit.

Hence, given that the Virtual Geo satellites never operate in the altitude/latitude regime in which O3b satellites are found, Virtual Geo satellites will never endanger O3b equatorial satellites -- they are simply far too widely separated at all times. As a result, there is effectively a zero probability of any collision between virtual Geo satellites and any satellite in the O3b equatorial constellation. Virtual Geo and the equatorial O3b satellites simply operate in different parts of space at all times. Thus, New Spectrum Satellite was not required to include in its application a collision risk assessment with regard to the O3b equatorial space stations.

In addition, while any assessment of collision risk with merely proposed constellations is speculative, in response to the SES/O3b Petition, New Spectrum Satellite has conducted an analysis of the risk of a collision with the proposed O3b inclined satellite constellation. That analysis is set forth in Appendix A. Using conservative estimates, such as satellite size, New Spectrum Satellite calculated the risk of a collision between the Virtual Geo and O3bi constellations over a 15-year period as 7.59×10^{-7}, or 1 chance in 1.320 million. This is significantly below the historically applied benchmark of 0.005 used for assessing the risk of collision with manned spaceflight, and also significantly less (by a factor of 1000) than the more stringent benchmark of 0.001 for constellations as a whole proposed by the Commission in its recent Orbital Debris Mitigation rulemaking.[6] Moreover, New Spectrum Satellite will comply with whatever ephemeris reporting, coordination and space traffic management procedures are adopted by the Commission in that proceeding (and/or adopted by another government entity),[7] and the Virtual Geo spacecraft will incorporate propulsion capabilities to take corrective actions in the event of a conjunction warning. Thus, any risk of collision between the Virtual Geo constellation and the O3b inclined orbit constellation, assuming it gets launched, will be eliminated. In sum, SES/O3b's concern regarding orbital collisions is unfounded.

In light of the demonstrations above that SES/O3b failed to raise any valid objections based on interference or collisions, and given the absence of any other petitions, New Spectrum Satellite urges the Commission to grant its Application expeditiously. Such action will well serve the public interest by allowing Americans to enjoy the manifold benefits of the services that will be provided by the Virtual Geo constellation.

Respectfully submitted,

New Spectrum Satellite, Ltd

By: _*/s/ Stephen L. Goodman*__________

Stephen L. Goodman
Stephen L. Goodman, PLLC
532 North Pitt Street Alexandria, VA 22314
(202) 607-6756
stephenlgoodman@aol.com
Counsel for New Satellite Spectrum, Ltd.

Dated: November 23, 2018

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6 *Mitigation of Orbital Debris in the New Space Age*, FCC 18-159, released November 19, 2018 at ¶ 26.

7 *Ibid*. at ¶¶ 13-17.

APPENDIX A

Analysis of Collision Probability between the Virtual Geo Satellites and Those of the O3b Inclined Constellation

In addition to its equatorial plane, O3b Ltd has received authority from the Commission for landing rights for a constellation of 16 satellites operating in two 70-degree inclined planes, 8 in each plane. O3b in a recent FCC filing has expressed concern that there may be an unacceptable collision risk between the Virtual Geo (VG) constellation and O3b, without distinguishing between its equatorial and proposed inclined-plane constellations. This analysis evaluates the probability of a collision between O3bi, their inclined constellation, and the Virtual Geo constellation of satellites.

The Orbits

Virtual Geo satellites operate in a highly elliptical inclined orbits having an apogee of 26,172 kilometers and a perigee of 1,632 kilometers. These orbits are inclined at 63.4 degrees. Each of the 5 satellites per ground track operate in a distinct orbit plane in order that the 5 may operate in a common ground track.[a]

According to the authorization, the Inclined O3b constellation of satellites operate in inclined circular orbits at a constant altitude of 8,062 kilometers. The 16 satellites operate in two orbital planes, 8 to a plane. These planes are inclined to the equator by 70 degrees, and the right ascension of the ascending nodes of the two planes are 180 degrees apart.

Figure 1 shows the Virtual Geo orbits (in various colors, but not red) and the O3b inclined orbits (shown in red). Figure 2 shows the same orbits, but from side-on to the O3bi orbits. It can be seen here that while the O3bi orbits are smaller in magnitude (*i.e.*, semi-major axis) than the Virtual Geo orbits, the VG orbits pass through the altitude of the O3bi orbits as they descend toward perigee and ascend from perigee. Although not very evident here, the orbits illustrated below nevertheless do not intersect, as all the VG orbits shown are offset to one side or another of the O3bi orbits as they pass by[b]. If the VG and O3bi orbits were actually deployed as proposed and remained constant in space relative to each other, they would not intersect as in the above illustrations, hence a collision will never occur. The satellites travel in different non-intersecting paths, which keeps them apart.

This is not to say however that such an intersection will not occur at time goes on and orbits drift or precess. This analysis therefore conservatively evaluates the probability of a collision occurring at such an intersection.

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[a] The orbit plane of each successive Virtual Geo satellite in a ground track must be displaced in longitude of the ascending node Eastward by the amount the earth has rotated during the interval between successive satellites.

[b] Visually it requires a 3-dimentional simulation of the orbits, and study of the simulation from various angles to see the gaps between orbit paths.

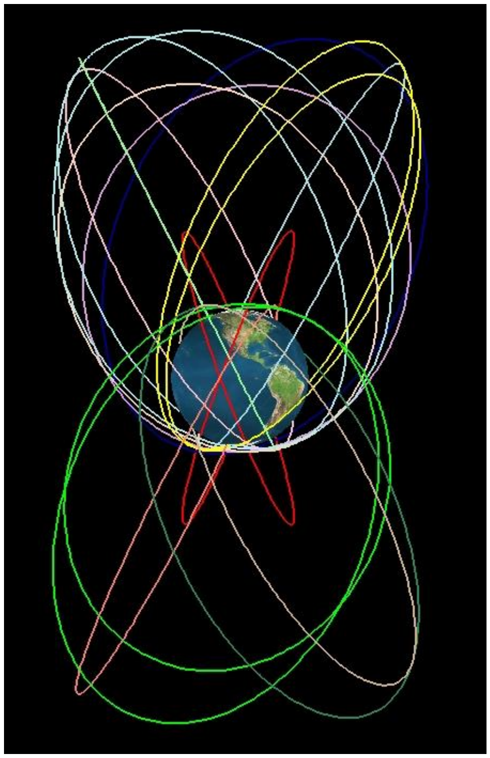

Figure 1, O3Bi orbits (red) and VG orbits (other colors)

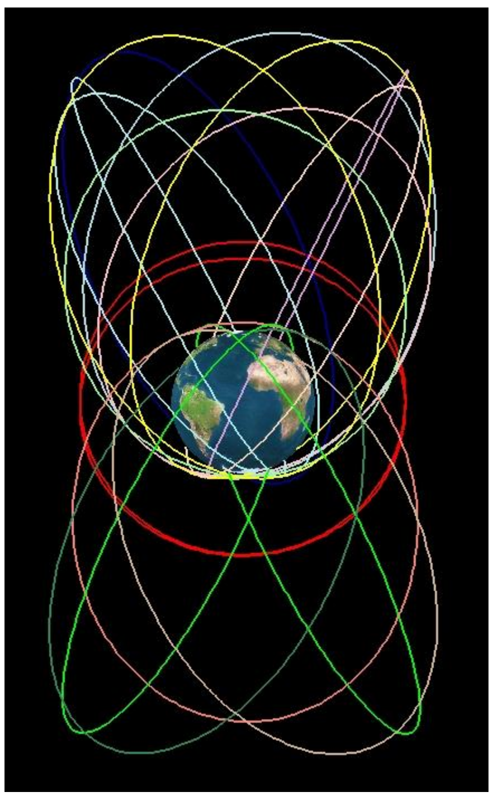

Figure 2, The orbits in Figure 1 rotated to see the O3Bi orbits face-on and illustrate where VG and O3Bi orbits cross

In general, differing orbits like the VG and O3bi orbits will not remain as they were initially established relative to each other, but will move, *i.e*. change their relative positions. To illustrate this, generally satellites in earth orbit are subject to, among other things, perturbations to their orbit due to the oblateness (equatorial bulge) of the earth. Most importantly, this causes orbit planes, specifically the line of nodes connecting the upward and downward equator crossings (of prograde orbits like these), to regress (move backward or Westward) around the earth slowly. The strength of this effect is dependent inversely on orbit altitude.

Calculations show that the O3bi orbits will regress by 0.1952 degrees per day. Virtual Geo orbits will regress by 0.1936 degrees per day. This means that the O3bi orbits will regress by 0.0015 degrees per day faster than the VG orbits. While this sounds like a small number, this translates to 22 kilometers per day or 3.7 kilometers per VG satellite pass, a distance much larger than the largest dimension of the collision volume. Hence if any one pass is a near miss, the next will be distant. With this observation it can be assumed for analytical purposes that, considering entire constellations over all the satellites, collision probabilities are to a first order distributed evenly in time and assumed uncorrelated from pass to pass.

Collision Rings and Collision Volume

Figure 2 also demonstrates that any orbit intersection -- the only places where collisions can happen - occur only in two rings encircling the earth: one parallel to the equator at an altitude of 8,062 km located 9.35 degrees North of the equator and one parallel to the equator at an altitude of 8,062 km located 9.35 degrees South of the equator. These are the latitudes where the Northern VG and Southern VG orbits pass through the O3bi altitude respectively.

For a collision to occur, a VG satellite must pass within contact distance of an O3bi satellite. In this analysis it is assumed conservatively that the VG and O3bi satellites are 10 by 20 by 5 meters in size. The collision volume is essentially the convolution of the volumes of the two colliding satellites. In this case, as an approximation, this volume is assumed to be twice the size of either satellite in each dimension. A VG satellite will need to intrude into this volume to sustain a collision with an O3bi satellite.

In summary, a collision ring is the locus of all points around the earth where a collision between O3bi and VG can occur. These loci form two annuluses, or rings. A collision volume is the volume of space around a satellite into which if another satellite intrudes, a collision is deemed to have occurred. Since a collision can only occur in a collision ring, the collision volume is a very short segment of the collision ring. This segment surrounds a satellite passing through the collision ring and hence at that moment vulnerable to collision.

While O3bi satellites have an orbital period of 17,269 seconds per orbit, the VG satellites have a period of 28,742 seconds per orbit. These numbers are sufficiently prime to each other that is no significant synchronization of any kind will occur between the orbits, and therefore a uniform probability distribution for encounters of the collision ring relative to each other seems appropriate.

Probabilities of Encounter

If one assumes that the cross-sectional area of the collision ring described above derives from the larger of the dimensions of the collision volume, that is 20 by 40 meters, then the collision ring total volume around the earth is this area swept around the collision ring circumference of 71.6 cubic kilometers. The collision volume is $1.11X10^{-7}$ of this volume. Therefore, relative to a single O3bi satellite, a VG satellite passing through the collision ring has a one in 9 million chance of passing through the collision volume of an O3bi satellite per VG pass, assuming that an O3bi satellite is also in the collision ring.

However, the largest axial thickness dimension of a collision ring is 40 meters, or 0.04 kilometers. Correcting for the angle of penetration, the O3bi path through the collision ring is 42.6 meters long, or 0.0435 kilometers. The O3bi orbit circumference is 90,279 kilometers in length, or 2.27 million times longer than the collision ring thickness. Therefore, for a uniform velocity distribution around the orbit, the O3bi satellite spends only 2/(2.27 million)[c] of its time in the collision ring. If VG satellites crossing the collision ring and O3bi satellites crossing the collision ring are independent events, which they appear to be, then the probability of an O3bi satellite being in the collision ring when a VG satellite crosses it is 1 in 1.13 million, or $8.82x10^{-7}$.

The VG satellites do not maintain a constant velocity over their orbit; velocity increases as altitude above the earth decreases. At 8,062 kilometers altitude the velocity of a VG satellite in its orbit is 5.95 kilometers per second. The collision ring is assumed to be 40 meters thick. The track through the collision ring occurs at an angle of 63.4 degrees to it, so the length of the VG satellite path through the ring is 40 meters divided by sin(63.4 degrees) or 44.7 meters. At this speed, the satellite will occupy the collision volume for only 0.00752 seconds before exiting. An entire VG orbit takes 28742 seconds. A VG orbit crosses the collision ring twice per orbit. Hence a VG satellite spends $5.23X10^{-7}$ of its orbital time in the collision ring, or, since correction has already been made for the slower velocity at the collision ring crossing, there is a likelihood of $5.23x10^{-7}$ that the satellite will be in the collision ring assuming independent random trials.

Hence, given the relative independence of the movements of the O3bi and VG satellites, the probability of a collision between a VG satellite and an O3bi satellite per O3bi satellite transit of the collision ring is the product of the probability that a VG satellite is in the collision ring given that an O3bi satellite is in the collision ring, times the probability that the VG satellite is inside the collision volume of the O3bi satellite when in the collision ring. This probability is then multiplied by the number of times an O3bi satellite transits the ring per year for a probability per year of a collision. Multiplying this figure by 15 yields the probability of a collision between any VG satellite and any O3bi satellite over a nominal constellation lifetime. The Southern VG orbits and collision ring are treated as though they were northern orbits, which would yield identical probabilities.

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[c] The O3bi satellite crosses the collision ring twice per orbit.

Conclusions regarding Collision Probabilities

The probabilities of collision therefore are

Probability a particular VG satellite is in collision ring when an O3bi satellite is in the collision ring	$5.23x10^{-7}$
Probability any of 15 VG satellites is in the collision ring per O3bi satellite ring pass	$7.85x10^{-6}$ or 1 in 127 thousand
Probability a VG satellite, if in the collision ring, being also in the collision volume around the O3bi satellite, per O3bi collision ring transit	$1.10x10^{-7}$ or 1 in 9 million
Number of times one O3bi satellite transits the collision ring per year	3654
Probability of a collision per year per O3bi satellite	$3.16x10^{-9}$
Number of O3bi satellites	16
Probability of a collision per year anywhere within the O3bi constellation	$5.06x10^{-8}$ or 1 chance in 19.8 million
Probability of any collision per 15 years for the whole O3bi constellation	7.59x10-7 or 1 chance in 1.320 million

From this analysis we conclude that the likelihood of a collision between a Virtual Geo satellite and an O3bi satellite is less than on chance in a million over the lifetime of the constellations. This is vanishingly small. Once source quotes that the "*specified level of risk for manned space programs from Apollo through the present has been essentially constant at 0.005 probability of penetration over the lifetime of the space system".*[d] A probability of 0.005 is one chance in 200. Alternatively, assuming the Commission adopts the more conservative proposed benchmark of 0.001 for constellations as a whole as specified in paragraph 26 of the recent *Orbital Debris NPRM*, the risk of collision is still significantly lower than that benchmark.

We have separately demonstrated that there is no risk of collision between the Virtual Geo constellation and the equatorial O3b satellites, since their orbits never intersect with Virtual Geo orbits, but always remain separated by more than 1,300 kilometers. The probabilities we have calculated here concerning collision between the O3b inclined orbit satellites and Virtual Geo satellites are orders of magnitude lower than the level cited above for space debris penetrations for manned operations or the Commission's more stringent recent proposals. We therefore conclude that the risk of collision between Virtual Geo and

[d] V.A Chobotov, Orbital Mechanics, American Institute of Aeronautics and Astronautics, 1991, pg 355.

O3b to be well within acceptable bounds for joint operations in space in their respective orbits, assuming that the O3bi constellation is launched.

Technical Certificate

The undersigned hereby certifies, under penalty of perjury, that I am the technically qualified persons responsible for the preparation of the technical information contained in the foregoing Opposition of New Spectrum Satellite, Ltd and Appendix A, that I am familiar with Part 25 of the Commission's Rules, and that I have either prepared or reviewed the technical information in the foregoing Opposition and found it to be complete and accurate to the best of my knowledge and belief.

*/s/John W. Brosius*___________
John W. Brosius
Acting Chief Technical Officer
New Spectrum Satellite, Ltd

November 23, 2018

CERTIFICATE OF SERVICE

I hereby certify that on this 23rd day of November, 2018, I caused a true and correct copy of the foregoing "Opposition of New Spectrum Satellite, Ltd" to be sent by first class mail, postage prepaid, and email to the following:

Petra A. Vorwig
Senior Legal and Regulatory Counsel
SES Americom, Inc.
1129 20th Street, NW, Suite 1000
Washington, DC 20036
petra.vorwig@ses.com

Suzanne Malloy
Vice President, Regulatory Affairs
O3b Limited
900 17th Street, NW, Suite 300
Washington, DC 20006
suzanne.malloy@ses.com

/*s/ Stephen L. Goodman*

Stephen L. Goodman