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August 10, 2017

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Written *Ex Parte* Presentation

GN Docket No. 14-177, *Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*

Dear Ms. Dortch:

In two recent *ex parte* letters,[1/] the Boeing Company ("Boeing"), EchoStar Satellite Operating Corporation, Hughes Network Systems, LLC, Intelsat Corporation, Inmarsat, Inc., O3b Limited, SES Americom, Inc., and WorldVu Satellites Ltd. d/b/a OneWeb (collectively, the "Satellite Companies") repeated their request to substantially alter the technical rules in this proceeding to further expand satellite rights in the 37/39 GHz band at the expense of Upper Microwave Flexible Use Service ("UMFUS") licensees. To summarize, the Satellite Companies propose that the Commission:

- reduce maximum effective isotropic radiated power ("EIRP") for UMFUS base stations by 10 dB;
- define the conditions under which satellites are permitted to increase their transmit power flux density ("PFD") levels by 12 dB;
- adopt equivalent power flux density ("EPFD") as the measure of satellite downlink interference to UMFUS in the 39 GHz band;

[1/] *See* Letter from Bruce A. Olcott, Counsel to The Boeing Company, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.* (filed June 19, 2017) ("Boeing June *Ex Parte*"); Letter from Audrey L. Allison, Senior Director, Frequency Management Services, The Boeing Company, Jennifer A. Manner, Senior Vice President, Regulatory Affairs, EchoStar Satellite Operating Corporation, Hughes Network Systems, LLC, Giselle Creeser, Director, Regulatory, Inmarsat, Inc., Susan H. Crandall, Intelsat Corporation, Suzanne Malloy, Vice President, Regulatory Affairs, O3b Limited, Petra A. Vorwig, Senior Legal & Regulatory Counsel, SES Americom, Inc., and Mariah Shuman, Senior Director, Regulatory Affairs, WorldVu Satellites Ltd. d/b/a OneWeb, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.* (filed June 13, 2017).

- adopt a revised population coverage limit for fixed satellite service ("FSS") earth stations in the 28 and 37/39 GHz bands;
- remove the prohibition on the operation of satellite end user terminals;
- eliminate the rules limiting FSS operators to three earth stations in any given county (for 28 GHz) or Partial Economic Area ("PEA") (for 37/39 GHz); and
- apply the 70/80/90 GHz band database approach to UMFUS facilities.

These requests, if allowed, will reverse the majority of the Commission's decisions in this proceeding regarding sharing in the 37/39 GHz band and rewrite the rules to favor FSS, disabling features essential to Fifth Generation ("5G") mobile wireless services. As a procedural matter, many of the Satellite Companies' proposals – including the UMFUS base station EIRP limit, the population coverage limit, and the three earth stations per county or PEA limit – are not part of the FNPRM. Therefore, the Commission should not change these decisions.

As ViaSat commented:

> "There is no reason to overturn and rewrite the rules for sharing between satellite and terrestrial mobile wireless services in the 27.5-28.35 GHz and 37.5-40 GHz band segments. It is possible to design, site, and operate an earth station that satisfies the 0.1 percent population coverage threshold adopted in the Order, even in rural areas. And it is possible to deploy such an earth station near fiber. Even in circumstances where that may not be the case, the Commission has provided a number of other ways to authorize earth stations."[2/]

The Commission did seek comment on two issues regarding sharing of the 37/39 GHz band between FSS and UMFUS. Specifically, the Commission sought comment on (1) whether there are any circumstances under which allowing FSS satellites in the 37.5-40 GHz band to operate at a higher PFD level than permitted under the existing rules would be consistent with terrestrial use of the 37.5-40 GHz band[3/] and (2) the possibility of repealing the prohibition on satellite user equipment in the 37.5-40 GHz band.[4/] In the following sections, we respond to some of arguments made by the Satellite Companies on these two issues in the two recent *ex parte* letters. Straight Path urges the Commission to reject the Satellite Companies' proposals and maintain the current PFD limit and gateway station limit for FSS use of the 37/39 GHz band.

As the mobile industry prepares for large scale deployment of fixed and mobile 5G in the 28 and 37/39 GHz bands and the global 5G race heats up, it is important that the Commission act expeditiously to make these bands available for 5G deployment. Any further delay or change of

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2/ ViaSat, Opposition to Petitions for Reconsideration, GN Docket No. 14-177 *et al.*, at i (filed Jan. 31, 2017).

3/ *See Use of Spectrum Bands Above 24 GHz For Mobile Radio Services*, Report and Order and Further Notice of Proposed Rulemaking, FCC 16-89, 31 FCC Rcd. 8014, ¶499 (2016).

4/ *See id.* ¶502.

rules will unnecessarily harm U.S. leadership in 5G and jeopardize the economic benefits that 5G will bring to the American public.[5/]

Increasing Satellite PFD is Inconsistent with Terrestrial Use of the 37.5-40 GHz Band

The 37/39 GHz band is critical for 5G. It accounts for 2.4 gigahertz of the 3.25 gigahertz of exclusively licensed spectrum allocated for 5G in this proceeding. The Commission must ensure that the rules in this band protect 5G services from FSS interference.

Allowing secondary user equipment in the 37/39 GHz band is inconsistent with the primary designation of terrestrial services in this band. The co-primary satellite gateway stations in this band are protected from terrestrial interference, as the rules allocate exclusion zones in which terrestrial operators cannot deploy their base stations. Conversely, the rules should also protect co-primary terrestrial base stations and mobile stations from satellite interference. However, each satellite downlink spot beam creates interference in an area of at least hundreds of square kilometers, making it impossible to protect 5G devices from these secondary transmissions from the satellite to the satellite user equipment. A true secondary service must protect primary services from interference and accept interference from the primary services. Although the so-called secondary use of the 37/39 GHz band by satellite transmission to satellite user equipment will accept interference from the primary 5G services, it cannot protect the primary 5G services from interference it causes. While the need to allow unlimited satellite user equipment and opportunistic access in the 37/39 GHz band is not justified, the impact of such use to 5G systems is clear:

1. The secondary transmissions to satellite user terminals can increase the interference to primary 5G services in this band by ~100x.[6/]
2. While the use of this band by satellite downlink may be "opportunistic," the unpredictable interference will make terrestrial 5G services unreliable.

As Straight Path has shown in previous filings,[7/] a single satellite transmitting at the current PFD limit of -117 dBW/m^2/MHz can cause:

[5/] *See The 5G economy: How 5G technology will contribute to the global economy*, IHS ECONOMICS & IHS TECHNOLOGY (Jan. 2017), https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf ("In 2035, 5G will enable $12.3 trillion of global economic output. . . The global 5G value chain will generate $3.5 trillion in output and support 22 million jobs in 2035.").

[6/] *See* Letter from Davidi Jonas, President and CEO, Straight Path Communications Inc., and Jerry Pi, Chief Technology Officer, Straight Path Communications Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at 4 (filed June 21, 2017) ("Straight Path June 2017 *Ex Parte*").

[7/] *See* Letter from Davidi Jonas, President and CEO, Straight Path Communications Inc., and Jerry Pi, Chief Technology Officer, Straight Path Communications Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at 2-10 (filed May 17, 2017) ("Straight Path May 2017 *Ex Parte*"); *see also* Letter from Davidi Jonas, President and CEO, Straight Path Communications Inc., and Jerry Pi, Chief Technology Officer, Straight Path Communications Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at 8, 20 (filed Dec. 20, 2016) ("Straight Path December 2016 *Ex Parte*").

- up to 2 dB rise over the noise floor, if satellite interference impinges directly upon 5G BS receivers with the broadside of antenna panels pointing at horizon;
- up to a 0.75 dB rise over the noise floor, if satellite interference is reflected by typical roofs with 8 dB reflection loss and then impinges upon 5G BS receivers at low elevation angle; and
- up to a 3.5 dB rise over the noise floor at 5G BS receivers, if satellite interference is reflected by metal roofs with no loss and then impinges upon 5G BS receivers at low elevation angle.

With the current satellite PFD limit, roof reflection alone in urban areas can increase the noise floor at 5G base station receivers by more than 0.5 dB more than 0.1% of the time in areas with more than 100 residential houses per km^2. The probability increases proportionally to the residential house density, the number of satellites transmitting, and the increased spatial utilization / MIMO order of 5G services.

The impact of a 12 -dB boosted PFD can cripple 5G base station receivers in many cases. A single satellite transmitting at the increased PFD limit of -105 $dBW/m^2/MHz$ can cause:

- up to an 11 dB rise over the noise floor, if satellite interference impinges directly upon 5G BS receivers with the broadside of antenna panels pointing at horizon;
- up to a 6 dB rise over the noise floor at 5G BS receivers, if satellite interference is reflected by typical roofs with 8 dB reflection loss and then impinges upon 5G BS receivers at low elevation angle; and
- up to a 13 dB rise over the noise floor, if satellite interference is reflected by metal roofs with no loss and then impinges upon 5G BS receivers at low elevation angle.

With the increased satellite PFD limit, roof reflection alone in urban areas can increase the noise floor at 5G base station receivers by more than 0.5 dB more than 0.4% of the time in areas with more than 100 residential houses per km^2. The probability increases proportionally to the residential house density, the number of satellites transmitting, and the increased spatial utilization / MIMO order of 5G services.

This set of data is only for 5G base station receivers with a 16×16 element antenna array and the antenna panel and beams pointing horizontally. Satellite interference with -117 $dBW/m^2/MHz$ PFD will have a much more significant impact to deployments, such as in-ground base stations with antenna panel or beams pointing upward,[8/] 5G connectivity to drones that fly up to 400 feet above ground,[9/] and airborne 5G base stations by drones.[10/] An increase of the PFD

[8/] *See Swisscom and Ericsson Plant LTE Small Cells Underground*, ERICSSON (Mar. 9, 2016), https://www.ericsson.com/en/news/2016/3/swisscom-and-ericsson-plant-lte-small-cells-underground; *see also Innovation Award for Kathrein Street Connect*, KATHREIN (Sept. 28, 2016), https://www.kathrein.com/en/newsroom/news/announcement/news/innovation-award-for-kathrein-street-connect/.

[9/] *See* Monica Alleven, *Qualcomm Shares LTE Drone Trial Results*, FIERCEWIRELESS (May 4, 2017, 12:14 PM), http://www.fiercewireless.com/wireless/qualcomm-shares-lte-drone-trial-results.

limit to -105 dBW/m^2/MHz will generally disable such deployments and services for 5G. This set of studies also only evaluates line-of-sight and reflections of satellite interference from roofs. In a real deployment, the scattering effect of millimeter waves is significant for most of the terrain features and landscape. For example, trees with heavy foliage scatter millimeter-wave frequencies. A study shows that scattering accounts for 60%-90% of the millimeter wave attenuation through trees.[11/] Snow-covered terrain can also exhibit significant scattering of millimeter-wave signals.[12/] Scattering redistributes the interference power to other directions, which can directly impinge upon the main lobes of 5G base station, fixed customer premises equipment ("CPE"), and mobile station receivers. This effect is not adequately modeled in Boeing's analysis. In the following analysis, we show that the scattering by the surrounding environment alone can be strong enough to significantly interfere with 5G base station and fixed CPE receivers.

Scattering is a Strong Contributor of Satellite Interference to 5G Receivers

Scattering by different terrain features is well studied for millimeter-wave radars. Due to the fact that in radar, the transmitter and the receiver are often collocated, most of the measurements for a scattering coefficient are obtained along the opposite direction of the incident waves, *i.e.*, backscattering. Table 1 shows the backscattering coefficients of common terrain features for 35 GHz with incident angle between 0° and 45°. The incident angle of 0° corresponds to satellite interference at 90° elevation angle and the incident angle of 45° corresponds to satellite interference at 45° elevation angle.

Table 1. Backscattering coefficient of terrain features at 35 GHz with incident angle between 0° and 45°

Terrain features	**Backscattering coefficient**
Foliage [13/]	-9 dB ~ -6 dB
Snow [14/]	-7 dB ~ 0 dB

10/ *See* David Nield, *Google Is Testing a Superfast 5G Network Powered by Drones*, TECHRADAR (Jan. 30, 2016), http://www.techradar.com/news/internet/google-is-testing-a-superfast-5g-network-powered-by-drones-1314082.

11/ *See* Fawwaz T. Ulaby, Thomas F. Haddock & Yasuo Kuga, *Measurement and modeling of millimeter-wave scattering from tree foliage*, 25 RADIO SCIENCE 193, 193-03 (1990).

12/ *See* Yasuo Kuga, Fawwaz T. Ulaby, Thomas F. Haddock, & Roger D. DeRoo, *Millimeter-wave radar scattering from snow 1. Radiative transfer model*, 26 RADIO SCIENCE 329, 329–41 (1991); Fawwaz T. Ulaby, Thomas F. Haddock, Richard T. Austin, & Yasuo Kuga, *Millimeter-wave radar scattering from snow: 2. Comparison of theory with experimental observations*, 26 RADIO SCIENCE 343, 343-51 (1991).

13/ *See* Fawwaz T. Ulaby, Thomas F. Haddock & Yasuo Kuga, *supra* note 10, at Figure 9(a) (showing the incident angle between 0° and 45°).

14/ *See* Yasuo Kuga, Fawwaz T. Ulaby, Thomas F. Haddock, & Roger D. DeRoo, *supra* note 11, at Figure 5 (showing the incident angle between 0° and 45° and liquid water content by volume of 0% and 1%).

Grass [15/]	-5 dB ~ 0 dB

For large areas with surfaces that are sufficiently rough and/or large or a collection of objects with surface orientations that are sufficiently random, the backscattering coefficient can be used as a reasonable estimate of the bistatic scattering coefficient with the same incident angle but a different scattering angle towards a 5G receiver. Based on these measurement data, we assume the average scattering coefficient of the surrounding environment ranges from -9 dB to 0 dB. An average scattering coefficient of -9 dB corresponds to a highly absorptive environment with 80% of the incident satellite interference absorbed, and an average scattering coefficient of 0 dB corresponds to a highly scattering environment with all incident satellite interference scattered.

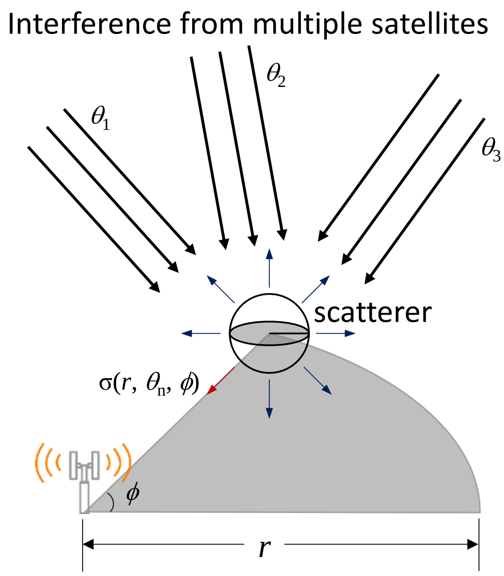

Figure 1. Impact of scattered satellite interference to 5G receivers

As shown in Figure 1, scattering changes incident parallel waves to scattered spherical waves. The total interference due to scattering of satellite interference can be represented as follows:

$$P_{\text{sat\_intf}} = \int_0^{2\pi} \int_{r_{min}}^{r_{max}} G_{rx}(\phi) \cdot \left(\frac{\lambda}{4\pi r}\right)^2 \cdot P \cdot \sum_{n=1}^{N} \sigma(r, \theta_n, \phi) \cdot r dr d\phi \qquad (1)$$

where $G_{rx}(\phi)$ is the receiver antenna gain along azimuth angle ϕ; N is the number of interfering satellites; P is the satellite PFD limit; θ_n is the incident angle of the n-th interfering satellite; $\sigma(r, \theta_n, \phi)$ is the bistatic scattering coefficient of the scatter at location (r, ϕ) with incident

[15/] *See* Thomas F. Haddock & Fawwaz T. Ulaby, *140-GHz Scatterometer System And Measurements Of Terrain*, 28 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING 492, Figure 6, (1990) (showing the incident angle between 0° and 45°).

angle θ_n and scattering angle ϕ. The term $P \cdot \sum_{n=1}^{N} \sigma(r, \theta_n, \phi) \cdot rdrd\phi$ represents the total scattered power towards the receiver at location $(0, 0)$ from a scatterer at location (r, ϕ) with a surface area of $rdrd\phi$. The total received scattered satellite interference, $P_{\text{sat\_intf}}$, can therefore be obtained by integrating across the area surrounding the receiver. Apparently, $P_{\text{sat\_intf}}$ is a random variable, the value of which depends on the bistatic scattering coefficients of the terrain around the receiver, the receiver antenna pattern, and the time and location varying satellite interference. We assume terrain scattering coefficients are sufficiently random across the deployment area and are uncorrelated with incident angles of the satellite interference and the location and orientation of the 5G receiver. The average level of received scattered satellite interference can be represented as follows:

$$\begin{aligned} E\left[P_{\text{sat\_intf}}\right] &= E\left[\int_0^{2\pi}\int_{r_{min}}^{r_{max}} G_{rx}(\phi) \cdot \left(\frac{\lambda}{4\pi r}\right)^2 \cdot P \cdot \sum_{n=1}^{N} \sigma(r, \theta_n, \phi) \cdot rdrd\phi\right] \\ &= G_{EL} \cdot \left(\frac{\lambda}{4\pi}\right)^2 \cdot N \cdot P \cdot \bar{\sigma} \cdot ln\frac{r_{max}}{r_{min}} = N \cdot \rho_{\text{sat\_intf}} \end{aligned} \qquad (2)$$

where G_{EL} is antenna gain in elevation, and $\bar{\sigma}$ is the average scattering coefficient across all scatters, incident angles, and scattering angles for the area surrounding the 5G receiver. The term $\rho_{\text{sat\_intf}} = G_{EL} \cdot \left(\frac{\lambda}{4\pi}\right)^2 \cdot P \cdot \bar{\sigma} \cdot ln\frac{r_{max}}{r_{min}}$ is the average interference power from a single satellite interference.

It is also reasonable to assume all scattered interference from the same satellite will have sufficiently random phases, amplitudes, and modulation symbols such that the total received scattered interference at a 5G receiver from a single satellite will manifest as a complex Gaussian random variable in baseband. Therefore, the power of the received scattered interference from a single satellite follows a Chi-squared distribution[16/] with 2 degrees of freedom. We further assume the interference from different satellites are independent and with the same strength. As a result, *the total power of received scattered interference from N satellites – normalized by* $\rho_{sat\_intf}/2$ *– follows a Chi-squared distribution with* $2N$ *degree of freedom.* To put it simply, the distribution of the satellite interference power can be characterized as follows:

$$\frac{2P_{\text{sat\_intf}}}{\rho_{\text{sat\_intf}}} \sim \chi^2_{2N} \qquad (3)$$

Equation (3) gives a complete characterization of the distribution of the scattered satellite interference power at a 5G receiver as a function of the PFD limit, the number of interfering satellites, and the average scattering coefficient of the environment.

As Straight Path suggested – and as generally accepted as a threshold for satellite interference – a rise of the noise floor caused by satellite interference at 5G receivers should not

16/ *See Chi-squared Distribution*, WIKIPEDIA, https://en.wikipedia.org/wiki/Chi-squared_distribution (last visited July 28, 2017).

exceed 0.5 dB. As 5G networks are deployed to provide fixed and mobile broadband services, the reliability and availability provision of the services are typically 98% or 99%, with the exception of Ultra Reliable Low Latency Connectivity ("URLLC") services that require much higher reliability. Preferably, a rise of the noise floor caused by satellite interference should be kept below 0.5 dB at all times. If an occasional violation of the threshold is needed to accommodate the random nature of the satellite interference, Straight Path suggests that the probability of such event should not exceed 0.5% for 99% of the 5G cells.

From Equation (3), it is straightforward to calculate the probability that the total received scattered satellite interference, $P_{\text{sat\_intf}}$, exceeds a certain interference power threshold, P_{th}, as follows:

$$\begin{aligned} P\{P_{\text{sat\_intf}} > P_{\text{th}}\} &= P\left\{\frac{2P_{\text{sat\_intf}}}{\rho_{\text{sat\_intf}}} > \frac{2P_{\text{th}}}{\rho_{\text{sat\_intf}}}\right\} = \frac{1}{(N-1)!}\Gamma\left(N, \frac{P_{\text{th}}}{\rho_{\text{sat\_intf}}}\right) \\ &= \exp\left\{-\frac{P_{\text{th}}}{\rho_{\text{sat\_intf}}}\right\} \cdot \sum_{n=0}^{N-1} \frac{1}{n!}\left(\frac{P_{\text{th}}}{\rho_{\text{sat\_intf}}}\right)^n \end{aligned} \quad (4)$$

where $\Gamma(s,x) = \int_x^\infty t^{s-1}e^{-t}dt$ is the upper incomplete Gamma function.[17/]

With typical assumptions of $G_{EL} = 18$ dB, $P = -117$ dBW/m^2/MHz, $r_{min} = 30$ m, $r_{max} = 3000$ m, 5 dB base station receiver noise figure, the average rise of the noise floor caused by scattered satellite interference is shown in Figure 2. Note that these results are obtained assuming sufficient averaging due to the large number of random scatterers around 5G base station or fixed CPE receivers. In real deployments, dominant scatterers may exist in close proximity to some 5G receivers, leading to a higher rise of the noise floor. The probability of such an event will depend on the terrain and landscape in each deployment and how close the 5G receivers are to these dominant scatters. One example of such a scatterer is a roof, which we provided quantitative estimates in our previous filings.[18/]

Nevertheless, the data shown in Figure 2 give us a reasonable, albeit optimistic, view of the distribution of a rise of the noise floor due to satellite interference at 5G base station and fixed CPE receivers. With a single satellite interferer generating ground PFD at -117 dBW/m^2/MHz, the probability of rise of noise floor exceeding 0.5 dB is generally small. Even for highly scattering environment with $\bar{\sigma} = 0$ dB (*i.e.*, all incident power scattered, nothing absorbed), the probability of a rise of the noise floor exceeding 0.5 dB is only 0.03%. However, the probability of a rise of the noise floor exceeding 0.5 dB increases rapidly with increasing satellite PFD. With satellite PFD at -105 dBW/m^2/MHz, a single satellite will cause the probability of a rise of the noise floor exceeding 0.5 dB to increase to 1.6% even for an highly absorbing environment with $\bar{\sigma} = -9$ dB (*i.e.*, only 20% of the incident power scattered with the

[17/] *See Incomplete Gamma Function*, WIKIPEDIA, https://en.wikipedia.org/wiki/Incomplete_gamma_function (last visited July 28, 2017).

[18/] *See* Straight Path May 2017 *Ex Parte* at 2-10.

rest absorbed). The results in Figure 2 also show that the probability of a rise of the noise floor exceeding 0.5 dB increases with the number of interfering satellites. For example, in the highly scattering environment shown in Figure 2(d), the probability of a rise of the noise floor exceeding 0.5 dB increases from 0.03% to 87% as the number of interfering satellites increases from 1 to 12.

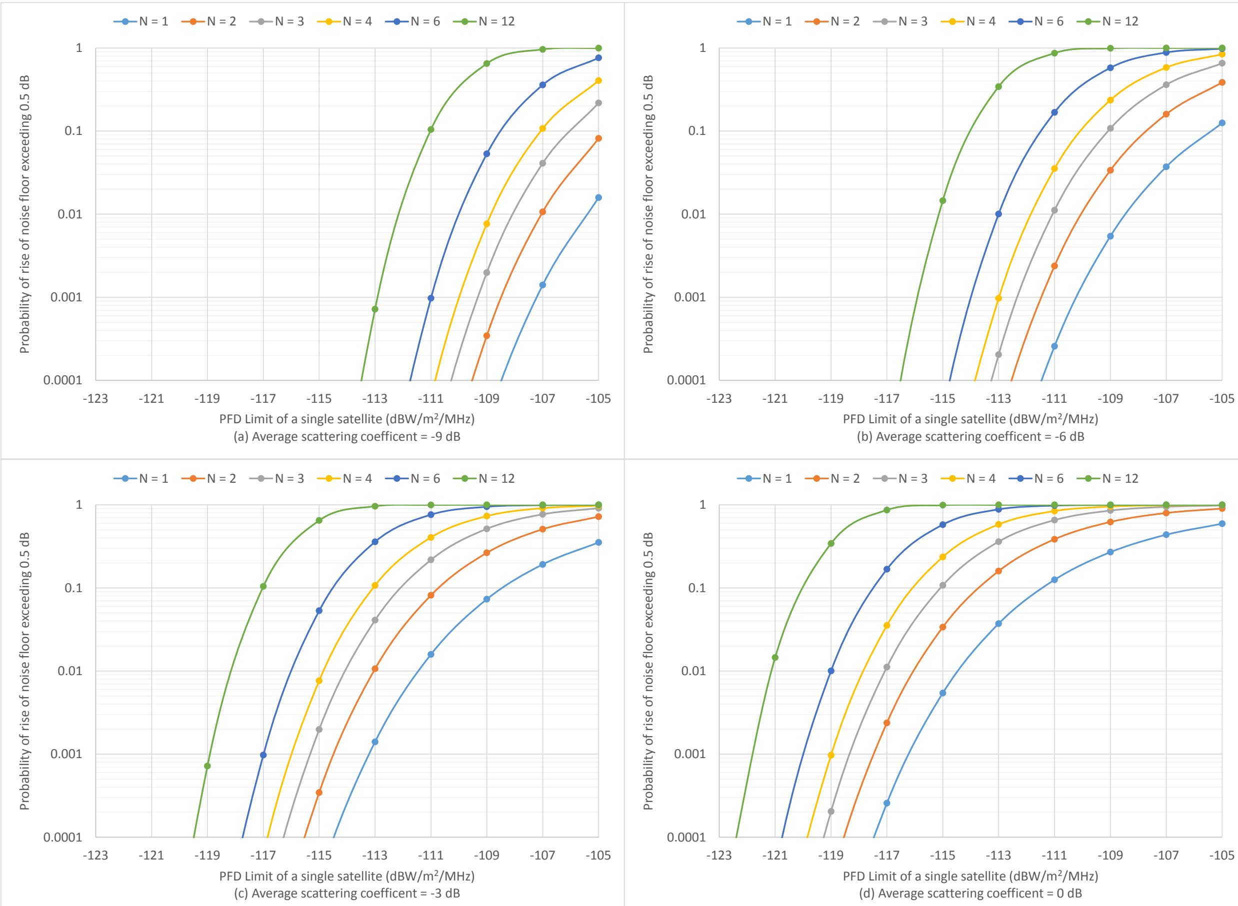

Figure 2. Probability of rise of noise floor exceeding 0.5 dB at 5G base station and CPE receiver due to satellite interference

This analysis also demonstrates that the EPFD as proposed by Boeing is not an acceptable approach in measuring satellite interference to 5G services. The EPFD measure makes restrictive assumptions on victim receivers' antenna patterns and largely ignores the impact of scattered interference.

From Equation (2) – (4) and the data presented in Figure 2, one may assume that there may be some room to allow higher PFD limit of satellite downlink without exceeding a rise of the noise floor by 0.5 dB for more than 0.5% probability. However, there is no sufficient data or agreed upon methodology at this point to determine the distribution of the average scattering coefficients of the environment for 5G deployment, making it difficult to accurately characterize the overall impact of satellite interference to the overall 5G deployment. For example, even if the total averaged scattering coefficient across the entire country may fall around -6 ~ -3 dB, a PFD

limit drawn upon such assumptions may greatly impact areas where the average scattering coefficient exceeds the assume values, leading to capacity and coverage loss across large 5G service areas. Moreover, this study only characterizes a rise of the noise floor due to scattered satellite interference to 5G receivers with antenna panels and beams pointing horizontally. Other 5G use cases with upward beams, including 5G connectivity for users in high rise buildings, in-ground 5G base stations, 5G connectivity for drones, and airborne 5G base stations by drones, will be more severely affected by direct satellite interference.

In summary, Straight Path has provided analysis for satellite downlink interference to 5G receivers in the following three scenarios:

- direct interference from satellite to 5G receivers with upward beams;[19/]
- roof reflection of satellite interference to 5G receivers pointing horizontally;[20/] and
- scattered satellite interference to 5G receivers pointing horizontally.[21/]

In each case, we have observed the severe interference impact for PFD limit higher than -117 dBW/m^2/MHz. Therefore, the Commission should maintain the current PFD limit of -117 dBW/m^2/MHz as a limit on the aggregated PFD from all transmitting satellites. If there is sufficient interest in further studying sharing between FSS and UMFUS in the V-band, the Commission should address that issue in a separate proceeding covering the entire V-band.

Boeing's Analysis Does Not Adequately Model Satellite Interference

In its recent filing, Boeing contests Straight Path's observation that the OSM Buildings data are incomplete and not suitable for ray-tracing based on evaluation of satellite interference to 5G base stations and user terminals. Boeing argues that it "ensured that the OSM Building data was accurate in each of the locations that was used in its analysis."[22/] We then examined the OSM Buildings data in two locations that were used in Boeing's analysis.

Table 2. Selected areas in Boeing's satellite interference study

Metro Area	**Environment**	**Neighborhood**	**Building Density** (#/km^2)
Chicago	Suburban	Evanston	90
Houston	Suburban	Lawndale	520

19/ *See* Straight Path December 2016 *Ex Parte* at 3-12.

20/ *See* Straight Path December 2016 *Ex Parte* at 14-18; Straight Path May 2017 *Ex Parte* at 4-10.

21/ *See* Straight Path May 2017 *Ex Parte* at 5-9.

22/ Boeing June *ex parte* at 7.

We compared the OSM Buildings data against Google Maps in the two locations listed in Table 2. These two locations are among the 22 locations that Boeing conducted its interference analysis.[23/] The comparison between the two locations is shown in Figure 3 and Figure 4.

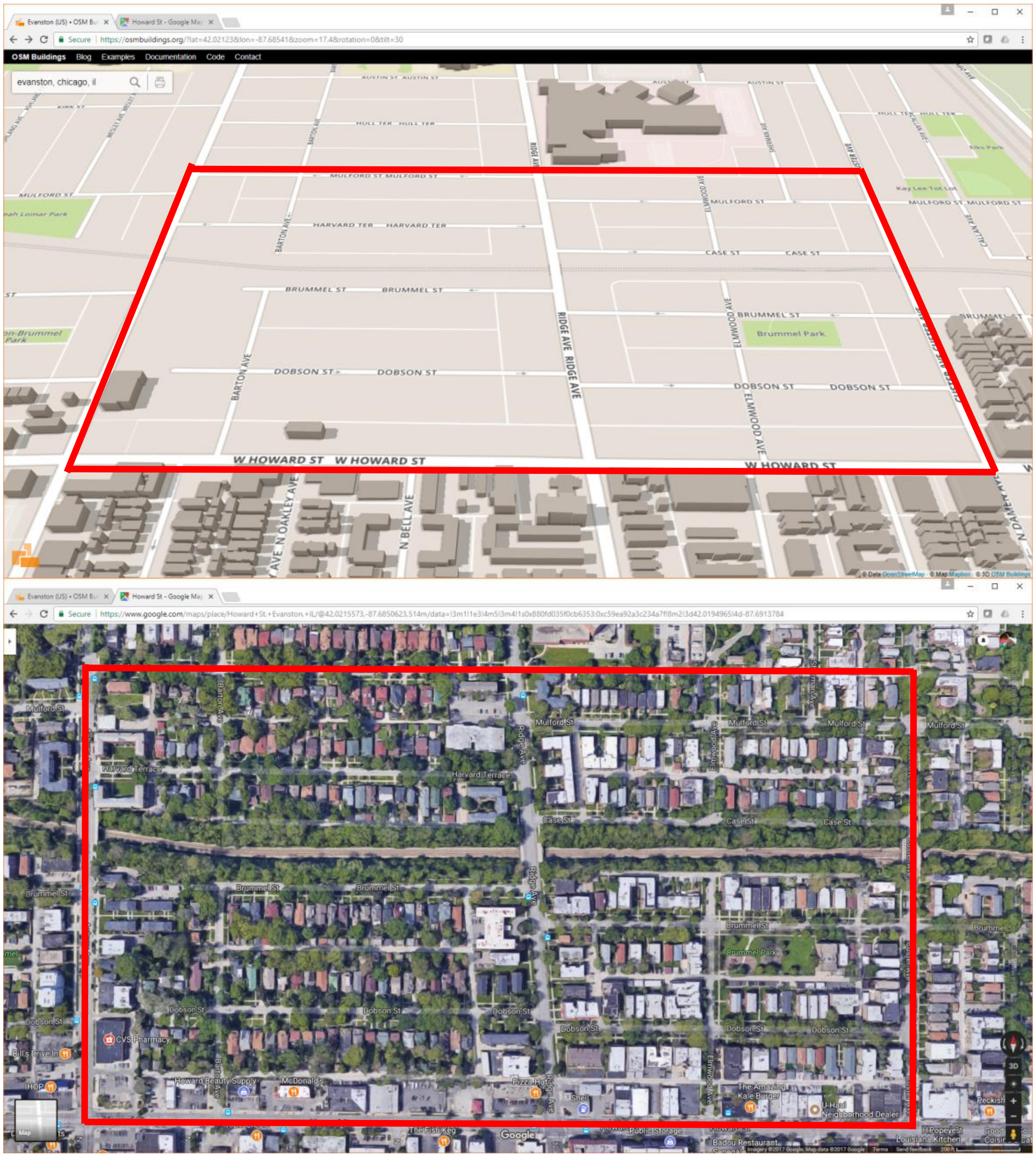

Figure 3. OSM Buildings vs. Google Maps data comparison in Evanston, Illinois

Figure 3 shows the comparison between OSM Buildings data and Google Maps data for an area east of Asbury Avenue, south of Mulford Street, west of Custer Avenue, and north of

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23/ *See id.* at 8, Table 1.

Howard Street in Evanston, Illinois. OSM Buildings shows two buildings in this area. Google Maps shows more than 200.

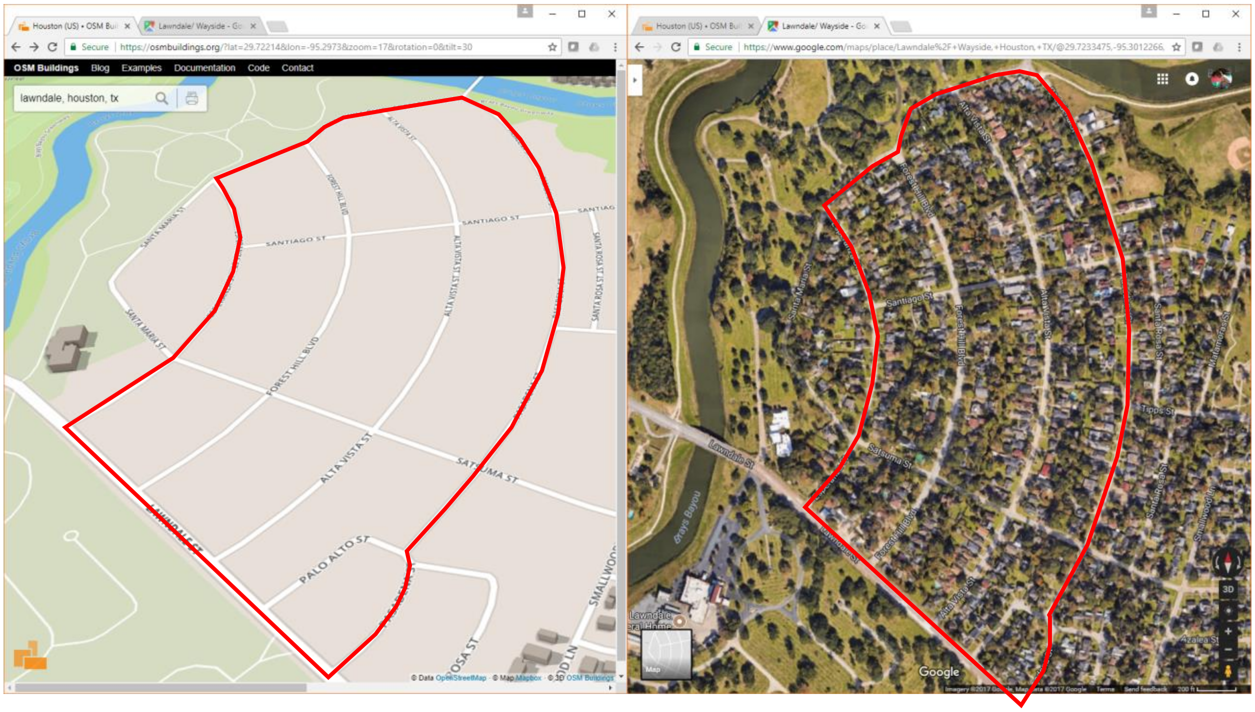

Figure 4. OSM Buildings vs. Google Maps data comparison in Lawndale, Houston

Figure 4 shows the comparison between OSM Buildings data and Google Maps data for an area east of Esperanza Street, south of Santa Maria Street, west of Pasadena Street, and north of Lawndale Street in Houston, TX. OSM Buildings show 0 buildings in this area. Google Maps shows more than 200.

In addition, it is not clear how large a surrounding area is and how scattering of satellite interference by terrain features in the surrounding area is modeled in Boeing's simulation. As interference from each interfering satellite typically covers the entire surrounding area of the victim 5G receiver, the scattering of satellite interference due to terrain features including grass, foliage, and pavement cannot be ignored. In fact, buildings only account for a small land area even in suburban and urban areas. The contribution from scattered interference by terrain features can be significantly bigger than that by buildings.

In contrast, equations (2) – (4) in our analysis provide a general representation of the individual and total interference power distribution for satellite interference due to scattering. The results in Figure 2 show that the scattered satellite interference is significant and must be taken into account in evaluating the satellite interference to 5G receivers.

The Satellite Companies Have Failed to Demonstrate the Need for User Equipment in the 37.5-40 GHz Band

The satellite broadband business today is built upon free access to enormous amount of spectrum. As acknowledged by SIA, the total amount of spectrum allocated to satellite use has reached tens of gigahertz.[24/] However, due to the poor spectrum utilization of satellite communications in comparison with terrestrial wireless communications, the satellite industry is only serving 2 million subscribers in the United States. In comparison, the terrestrial wireless industry has served 375 million subscribers with the same or less amount of spectrum, and has achieved better coverage and higher capacity. Moreover, a large number of rural broadband providers have built their access networks entirely with unlicensed spectrum.[25/] These providers have managed to serve more subscribers than the satellite industry, which is equipped with tens of gigahertz of spectrum.[26/]

The Satellite Companies claim that by placing satellites on different orbits they can achieve thousands of satellites in the same frequency with each satellite providing hundreds of spot beams. Boeing, however, also requests another 10 gigahertz of spectrum for its new satellite system, while the C, X, Ku and Ka bands that have already been allocated for satellite use are still far from being fully utilized. The Commission must re-examine the vast amount of spectrum already allocated to the satellite industry and determine why the spectrum utilization in bands where FSS is the primary service has been so low while the satellite industry continues to request additional spectrum. If it takes tens of gigahertz of spectrum for the satellite industry to serve 2 million subscribers, allocating additional spectrum to compensate for the extremely low spectrum utilization is not the solution. If the satellite industry believes it can achieve better spectrum utilization and serve more Americans, it should demonstrate that in the tens of gigahertz of spectrum that is already allocated but is only utilized to serve 2 million subscribers. The satellite industry is already allocated the 40 – 42 GHz band. This band has been laying fallow for more than 15 years. As a minimum, the satellite industry should demonstrate that it can put the 40 – 42 GHz band to productive use before requesting additional rights in a band in which 5G deployment is imminent.

[24/] *See* Letter from Tom Stroup, President, Satellite Industry Association, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at Attachment (filed April 17, 2017) (showing that 28 gigahertz of spectrum between 24 GHz and 86 GHz is allocated for FSS/MSS use in the U.S.); Letter from Scott K. Bergmann, Vice President, Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, Attachment at 2 (filed Mar. 30, 2017) (showing that 16.5 gigahertz of spectrum is allocated to satellite).

[25/] *See Small Internet Service Providers Applaud FCC Action to Promote Broadband Build-Out in Under-Served Areas*, WISPA (May 25, 2016), http://www.wispa.org/News/wispa_news_05-25-16_FCC_CAF_II (noting that the importance of unlicensed spectrum is "to connect millions of rural Americans").

[26/] *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*, 2016 Broadband Progress Report, GN Docket 15-191, at Appendix F, note 3 (rel. Jan. 29, 2016) ("2016 Broadband Progress Report") ("Considering all residential customers in the Form 477 data, as of December 31, 2014, there are 1.467 million subscribers to a satellite service compared to 87.385 million subscribers to fixed terrestrial subscribers.").

If the satellite industry desires opportunistic use of free spectrum, this need can be better met by unlicensed spectrum or shared spectrum, which the current rules provide. Seven gigahertz of bandwidth has been provisioned for unlicensed access in the 64–71 GHz band. The average atmospheric absorption in this band is around 0.2–1 dB/km, which lends itself well for satellite communication. In searching for opportunistic use of free spectrum, the cellular industry has been using Wi-Fi in the 2.4 GHz band and 5 GHz band for years. The recent development of LTE-U and LAA further expanded the ability for the terrestrial wireless industry to utilize the unlicensed bands to opportunistically increase capacity. There is no reason why satellite industry cannot do the same. With more than 7 gigahertz of unlicensed band available for opportunity access, there is no need to allow opportunistic access of the 37/39 GHz band where satellite industry has no practical mechanism to avoid the interference caused by the *secondary* satellite downlink transmissions (from satellite to user equipment) to *primary* 5G uses.

The Satellite Companies Have Not Provided Broadband Service to All Americans and Cannot Provide Broadband Services to All Americans

In many filings, Boeing and the other Satellite Companies repeatedly claim that satellite broadband can provide broadband services to *all* Americans. However, history and facts belie that claim. Radiating radiofrequency ("RF") power over the entire country does not equate to broadband connections for all Americans. After more than four decades of trying with multi-gigahertz of spectrum occupied, satellite communication is barely serving 2 million subscribers in a nation with 320 million people,[27/] a far cry from the claim of serving *all* Americans. The high cost, limited capacity, and extremely poor spectral inefficiency has limited the use of satellite communication to niche markets. In the 2016 Broadband Progress Report, the Commission finds that "no satellite broadband provider offers residential service meeting our fixed speed benchmark of 25 Mbps/3 Mbps."[28/] The facts over the past 4 decades prove more than 98% of the American households do not need, do not want, cannot get, or cannot afford the services provided by satellite communication.

Facts and data also belie another claim by the satellite industry regarding rural broadband. Satellite Companies claim that satellite broadband is crucial in connecting Americans in rural areas and bridging the broadband divide. Actual data on satellite broadband and rural broadband shows otherwise. *First*, most of the satellite broadband connections are in urban and suburban areas. Throughout the course of this proceeding, ViaSat has clarified that "satellite broadband service is not focused on rural areas"[29/] and "most of its customers are located in or near populated areas."[30/] *Second*, most of the rural broadband connections are not provided by satellite broadband. A survey from the NTCA – The Rural Broadband Association found that among the "more than 128 rural telecom and cable companies" that were surveyed by the NTCA,

27/ In comparison, with similar or less amount of spectrum, mobile communication is now serving more than 375 million subscribers in the U.S.

28/ *See* 2016 Broadband Progress Report at ¶ 48.

29/ *See* Reply Comments of ViaSat, Inc. GN Docket No. 14-177, *et al.*, at 5 (filed Feb. 24, 2017).

30/ *See* Opposition of ViaSat, Inc., GN Docket No. 14-177, *et al.*, at 5 (filed Jan. 31, 2017).

"satellite was cited by less than a fraction of 1 percent of respondents"[31/] as the technology for broadband services. *Third*, the Organisation for Economic Co-operation and Development's ("OECD") Broadband Portal provides data shows that satellite accounts for a mere 0.6% of the fixed broadband connections in OECD countries.[32/] Therefore, the data shows that the satellite industry's minimal spectrum utilization and capacity severely limits its ability to provide broadband to mass markets.

The mobile industry's significant progresses in the past few years show that millimeter-wave bands can achieve wide area coverage and gigabit mobility. Samsung demonstrated gigabit data rate with vehicular speed at more than 100 kmph as early as 2014.[33/] Ericsson and Verizon further pushed the envelope in its recent demonstration with download speed of 6.4 Gbps in a vehicle travelling at 60 mph (100 kmph) and very low latency that enables the driver to operate the car while wearing a set of virtual reality glasses, relying solely on video captured from a camera on the hood of the car.[34/] Both Verizon[35/] and AT&T[36/] have launched field trials of fixed 5G for business and residential broadband access. Extensive channel measurement campaigns have been conducted and have confirmed the viability of millimeter-wave communication in rural areas.[37/] These facts directly rebut Boeing's assertion that millimeter-wave 5G systems will only be deployed for cells with radii 200 meters or less.[38/]

31/ *See* Jeff Moore, *NTCA: More rural broadband customers are receiving FTTH than other broadband technologies*, FIERCEINSTALLER (June 23, 2015), http://www.fiercetelecom.com/installer/ntca-more-rural-broadband-customers-are-receiving-ftth-than-other-broadband-technologies.

32/ *See OECD Broadband Portal*, ORGANISATION FOR ECONOMIC CO-OPERATION & DEVELOPMENT, Table 1.3, www.oecd.org/sti/broadband/oecdbroadbandportal.htm (last updated July 7, 2017).

33/ *Samsung 5G Vision*, SAMSUNG, http://www.samsung.com/global/business/networks/insights/5g.html.

34/ *See* Corinne Reichert, *Ericsson trials Verizon 5G and VR at Indianapolis 500*, ZDNET (May 23, 2017), http://www.zdnet.com/article/ericsson-trials-verizon-5g-and-vr-at-indianapolis-500/.

35/ *See Verizon Announces 5G Customer Trials in 11 Cities with 5G Forum Partners*, WIRELESS WEEK (Feb. 22, 2017, 9:01 AM), https://www.wirelessweek.com/news/2017/02/verizon-announces-5g-customer-trials-11-cities-5g-forum-partners.

36/ *See AT&T Kicks Off 5G-Powered DirecTV Now Trial*, BROADCASTING & CABLE (June 27, 2017, 11:42 AM), http://www.broadcastingcable.com/news/technology/att-kicks-5g-powered-directv-now-trial/166830.

37/ Amy Nordrum, *Millimeter Waves Travel More Than 10 Kilometers in Rural Virginia 5G Experiment*, IEEE SPECTRUM (Nov. 7, 2016), http://spectrum.ieee.org/tech-talk/telecom/wireless/millimeter-waves-travel-more-than-10-kilometers-in-rural-virginia.

38/ Nevertheless, Boeing believes millimeter waves can travel thousands of kilometers if used for satellite downlink communication in the same band.

In contrast, it has been more than a year since Boeing submitted its application for its satellite broadband system that requires 10 gigahertz of bandwidth and almost 3,000 satellites.[39/] No technology or development progress on the satellite broadband system has been reported, and no partnership with an actual satellite broadband operator has been announced. Boeing has not demonstrated any business commitment or plan to take on this business endeavor. Given that Boeing has never served as a satellite broadband service provider, this effort – if realized – will be a significant departure from its current business. There is no evidence that Boeing's application differs from past satellite broadband system applications with hyperbolic goals and little action.[40/]

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As the U.S. broadband industry gears up for 5G deployment, the Commission must retain the rules adopted in this proceeding and make 28, 37, and 39 GHz spectrum available for 5G services expeditiously. The Commission must reject the Satellite Companies' repeated requests to further expand satellite rights in the 37/39 GHz band to the detriment of 5G deployment in this band. Instead, the Commission may revisit the sharing issue in a separate proceeding that addresses sharing of the entire V-band, including how to increase utilization of the 37/39 GHz band for FSS and how to increase utilization of the 40 – 42 GHz band for 5G services.

Pursuant to Section 1.106 of the Commission's rules, a copy of this letter has been filed in the record of the above referenced-proceeding.

Respectfully submitted,

/s/ Davidi Jonas

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39/ *See* The Boeing Company, Application for Authority to Launch and Operate a Non-Geostationary Low Earth Orbit Satellite System in the Fixed Satellite Service, IBFS File No. SAT-LOA-20160622-00058 (filed June 22, 2016).

40/ *See* Letter from Scott K. Bergmann, Vice President, Regulatory Affairs, CTIA, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177 *et al.*, at 7-8 (filed July 7, 2016) ("Satellite companies have a long history of filing speculative applications that ultimately fail to bear fruit.").