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

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|---|---|---|
| In the Matter of | ) | |
| | ) | |
| **VIASAT, INC.** | ) | Call Sign: S2985 |
| | ) | |
| Petition for Declaratory Ruling Granting Access to the U.S. for a Non-U.S.-Licensed Nongeostationary Orbit Satellite Network | ) | File No. SAT-PDR-20161115-00120 |

## COMMENTS OF SPACE EXPLORATION TECHNOLOGIES CORP.

Space Exploration Technologies Corp. ("SpaceX") hereby comments on the petition filed by ViaSat, Inc. for authority to serve the U.S. market with its proposed non-geostationary satellite orbit ("NGSO") system providing Fixed-Satellite Service ("FSS") in the Ku and Ka bands. The proposed system would consist of 24 satellites evenly divided across three orbital planes, at an altitude of 8,200 km using Ku and Ka band spectrum.[1] ViaSat proposes to use extremely large "footprint coverage" beams to transmit and receive control signals as well as narrow steerable service beams that may be redirected anywhere within that footprint.[2] As depicted in ViaSat's technical appendix, each of these footprints is significantly larger than the entirety of North America.[3] ViaSat's use of such large

1 *See Petition for Declaratory Ruling Granting Access to the U.S. for a Non-U.S.-Licensed Nongeostationary Orbit Satellite Network*, IBFS File No. SAT-PDR-20161115-00120, at 3-4 (Nov. 15, 2016).

2 *Id.*, Attachment A at 2.

3 *Id.* at 3.

coverage areas will greatly complicate equitable spectrum sharing between NGSO systems in these bands, and reduce spectral efficiency.

In addition, due to ViaSat's proposed operational altitude, its uplink beams are likely to cause significant interference to LEO satellites whenever a LEO satellite passes through a ViaSat earth station's main beam or sidelobe. This would effectively prevent a LEO system with steerable beams (like SpaceX's) from working around the in-line event, forcing the default arrangement of band segmentation. The Commission should ensure that all system types under consideration in this processing round will be able to equitably share spectrum with one another while making efficient use of this scarce resource. If necessary, the Commission should impose license conditions to ensure that operators have the proper incentives to coordinate fairly and effectively with every other NGSO system.

## I. EXTREMELY LARGE COVERAGE AREAS AND HIGH OPERATIONAL ALTITUDES EXACERBATE COEXISTENCE CHALLENGES, IN THE ABSENCE OF REAL-TIME INFORMATION SHARING

When the Commission adopted its current avoidance of in-line interference approach, it anticipated that in-line events would be relatively infrequent.[4] However, due to the very large footprint of ViaSat's satellites, there will virtually always be at least one, and often more LEO satellites within that footprint, greatly increasing the frequency of apparent in-line events beyond what the Commission anticipated. In fact, such in-line events involving three or more operators may not be uncommon.

Large coverage areas and high altitude increases the number of in-line events that a ViaSat satellite is likely to experience with other systems, increases the duration of those

[4] *Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ka-Band*, Report and Order, 18 FCC Rcd. 14708, ¶ 19 (2003).

in-line events, and increases the odds that a given satellite will experience in-line events with multiple operators at one time. Instead of a fleeting event, an in-line event with a ViaSat satellite will last a significant period of time, during which affected satellites will remain in either a band-splitting or other spectrally inefficient coordination regime. LEO satellites may experience long-duration in-line events with a ViaSat satellite and a large number of LEO satellites may be affected simultaneously by one single ViaSat satellite. Both operators will take the burden of long periods of in-line coexistence due to ViaSat's large satellite footprint and high altitude. This will significantly reduce the spectrum available to the ViaSat system itself and also other systems, especially in cases of in-line events with more than one operator.

Figure 1 illustrates the size of a ViaSat Ku-band satellite footprint and the huge area within it affected by in-line events with the SpaceX constellation. All of the area in red is considered in-line based on a 10 degree separation angle—though this illustration actually understates the problem as it ignores service over the ocean.

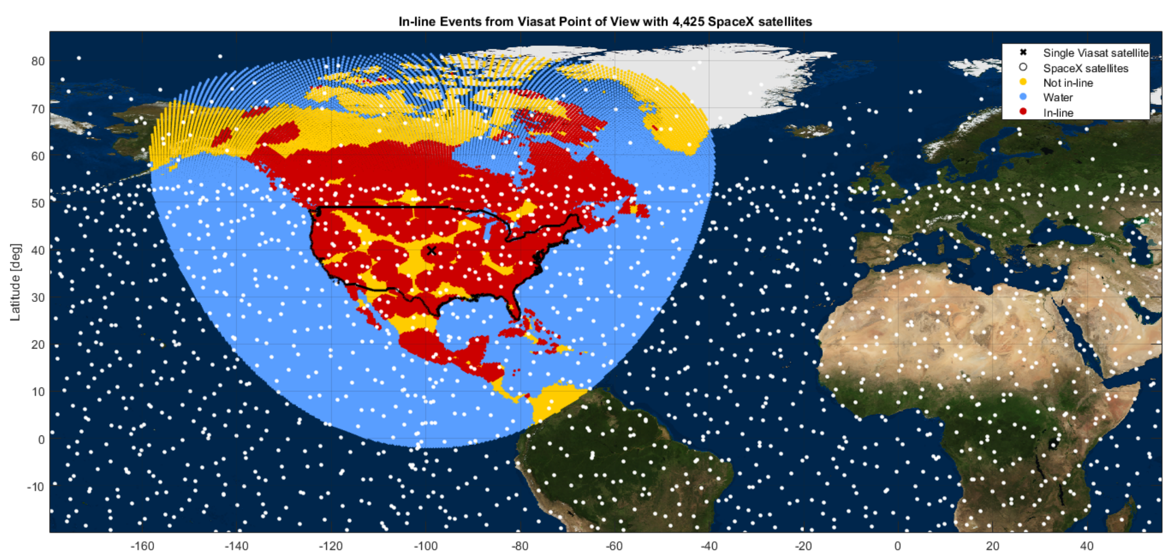


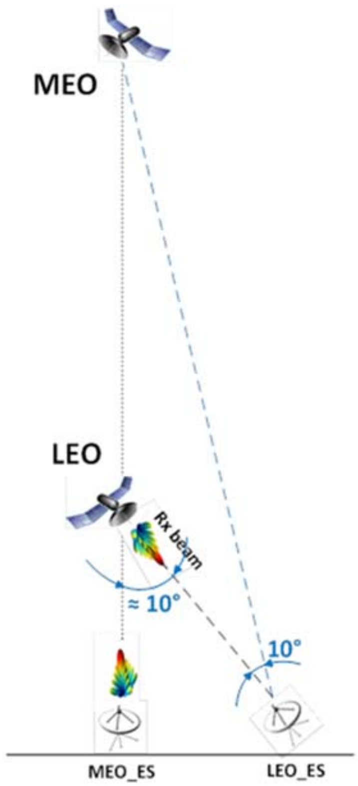

**Figure 1. Illustration of ViaSat In-Line Event Scope**

Troublingly, because ViaSat coverage beams will only illuminate a fraction of a given satellite's footprint at a given time, the large majority of these in-line events would, in fact, be "false" in-line events that, unbeknownst to other operators, would not have caused harmful interference. ViaSat can avoid this and greatly increase spectral efficiency by committing to provide real-time coordination data with other operators that includes the steering angle of each of its beams at a given time. However, in the absence of this information, other operators will be forced to assume that in-line interference is possible at anytime, anywhere within the ViaSat footprint. Yet addressing the false in-line event issue does not resolve the very real interference issues arising from the operation of ViaSat's NGSO system.

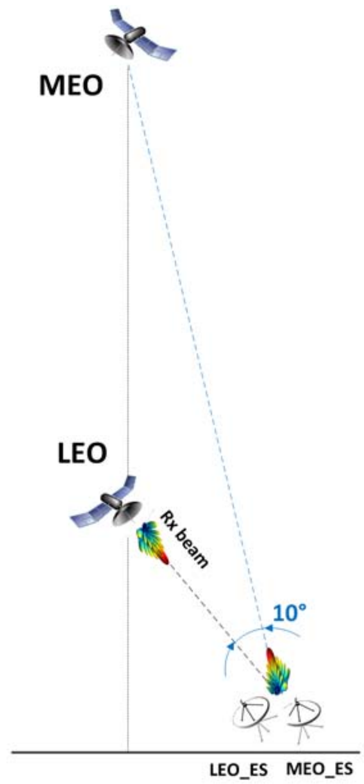
## II. Higher-Orbit Systems May Cause Interference to Any LEO Satellite within or Near Their Beams, Even Outside an In-line Event

The ViaSat system, and other systems with high operational altitudes, are likely to cause interference to LEO systems due to the very high EIRP of these systems' earth station uplink beams. For example, in order to communicate with satellites at altitudes of 8,200 km, ViaSat's uplink beams will transmit at EIRP levels much higher than SpaceX's. With such an extreme EIRP disparity, the ViaSat uplink beam would likely degrade SpaceX's or any other LEO satellite's ability to receive any uplink signal in the affected band from *any* location on the Earth, whether or not it is near the transmitting ViaSat earth station. This would essentially prevent a LEO satellite with steerable beams from using that steering capability to avoid an in-line event, forcing both operators to default to band segmentation.

To illustrate this point, consider two in-line scenarios involving the NGSO systems proposed by ViaSat and SpaceX. As depicted below, in Scenario 1, the SpaceX LEO satellite is in the main beam of the ViaSat earth station uplink to a ViaSat MEO satellite.[5] In Scenario 2, the SpaceX and ViaSat earth stations are essentially collocated while their satellites have an apparent angular separation of 10 degrees.




**Scenario 1**




**Scenario 2**

Using operational parameters from the SpaceX and ViaSat applications, we can determine the impact (measured as ΔT/T) of these in-line events.

5 Note that, given the extreme difference between the operating altitudes of the two systems, the separation angle between MEO_ES and LEO_ES from the LEO satellite perspective is essentially the same as the angle between MEO and LEO from the LEO_ES perspective.

For example, Table 1 below sets forth the analysis of the impact that the uplink beam from a ViaSat 7-meter earth station would have on SpaceX in Scenario 1. As this analysis demonstrates, the uplink beam from a ViaSat earth station would cause a dramatic increase in noise temperature relative to the desired signal at the receive antenna of SpaceX satellites, with ΔT/T of 208,412%, assuming 10 degrees of angular separation.[6]

| | | |
|---|---|---|
| SpaceX SAT Rx antenna gain at nadir [dB] | 41.00 | |
| SpaceX SAT Rx antenna G/T at nadir [dB/K] | 13.70 | *see SpaceX FCC filing* |
| SpaceX SAT Rx antenna G/T at 10º [dB/K] | -20.30 | *32-25log(φ) at 10° separation* |
| ViaSat ES EIRP [dBW/40kHz] | 53.20 | *for 7m ES in 27.5-28.6 GHz* |
| ViaSat ES EIRP [dBW/Hz] | 7.18 | |
| **I/N [dB]** | **33.19** | *at 10° separation* |
| **ΔT/T [%]** | **208,412%** | *at 10° separation* |

**Table 1. Impact of 7 m ViaSat Earth Station in Scenario 1**

Smaller earth stations will have similar effects, with a 60 centimeter earth station causing ΔT/T of 2,624%, and a 30 cm earth station causing ΔT/T of 644%, as shown in Tables 2 and 3, respectively.

| | | |
|---|---|---|
| SpaceX SAT Rx antenna gain at nadir [dB] | 41.00 | |
| SpaceX SAT Rx antenna G/T at nadir [dB/K] | 13.70 | *see SpaceX FCC filing* |
| SpaceX SAT Rx antenna G/T at 10º [dB/K] | -20.30 | *32-25log(φ) at 10° separation* |
| ViaSat ES EIRP [dBW/40kHz] | 34.20 | *for 0.6m ES in 27.5-28.6 GHz* |
| ViaSat ES EIRP [dBW/Hz] | -11.82 | |
| **I/N [dB]** | **14.19** | *at 10° separation* |
| **ΔT/T [%]** | **2,624%** | *at 10° separation* |

**Table 2. Impact of 60 cm ViaSat Earth Station in Scenario 1**

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6 For purposes of this analysis, SpaceX used a representative frequency (28 GHz) and a representative orbital altitude for its system (1,110 km), and EIRP values for ViaSat earth stations taken from the EPFD_up simulations submitted with its application. I/N is calculated using this equation (where k = Boltzmann constant):

$$\frac{I}{N} = EIRP - 10\log(4\pi d^2) - 10\log\left(\frac{4\pi}{\lambda^2}\right) + \frac{G}{T} - 10\log(k)$$

| | | |
|---|---|---|
| SpaceX SAT Rx antenna gain at nadir [dB] | 41.00 | |
| SpaceX SAT Rx antenna G/T at nadir [dB/K] | 13.70 | *see SpaceX FCC filing* |
| SpaceX SAT Rx antenna G/T at 10º [dB/K] | -20.30 | *32-25log(φ) at 10° separation* |
| ViaSat ES EIRP [dBW/40kHz] | 28.10 | *lowest EIRP, 0.3m ES, 27.5-28.6 GHz* |
| ViaSat ES EIRP [dBW/Hz] | -17.92 | *lowest possible ES EIRP used here* |
| **I/N [dB]** | **8.09** | *at 10° separation* |
| **ΔT/T [%]** | **644%** | *at 10° separation* |

**Table 3. Impact of 30 cm ViaSat Earth Station in Scenario 1**

In all three cases, interference is so strong that it would prevent the SpaceX satellite from using its steerable beams to service other users (even outside the area subject to the in-line event) using spectrum shared with ViaSat, and thus essentially prevents SpaceX from using those frequencies anywhere during the in-line event.

An analysis of Scenario 2 yields similar results, although here it is the sidelobes of the various ViaSat earth stations[7] that interfere with the main beam of the SpaceX earth station's uplink transmissions. Tables 4, 5, and 6 below show the increase in noise temperature expected in the SpaceX uplink when the separation angle between a SpaceX satellite and a ViaSat satellite is 10 degrees from the point of view of ViaSat earth stations of various sizes.

| | | |
|---|---|---|
| SpaceX SAT Rx antenna G/T at nadir [dB/K] | 13.70 | *see SpaceX FCC filing* |
| ViaSat ES Diameter D [m] | 0.30 | *per ViaSat FCC filing* |
| ViaSat ES Gmax [dB] | 36.64 | *estimated* |
| ViaSat ES Gain @ 10º [dB] | 7.00 | *32-25log(φ), per Rec. ITU-R S.465-6* |
| ViaSat ES EIRP @ 10º [dBW/40kHz] | -1.54 | *lowest EIRP, 0.3m ES, 27.5-28.6GHz* |
| ViaSat ES EIRP @ 10º [dBW/Hz] | -47.56 | |
| **I/N [dB]** | **12.45** | *at 10º separation* |
| **ΔT/T [%]** | **1,756%** | *at 10º separation* |

**Table 4. Impact of 30 cm ViaSat Earth Station in Scenario 2**

[7] For this analysis, SpaceX determined off-axis gain of ViaSat earth stations using the formula 32 - 25log(ϕ) from Recommendation ITU-R S.465-6, *available at* https://www.itu.int/dms_pubrec/itu-r/rec/s/R-REC-S.465-6-201001-I!!PDF-E.pdf.

| | | |
|---|---|---|
| SpaceX SAT Rx antenna G/T at nadir [dB/K] | 13.70 | *see SpaceX FCC filing* |
| ViaSat ES Diameter D [m] | 0.60 | *per ViaSat FCC filing* |
| ViaSat ES Gmax [dB] | 42.66 | *estimated* |
| ViaSat ES Gain @ 10º [dB] | 7.00 | *32-25log(φ), per Rec. ITU-R S.465-6* |
| ViaSat ES EIRP @ 10º [dBW/40kHz] | -1.46 | *for 0.6m ES in 27.5-28.6GHz* |
| ViaSat ES EIRP @ 10º [dBW/Hz] | -47.48 | |
| **I/N [dB]** | **12.53** | *at 10º separation* |
| **ΔT/T [%]** | **1,789%** | *at 10º separation* |

**Table 5. Impact of 60 cm ViaSat Earth Station in Scenario 2**

| | | |
|---|---|---|
| SpaceX SAT Rx antenna G/T at nadir [dB/K] | 13.70 | *see SpaceX FCC filing* |
| ViaSat ES Diameter D [m] | 7.00 | *per ViaSat FCC filing* |
| ViaSat ES Gmax [dB] | 64.70 | *estimated* |
| ViaSat ES Gain @ 10º [dB] | 7.00 | *32-25log(φ), per Rec. ITU-R S.465-6* |
| ViaSat ES EIRP @ 10º [dBW/40kHz] | -4.50 | *for 7m ES in 27.5-28.6GHz* |
| ViaSat ES EIRP @ 10º [dBW/Hz] | -50.52 | |
| **I/N [dB]** | **9.49** | *at 10º separation* |
| **ΔT/T [%]** | **888%** | *at 10º separation* |

**Table 6. Impact of 7 m ViaSat Earth Station Scenario 2**

As these tables demonstrate, the high EIRP of the ViaSat earth stations will make efficient and equitable spectrum sharing difficult or impossible. Because SpaceX will experience an unacceptable level of interference without a separation angle much larger than 10 degrees, the operators would have to expand the in-line event zone which would negatively impact spectral efficiency and usable capacity for both systems.

Without effective coordination, this pervasive interference will significantly reduce the overall utility of NGSO operations throughout the band. The Commission is currently considering whether to adopt default limits for EIRP density of NGSO uplink transmissions in order to facilitate spectrum sharing among systems,[8] and SpaceX believes that such

[8] *See Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, 31 FCC Rcd. 13651, ¶¶ 28-30 (2016).

limits will be critical to equitable spectrum sharing among non-homogeneous NGSO systems. At a minimum, any grant of ViaSat's application should be conditioned upon compliance with the outcome of that rulemaking proceeding. The Commission should also consider whether it would be appropriate to impose additional conditions to address this potential interference and enhance the potential for efficient spectrum sharing.

## III. CONCLUSION

In effect, systems operating at high altitudes and with large coverage areas cause a very large number of in-line events inefficiently splitting spectrum during a large portion of its satellites' time on orbit. Higher-altitude systems such as ViaSat's compound these challenges by posing an asymmetric interference risk to lower-altitude operators whenever they pass through the main beam or sidelobe of a ViaSat uplink transmission. The Commission should carefully consider whether the public interest would be served by authorizing systems that are only workable if other, more adaptable systems take a disproportionate burden of sharing, as the compromises required would reduce the overall capacity available to serve consumers, and also evaluate how it can foster spectrally efficient coexistence between systems of widely differing altitudes.

Respectfully submitted,

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June 26, 2017

**ENGINEERING CERTIFICATION**

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

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

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

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

Signed:

*/s/ Mihai Albulet*

Mihai Albulet, PhD
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SPACE EXPLORATION TECHNOLOGIES CORP.

June 26, 2017

Date

**CERTIFICATE OF SERVICE**

I hereby certify that, on this 26th day of June, 2017, a copy of the foregoing Comments was served by electronic mail upon:

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