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

In the Matter of	)	
LEOSAT MA, INC.	)	Call Sign: S2979
Petition for Declaratory Ruling to Permit U.S. Market Access for the LeoSat Ka-band Low-Earth Orbit Satellite System	)	File No. SAT-PDR-20161115-00112

COMMENTS OF SPACE EXPLORATION TECHNOLOGIES CORP.

Space Exploration Technologies Corp. ("SpaceX") hereby comments on the application filed by LeoSat MA, Inc. for authority to serve the U.S. market with its non-geostationary satellite orbit ("NGSO") system providing Fixed-Satellite Service ("FSS") in the Ka band. The proposed system would consist of "approximately 78"[1] satellites in low-Earth orbit ("LEO"), with operational altitudes of approximately 1,400 km at an inclination of 90 degrees.[2] However, LeoSat provides no substantive discussion of how it plans to share spectrum with other NGSO operators, leaving the Commission with no basis upon which to determine whether the LeoSat constellation would promote efficient use of scarce spectral resources. Indeed, LeoSat's proposed system raises important substantive interference concerns that make this showing all the more crucial to ensure that granting LeoSat access to the U.S. market would serve the public interest. LeoSat's disposal plans also raise concerns, as they appear to consider omitting operations to deorbit within 25

[1] *Petition for Declaratory Ruling to Permit U.S. Market Access for the LeoSat Ka-band Low-Earth Orbit Satellite System*, IBFS File No. SAT-PDR-20161115-00112, at 2 (Nov. 15, 2016) ("LeoSat Petition").

[2] *Id.* at 6.

years, by inefficiently relying on a semi-permanent disposal orbit even though the system's operational altitude is only 1,400 km.

I. A SUBSTANTIVE COEXISTENCE SHOWING IS NEEDED TO DETERMINE WHETHER MARKET ACCESS WOULD BE IN THE PUBLIC INTEREST

Uniquely among NGSO applicants in this processing round, LeoSat has provided no substantive information about the strategies it will employ to efficiently share spectrum with other NGSO operators. SpaceX, for example, provided a detailed explanation of its system's ability to minimize the frequency of in-line events through satellite diversity, and its ability to limit the impact of those in-line events that do occur through the use of highly flexible and extremely narrow spot beams.

LeoSat, however, indicates only that "LeoSat will coordinate its operations internationally with other planned NGSO FSS systems on a first-come, first-served basis,"[3] and notes that "[b]ased upon the LeoSat system's ITU date priority, LeoSat expects to coordinate successfully with later ITU filings for other planned NGSO FSS systems."[4] LeoSat also requests a waiver of the Commission's band-segmentation rules in favor of a regime based on avoidance of in-line events.[5] SpaceX agrees that the avoidance of in-line events regime would best promote efficient use of spectrum. However, LeoSat's claimed ITU priority and mere citation of the avoidance of in-line events approach cannot serve as a substitute for a substantive showing that the LeoSat system will be able to share spectrum efficiently and equitably with other Ka-band NGSO systems.

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3 *Id.*, Attachment A at 18.

4 *Id*.

5 *Id.* at 14-15.

LeoSat overlooks the need to ensure that the grant of market access to any applicant in this processing round will serve the public interest. This means establishing that an operator will not unduly degrade the spectral environment in which it and other systems will operate. For example, the Commission should deny an application for U.S. market access or launch authority regardless of the applicant's ITU priority if it is clearly shown that poor system design would cause that applicant to reduce the spectrum available to all other applicants well beyond the actual needs of that system.

As SpaceX has explained, for example, the Commission should carefully consider whether to authorize any system with large, inflexible beams, which will greatly complicate coexistence between NGSO systems in these bands, and reduce spectral efficiency. When the Commission adopted its current avoidance of in-line interference sharing regime, it anticipated that in-line events would be relatively infrequent.[6] But these analyses were made in the context of a limited number of first-generation NGSO/FSS systems with constellations of just tens of satellites apiece.[7] With numerous current-generation NGSO/FSS constellations each proposing to deploy hundreds or even thousands of satellites, in-line events are likely to occur much more frequently. In fact, in-line events involving three or more operators may not be uncommon. In this environment, it is essential that operators design their systems with technical characteristics that will enable them to minimize the impact of these events. LeoSat's proposed system raises special

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6 *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).

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

concerns as well due to the fact that every satellite in each of LeoSat's orbital planes will pass directly over the poles. This means that, at the very least, the conjunction of numerous LeoSat satellites in these areas will create serious coexistence challenges for any Ka-band NGSO satellite in a polar orbit.

LeoSat also proposes to use very high-EIRP earth station uplink beams, which are likely to cause interference to other LEO systems. For example, although both SpaceX and LeoSat propose to operate at LEO altitudes, LeoSat's uplink beams will transmit at EIRP levels much higher than SpaceX's. With such a large EIRP disparity, the LeoSat 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 LeoSat 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, we consider two in-line scenarios involving the NGSO systems proposed by LeoSat and SpaceX, and use operational parameters from their respective applications to determine the impact (measured as $\Delta T/T$) of these in-line events. In Scenario 1, the SpaceX satellite is in the main beam of the LeoSat user terminal uplink beam. In this scenario, SpaceX has the ability to redirect beams to serve areas unaffected by the in-line event. Table 1 sets forth the analysis of the impact on SpaceX in this scenario, where the SpaceX beams have been redirected to achieve 30 degrees of angular separation from the SpaceX satellite's point of view. As this analysis demonstrates, the uplink beam from a LeoSat 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 189%, even assuming 30 degrees of angular separation.[8]

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 30º [dB/K]	-32.23	*32-25log(φ) at 30° separation*
LeoSat ES EIRP [dBW/40kHz]	35.00	*Estimated from EIRP mask*
LeoSat ES EIRP [dBW/Hz]	-11.02	
I/N [dB]	**2.76**	*at 30° separation*
ΔT/T [%]	**189%**	*at 30° separation*

Table 1. Impact of LeoSat User Terminals in Scenario 1

In Scenario 2, the SpaceX and LeoSat earth stations are essentially collocated while their satellites have an apparent angular separation of 10 degrees (*i.e.*, the edge of an in-line event). Here again, the analysis in Table 2 demonstrates that the high-EIRP transmissions from the LeoSat earth station would cause a dramatic increase in interference, with ΔT/T of 147%.

SpaceX SAT Rx antenna G/T at nadir [dB/K]	13.70	*see SpaceX FCC filing*
LeoSat ES EIRP @ 10º [dBW/40kHz]	-12.00	*Estimated from EIRP mask*
LeoSat ES EIRP @ 10º [dBW/Hz]	-58.02	
I/N [dB]	**1.68**	*at 10° separation*
ΔT/T [%]	**147%**	*at 10° separation*

Table 2. Impact of LeoSat User Terminals in Scenario 2

In Scenario 1, 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 LeoSat, and thus essentially prevents SpaceX from using those frequencies anywhere during the in-line event. In Scenario 2, because SpaceX will

[8] For purposes of this analysis, SpaceX used a representative frequency (29 GHz) and representative orbital altitude for its system (1,110 km), and EIRP values for LeoSat earth stations taken from the EIRP mask in Figure 1, page 26 of Attachment A to the LeoSat Petition. I/N is calculated using this equation (where k = Boltzmann constant):

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

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,[9] and SpaceX believes that such limits will be critical to spectrum sharing among non-homogeneous NGSO systems. At a minimum, any grant of LeoSat'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.

LeoSat's emphasis on its ability to coordinate with operators "[b]ased upon the LeoSat system's ITU date priority,"[10] however, suggests that LeoSat has done little to ensure that its system can share spectrum equitably and efficiently with other NGSO systems, regardless of priority date. Although the ITU Radio Regulations offer important guidance in the actual negotiation of coordination agreements between NGSOs, these considerations should remain independent of the Commission's threshold determination that a system and operator have the incentive and ability to coordinate with all operators in a way that promotes efficient use of the band, consistent with the public interest.

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

10 LeoSat Petition, Attachment A at 18; s*ee also* Letter from Phillip Marchesiello and Lynne Montgomery, Counsel to LeoSat, to Jose Albuquerque, Chief, Satellite Division, International Bureau, IBFS File No. SAT-PDR-20161115-00112, at 7 (May 15, 2017) ("LeoSat IB Response").

II. LEOSAT'S DISPOSAL PLANS UNNECESSARILY UNDERMINE THE SAFETY OF SPACE

LeoSat proposes to dispose of its satellites by moving them into a higher, 2,000 km disposal orbit, where they will remain for more than 100 years.[11] This proposal is troubling as it imposes the risks and challenges of tracking, avoiding, and eventually managing the safe deorbit on future generations of humans, living 100 years from now. For example, LeoSat seems to suggest that there is no risk of collision between these satellites and the International Space Station ("ISS"), because 100 years is longer than the ISS's expected life. Although this may be true, it does not address the likelihood that humanity will launch other projects into Earth orbit similar to or even more valuable than the ISS in the next century. And in the interim, the chances will grow that LeoSat satellites will be damaged, creating new untrackable debris. In addition, after these 100 years have elapsed, the LeoSat's satellites' disposal orbits will apparently decay, causing them to transit through the orbits of every other object operating below 2,000 km at that time. This would not be an acceptable means of disposal were it to be done today, and it likely will pose even greater risks 100 years hence when mankind will likely have achieved far more intensive use of space.

GSO satellite operators, which use a similar approach to satellite disposal, have good reason to do so. Reducing perigee from approximately 36,000 km to achieve atmospheric demise requires such a large quantity of fuel that doing so would be

[11] LeoSat IB Response at 7. LeoSat has raised the additional possibility that it might deorbit its satellites from a lower disposal orbit within 25 years. *See id.* LeoSat has not committed to disposing of its satellites in this way, and even this approach would leave LeoSat satellites in orbit for far longer than any other applicant in this processing round.

impracticable.[12] LeoSat, however, proposes to operate in low-earth orbit at only 1,400 km, and therefore should be able to achieve prompt and orderly atmospheric demise with minimal additional fuel requirements and little additional operational complexity. In this context, LeoSat's failure to commit to dispose of its satellites at any point in the next 100 years raises serious questions about whether LeoSat's proposed operations are consistent with safe space and the public interest.

III. CONCLUSION

Numerous operators, with thousands of proposed satellites, have applied to operate NGSO systems in the Ka-band in the current processing round. This intensity of interest suggests that NGSO operations will make intensive use of this band, with healthy competition between operators with diverse technologies and business models to provide advanced services to customers throughout the U.S. and the world. However, this also means that equitable and efficient use of spectrum, and careful maintenance of safe space, will continue to be paramount concerns. Unfortunately, LeoSat has provided little information upon which the Commission could determine that LeoSat's operations would be consistent with these goals or with the public interest more broadly.

[12] Instead, GSO operators boost their satellites at end of life to a disposal orbit approximately 300 km above their operational altitude. *See* 47 C.F.R. § 25.283(a) (setting forth requirements for end-of-life disposal).

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

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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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