

May 15, 2017

Mr. Jose P. Albuquerque
Chief, Satellite Division, International Bureau,
Federal Communications Commission
445 12th Street, S.W.
Washington, DC 20010

Re: *LeoSat MA, Inc., Petition for Declaratory Ruling to Permit U.S. Market
Access for the LeoSat Ka-Band Low-Earth Orbit Satellite System;
Call Sign S2979, IBFS File No. SAT-LOI-20161115-00112*

Dear Mr. Albuquerque:

LeoSat MA, Inc. (“LeoSat”) hereby responds to the letter dated March 15, 2017,¹ in which the Satellite Division (“Division”) of the Federal Communications Commission’s (“Commission” or “FCC”) International Bureau (“Bureau”) requested additional information regarding LeoSat’s Petition for Declaratory Ruling (“PDR”) seeking market access to the United States for LeoSat’s proposed Ka-band non-geostationary orbit (“NGSO”) fixed-satellite service (“FSS”) constellation (“LeoSat System”).² LeoSat appreciates the opportunity to respond to the Division Letter.³ This response repeats each question posed in the Division Letter and provides LeoSat’s response.

¹ Letter from Jose P. Albuquerque, Chief, Satellite Div., Int’l Bur., FCC, to Joseph C. Anders, Founder and President, LeoSat MA, Inc., IBFS File No. SAT-LOI-20161115-00112 (Call Sign S2979) (Mar. 15, 2017) (“Division Letter”).

² LeoSat MA, Inc., Petition for Declaratory Ruling To Permit U.S. Market for the LeoSat Ka-Band Low-Earth Orbit Satellite System, Call Sign S2979, IBFS File No. SAT-LOI-20161115-00112 (Call Sign S2979) (filed Nov. 15, 2016) (“PDR”).

³ On April 10, 2017, the Division granted LeoSat’s April 7, 2017 request for a thirty day extension to respond to the Division Letter. See Letter from Phillip R. Marchesiello and Lynne Montgomery, Counsel for LeoSat, to Jose P. Albuquerque, Chief, Satellite Div., Int’l Bur., FCC, IBFS File No. SAT-LOI-20161115-00112 (Call Sign S2979) (Apr. 7, 2017) (stamp granted by FCC).

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To aid in the Commission's evaluation of LeoSat's petition, please provide the following:

1- A statement concerning whether it is LeoSat's intent to seek registration of the LeoSat NGSO FSS system by France consistent with the Convention on the Registration of Objects Launched into Outer Space.

In its PDR, LeoSat initially stated that “the LeoSat System is expected to be authorized under a space operations license issued pursuant to the French Space Operations Act of 2008.”⁴ After further evaluating the matter, LeoSat intends to seek an authorization for the LeoSat System from the Radiocommunications Agency Netherlands (“RA”) instead of from the French licensing authority.⁵ LeoSat has held productive preliminary discussions with the RA, and LeoSat's board has approved the decision to seek a space station authorization from the RA. LeoSat intends to file an application with the RA in June 2017.

2- Any software used to generate the EPFD results shown in the petition, including inputs and output results.

To generate the EPFD results that were submitted with the PDR, LeoSat used proprietary software developed by its partner Thales Alenia Space (“TAS”), which is designing and will construct the LeoSat System. The EPFD results set forth in the PDR demonstrate that the LeoSat System will fully comply with the applicable Article 22 EPFD limits.⁶ LeoSat used TAS's proprietary software (“TAS Software”) for its EPFD analysis because the algorithm used by the ITU Software does not adequately take into account the use of steerable beams in NGSO constellations. The ITU Software, which is compliant with ITU-R Recommendation S.1503-2 (“ITU Recommendation”), can generate overly conservative results that inaccurately suggest that an NGSO constellation may interfere with a geostationary satellite orbit (“GSO”) system.

⁴ See PDR at 3. The LeoSat System will remain registered with the ITU under filings by France for the MCSAT-2 LEO-2 network.

⁵ Under the Commission's *DISCO II* policies and Section 25.137(a)(2) of its rules, U.S. market access requests for satellites licensed by World Trade Organization (“WTO”) member countries to provide WTO-covered services, including FSS, are presumed to enhance competition and thus serve the public interest. See *Amendment of the Commission's Regulatory Policies to Allow Non-U.S. Licensed Space Stations to Provide Domestic and International Satellite Service in the United States*, Report and Order, 12 FCC Rcd 24094 (1997), *on recon.*, 15 FCC Rcd 7207 (1999), *recon. denied*, 16 FCC Rcd 19794 (2001); 47 C.F.R. §25.137(a)(2). Given that LeoSat has decided to seek a space station authorization from the RA, LeoSat will remain in compliance with Commission's rules and policies because the Netherlands is a WTO-member country. Therefore, grant of the PDR should continue to be presumed by the Commission to be pro-competitive and in the public interest.

⁶ PDR, Technical Appendix at 14-15, Annex A.

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Indeed, discussions at World Radio Communication Conference 2015 (“WRC-15”) led to the conclusion that improvements to the algorithm used by the ITU Software are required to improve EPFD calculations for NGSO constellations employing steerable beams.⁷ For this reason, the ITU Recommendation currently is under review by Working Party 4A, which intends to take into account additional parameters such as the minimum tracking duration of NGSO satellites by their associated earth stations. In contrast to the ITU Recommendation procedure, these parameters are taken into account by the TAS Software, which effectively demonstrates LeoSat’s compliance with the applicable EPFD limits.

LeoSat is not in a position to provide the TAS Software to the Commission because it is proprietary to TAS and because it lacks an appropriate user interface. Consequently, after receiving the Division Letter, LeoSat separately used ITU Software to conduct an EPFD analysis.⁸ A full discussion of the results of this analysis is included in Attachment A hereto. The results generated by the ITU Software demonstrate that the LeoSat System will satisfy the Commission’s standards for EPFD_{up}, EPFD_{is}, and EPFD_{down} for the 18 GHz downlink and for the 20 GHz downlink with respect to GSO earth stations with a 5m antenna diameter. As noted above, however, use of the ITU Software results in undue degradation when the number of satellites in an NGSO constellation increases at high latitudes, and it is unable to adequately model the use of steerable beams by NGSO constellations. Consequently, the ITU Software generated results suggesting that LeoSat’s proposed 20 GHz downlink operations may slightly exceed the Commission’s EPFD_{down} limit for smaller GSO earth station antenna sizes.

3- Commission rules require petitioners requesting U.S. market access for non-U.S. licensed space stations to provide a narrative description of the design and operational strategies that will be used to mitigate orbital debris. Alternatively, an applicant seeking market access for a non-U.S. licensed system can satisfy this requirement “by demonstrating that debris mitigation plans for the space station(s) for which U.S. market access is requested are subject to direct and effective regulatory oversight by the national licensing authority.” LeoSat states that it satisfies this requirement because the operations of its NGSO FSS system are subject to direct and effective regulatory oversight by France. LeoSat also disclosed certain information concerning its orbital debris mitigation plans pursuant to Section 25.114(d)(14) of the Commission’s rules. In order to assist in our assessment of whether LeoSat has demonstrated that it is subject to direct and effective regulatory oversight, or alternatively, to permit analysis of the debris mitigation plans for the constellation we request the following additional information:

⁷ Preliminary draft revision to Recommendation ITU-R S.1503: Functional description to be used in developing software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite system networks with limits contained in Article 22 of the Radio Regulations, ITU-R WP4A/TD/161 (May 12, 2017).

⁸ The ITU also requested that LeoSat provide EPFD results generated by the ITU Software, and LeoSat intends to file with the ITU the same EPFD information attached hereto.

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LeoSat and TAS are committed to developing an innovative and safe design for the LeoSat System that complies with all Commission rules. Given the large number of satellites proposed by the pending Ka-band NGSO constellation applications in this and other recent processing rounds, LeoSat recognizes the importance of ensuring that all new NGSO constellations fully comply with the Commission's orbital debris requirements. The Commission's requirements will minimize satellite collisions with space debris and prevent satellite collisions, thereby preventing the introduction of additional orbital debris into low Earth orbit.

As noted above, LeoSat's board has approved seeking a space station license from the RA rather than France, and LeoSat expects to file an application with the RA for authorization of the LeoSat System in June 2017. The RA requires its satellite licensees to adhere to the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space and the Inter-Agency Debris Coordination Space Debris Mitigation Guidelines, ITU Recommendation ITU-R S.1003. Accordingly, pursuant to Section 25.114(d)(14)(v) of the Commission's rules, the RA conducts "direct and effective regulatory oversight" of orbital debris mitigation.⁹

Out of an abundance of caution, however, LeoSat nevertheless will demonstrate compliance with the Commission's orbital debris requirements set forth in Section 25.114(d)(14)(i)-(iv) of the FCC's rules.¹⁰ But, like other applicants in the instant processing round, LeoSat has not yet completed the final design of the LeoSat System.¹¹ Pursuant to a design contract for the LeoSat System between LeoSat and TAS, the parties expect to complete the systems' final design within nine months—i.e., by early 2018.¹² LeoSat's comprehensive orbital debris analysis will be

⁹ See 47 C.F.R. § 25.114(d)(14)(v).

¹⁰ See *id.* § 25.114(d)(14)(i)-(iv).

¹¹ See, e.g., ViaSat, Inc., Petition for Declaratory Ruling, IBFS File No. SAT-LOI-20161115-00120, Technical Appendix at 11-12 (filed Nov. 15, 2016) (stating that ViaSat has completed a "preliminary assessment of orbital debris mitigation," but suggesting that ViaSat has not yet completed a preliminary design review or critical design review of its proposed satellite system); Kepler Communications Inc., Kepler's Response to Request for Further Information, IBFS File No. SAT-LOI-20161115-00114, at 5 (filed Apr. 20, 2017) (stating that it is still finalizing its constellation architecture for Phase III of its constellation deployment); Letter from Elisabeth Neasmith, Director, Spectrum Management and Development, Telesat Canada, to Jose P. Albuquerque, Chief, Int'l Bur., Satellite Div., FCC, IBFS File No. SAT-LOI-20161115-00114, at 4, 6 (filed Apr. 14, 2017) (stating that Telesat is analyzing a more efficient elliptical orbit and still completing its final mission design)

¹² LeoSat and TAS have completed "Phase A" under the contract, which includes a preliminary design of the LeoSat System's critical elements. The information about the LeoSat System that was provided to the Commission in the PDR is based on the Phase A design of the LeoSat System. LeoSat and TAS currently are working on "Phase B" under their contract, which

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finalized as part of the final design phase and is dependent on certain technical decisions about the LeoSat System that will be made during the final design phase. Consequently, LeoSat will be unable to provide all of the information required by the Commission's orbital debris mitigation rules until the final design of the LeoSat System is completed early next year.¹³

In light of the foregoing, LeoSat requests conditional approval of its PDR pending LeoSat's demonstration of either (i) full compliance with the Commission's orbital debris mitigation requirements through one or more supplements filed in connection with the PDR, or (ii) a Commission determination that the RA provides "direct and effective regulatory oversight" of orbital debris mitigation.¹⁴ Specifically, if the Commission decides to grant applications filed in the instant processing round before LeoSat's final design is completed and the Commission has reviewed and approved LeoSat's orbital debris mitigation plan, then LeoSat requests the Commission to grant the PDR in the normal course but impose a condition in the PDR grant that requires Commission approval of LeoSat's orbital debris mitigation plan prior to any access by the LeoSat System to the U.S. market.

LeoSat's request is consistent with Commission precedent. The Commission previously has granted space station authorizations conditioned on later compliance with Commission requirements, including orbital debris mitigation requirements. For example, the Bureau separately issued conditional grants to Northrop Grumman and contactMEO, both of which applied to launch NGSO constellations.¹⁵ In each case, the Bureau required the applicants to file their final orbital

includes, among other things, a comprehensive and detailed system design. The Technical Specifications, Statement of Work, and Test Plans for the LeoSat System, including failure modes and effects analyses involving systems telemetry, tracking, and command systems and propulsion and energy systems, all will be developed as part of Phase B, which will include comprehensive compliance with the Commission's orbital debris requirements.

¹³ The first two satellites of LeoSat's 78-satellite constellation will be launched in 2019. The PDR inadvertently stated that the satellites would be launched in 2018. PDR at 8, n.12. As explained in the PDR, these two initial satellites will demonstrate the effectiveness of the advanced technologies employed by the LeoSat System, and LeoSat has entered into a memorandum of understanding with the National Science Foundation ("NSF") for these satellites to collect and deliver data from an NSF outpost in Antarctica to a scientific station in Norway. *See id.*

¹⁴ Although LeoSat is previewing its conditional grant request herein, it will incorporate the request in a supplement to the PDR that includes the additional information about the LeoSat System set forth in this response to the Division Letter.

¹⁵ *See Northrop Grumman Space & Mission Systems Corporation, Applications for Authority to Operate a Global Satellite System Employing Geostationary Satellite Orbit and Non-Geostationary Satellite Orbit Satellites in the Fixed-Satellite Service in the Ka-band and V-band*, Order and Authorization, 24 FCC Rcd 2330, 2363-64, at ¶ 102 (IB 2009); *contactMEO*,

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debris plans following the issuance of the Bureau's conditional grant and within thirty days of the plans' completion. The Bureau conditioned the applicants' launch and operational authority upon that showing. Similarly, the Bureau granted a Globalstar space station application on the condition that Globalstar obtain an authorization to operate from France.¹⁶ LeoSat believes that a similar approach is appropriate here to prevent the Commission's processing round timing, over which LeoSat had no control, from prejudicing LeoSat's equal access to the U.S. market.¹⁷

3a- The current status of French licensing authority's review of the orbital debris mitigation plans for the LeoSat NGSO FSS system.

As set forth above, LeoSat has not completed its orbital debris mitigation plan, and, upon further evaluation, LeoSat determined not to seek a space station authorization from the French licensing authority. LeoSat now intends to apply for a space station from the RA. Although LeoSat has not yet completed and filed an application with the RA, LeoSat has commenced discussions regarding the matter with the Netherland's licensing authority, including discussions about what orbital debris showings the RA will require. The RA has informed LeoSat that it will require the LeoSat System to adhere to the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space and the Inter-Agency Debris Coordination Space Debris Mitigation Guidelines, ITU Recommendation ITU-R S.1003. In addition to complying with the Commission's orbital debris mitigation requirements, LeoSat expects that its system will be fully compliant with each of the foregoing.

3b- A statement from LeoSat disclosing the accuracy within which the space station orbital parameters will be maintained for any orbit in which the LeoSat NGSO satellites will operate, including apogee, perigee, inclination, and the right ascension of the ascending node(s)

LeoSat's 78 satellites will operate in polar (inclination angle = 90°), quasi-circular orbits at an altitude of 1,400 km, with an eccentricity around 1E-3 in six planes with 13 active satellites per plane. LeoSat's additional six in-orbit spare satellites will be distributed among the orbital planes to ensure system availability in the event of an anomaly with respect to any of its 78 active satellites.

LLC For Authority to Launch and Operate a Non-Geostationary Orbit Fixed-Satellite System in the Ka-band Frequencies, Order and Authorization, 21 FCC Rcd 4035, 4052-53 ¶ 47 (IB 2006).

¹⁶ *See Globalstar Licensee LLC, Application for Modification of Non-geostationary Mobile Satellite Service Space Station License, Order, 26 FCC Rcd 3948, 3962 ¶ 35 (IB 2011).*

¹⁷ In the alternative, if the Division deems conditional approval of LeoSat's PDR to be inappropriate, LeoSat requests the Division to delay acting on the PDR until LeoSat has completed the final design of its system and supplemented the PDR to include its final orbital debris analysis demonstrating compliance with the Commission's requirements.

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The orbital planes are distributed over 180° of right ascension, with 29.96° inter-plane spacing. The complete parameters of the constellation are provided in Schedule S to the PDR.¹⁸ The 13 satellites in each plane will be equally spaced around the plane. For coverage purposes, the satellites will be staggered from plane to plane by an amount that is close to one-half of the in-plane spacing between satellites. The spacing will be offset to ensure that satellites arriving at the polar plane at the same time do not collide.

In mission orbit, all of LeoSat's satellites will be operated in a control box, with position tolerances compatible with communications propagation constraints. The preliminary control box tolerances are ± 25 km intrack, ± 5 km crosstrack and ± 0.5 km radial.

3c- Please provide an analysis of collision risk for satellites during the passive disposal phase, i.e., after all propellant is consumed. As part of that analysis, please provide an assessment of how many conjunctions and/or collision avoidance maneuvers might be required of the International Space Station (ISS), assuming it is in operation throughout the period in which LeoSat satellites would transit the ISS orbit.

Although details of its post-mission disposal strategy are still being finalized, LeoSat anticipates that post-mission disposal will be performed by propulsive maneuvering of the satellite into either (i) a higher orbit with a perigee altitude higher than 2000 km that will remain stable for more than 100 years, which is longer than the expected life of the ISS; or (ii) a lower orbit, which will lead to a predicted orbital lifetime of less than 25 years until atmospheric reentry occurs as a result of natural orbital decay processes. If LeoSat chooses the higher disposal orbit, there will be no risk of collision with the ISS. If LeoSat chooses the lower disposal orbit, LeoSat's satellites will have a perigee low enough to cross the orbit of the ISS at around 400 km altitude after a period of time. Preliminary assessment envisaged several orbits to finally select a decayed orbit with an apogee 900 km and a perigee of 475 km. This orbit allows for a LeoSat satellite to reenter the Earth's atmosphere approximately 24 years after post-mission disposal while keeping the satellite's perigee above the ISS orbit for approximately 21 years. The decayed orbit allows LeoSat to limit to approximately three years the duration of a possible conjunction risk between a LeoSat satellite and the ISS that could require the ISS to perform collision avoidance ("COLA") maneuvers. The preliminary assessment shows a possibility of two conjunctions that may require ISS COLA maneuvers. The criteria used to determine collision risk with the ISS is when a LeoSat satellite is predicted to pass within the range of 2 km

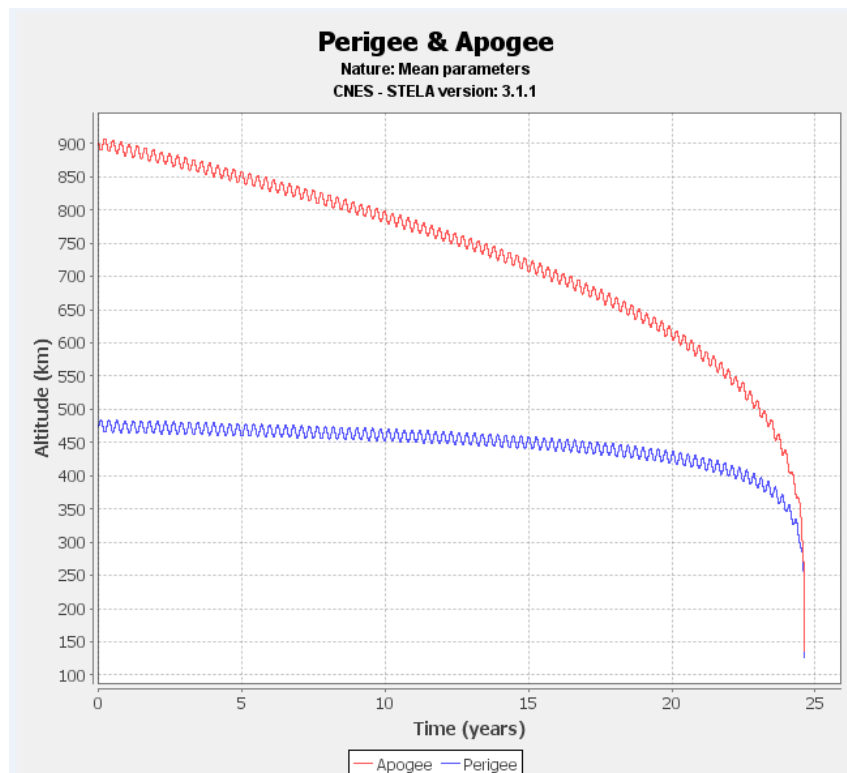
¹⁸ LeoSat PDR, Schedule S.

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(local vertical) x 25 km x 25 km (local horizontal) within the next 72 hours.¹⁹ Apogee & perigee evolution versus time are depicted in the following figure:



3d- Please provide an analysis of collision risk, assuming rates of satellite failure resulting in the inability to perform collision avoidance procedures of 10, 5 and 1 percent. This analysis should include a study performed assuming all failures occur at the mission altitude, but may also include additional studies specifying alternative assumptions concerning the orbital locations (such as injection altitude) at which failures might occur.

LeoSat will use specialized software in its mission control facility to regularly evaluate collision risks with large debris that exceeds 10 cm in diameter that can be identified using the most current available orbital element sets disseminated by USSTRATCOM and JSpOC. Using this information, LeoSat will be able to plan and execute COLA maneuvers to avoid collisions with

¹⁹ Bryan Corley, *Human Spaceflight CA Overview SSA Operators' Workshop*, NASA/Johnson Space Center, Trajectory Operations (Nov. 2016), https://advancedssa.com/assets/img/workshop/presentations/Human_Spaceflight_SSA_161105.pdf.

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catalogued debris. The satellites' propellant budget will include propellant consumption for those COLA maneuvers.

The LeoSat constellation design will benefit from TAS' experience in GSO and LEO satellite development to ensure that the probability of a satellite failure resulting in the inability to perform COLA procedures will be maintained below specifications. As part of TAS' standard policy for manufactured satellites (including GSO, scientific, LEO/MEO satellites), a platform reliability figure is demonstrated not only for satellite disposal but also throughout the satellite's lifetime, including during orbit raising and mission orbit. Reliability is achieved through the redundancy of commanding and actuating functions and units where possible. The commanding and actuating devices used for COLA maneuvers are the same as those used for satellite disposal maneuvers and therefore benefit from the same reliability. Such design features are already implemented in current in-orbit LEO satellites based upon the ELITEBUSTM 2000 platform designed and manufactured by TAS.²⁰

Furthermore, LeoSat's satellite design will limit the consequences of collision with small debris, including debris that is un-catalogued and/or that does not exceed 10 cm in diameter. Specifically, LeoSat will perform a micrometeorite/small debris penetration analysis according to NASA Safety Standard (NSS) 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris.²¹

For the purpose of the collision risk assessment, LeoSat considered the following two cases:

1. Catalogued objects. This calculation relates to the risk of a collision between a catalogued object and a passive LeoSat satellite that is unable to perform any kind of avoidance maneuvers, including during COLA and deorbit. The orbit of the passive LeoSat satellite is assumed to be the nominal orbit of the LeoSat constellation. The probability of a collision in these situations is computed below.
2. Uncatalogued objects. Uncatalogued objects present a collision risk regardless of the ability of a LeoSat satellite to perform avoidance maneuvers because they generally cannot be detected.

The probability of the failure of a LeoSat satellite leading to the inability to perform COLA was analyzed at ten percent, five percent, and one percent for the LeoSat System. A ten percent

²⁰ The ELITEBUSTM 2000 platform is an evolution of the ELITEBUSTM 1000 platform that was used in several existing and planned constellations, including Globalstar's second generation constellation, O3b (blocks 1, 2 and 3), and Iridium NEXT. See Attachment A at 8.

²¹ NASA Safety Standard (NSS) 1740.14, Guidelines and Assessment Procedures for Limiting Orbital Debris, Aug. 1995.

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likelihood of failure at end-of-life corresponds to currently admitted specifications. In addition, as part of its analysis, LeoSat assumes the delivery of its satellites to an orbit at 1350 km, and a mission lifetime for each satellite of 10 years.

LeoSat and TAS developed the following table using NASA's Debris Assessment Software v2.0.2 ("DAS") to compute the collision probability for a LeoSat satellite pursuant to the foregoing considerations. The table below addresses collision probability in three separate cases: (i) when a satellite is unable to perform COLA; (ii) the probability of a collision of a LeoSat satellite with a catalogued object; and (iii) the compound collision probability for one satellite over the course of ten years.

Case	<u>A</u> : Probability that the LeoSat satellite is unable to perform COLA	<u>B</u> : Probability of collision with a catalogued object over a 10-year mission lifetime	<u>A x B</u> : Compound collision probability for one satellite over a 10-year mission lifetime
10 percent	0.1	0.00121	1.21E-04
5 percent	0.05	0.00121	6.05E-05
1 percent	0.01	0.00121	1.21E-05

In addition to the above on-orbit break-up analysis of a satellite due to a collision with catalogued debris, the probability that LeoSat will be unable to dispose of a satellite due to a collision with uncatalogued debris smaller than 10 cm is estimated to be 9.48E-06 over the course of the satellite's 10-year lifetime.

3e- Any additional information you may wish to provide concerning human casualty risk resulting from satellite disposal, such as any risk or loss mitigation strategies under development.

As part of the final design phase for the LeoSat System, LeoSat and TAS will complete an analysis of any satellite components that may present a risk of human casualty during satellite reentry. As part of this analysis, LeoSat will ensure that its deorbit procedure will comply with all applicable NASA guidelines. For example, LeoSat intends to meet or exceed the 1:10,000 casualty risk established by NASA and other regulators.²² This analysis will be carried out using the NASA Debris Assessment Software during the final design phase. LeoSat and TAS will evaluate current technological solutions to ensure that the maximum amount of debris will be burned up before entering the Earth's atmosphere and to mitigate the potential for debris

²² See U.S. Government Orbital Debris Mitigation Standard Practices, at 3 § 4-1; ESA, Space Debris Mitigation Policy for Agency Projects, ESA/ADMIN/IPOL(2014)2, § 2 (Mar. 28, 2014).

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returning to Earth. Once the final design phase of the LeoSat System is completed, LeoSat will supplement the PDR to include this information.

3f- Any information or analysis you may wish to provide with respect to treatment of this application under the Commission's environmental processing rules.

During satellite development, LeoSat and TAS will complete an analysis that describes all materials used to construct the satellites that may present high levels of toxicity for the environment or human beings. This information will be available once the final design phase has been completed, and LeoSat will supplement its PDR at that time to include this information. The debris analysis performed on previous programs using the ELITEBUS™ 1000 platform, which is referenced above, identified in each satellite's composition small quantities (*i.e.*, up to 10 g) of Beryllium oxide, as well as some traces of Samarium Cobalt and lead used for components soldering (*i.e.*, SnPb). There is a chance that some portion of these materials could survive reentry into the Earth's atmosphere but any such materials that survive reentry will be sufficiently *de minimis* that they will not pose a threat to the environment.

The Division Letter references the *Space Data* decision in connection with this question.²³ The operation of the LeoSat System will be markedly different from the operations described in the *Space Data* decision and, as a result, LeoSat does not believe that it is relevant Commission precedent in connection with the PDR. First, LeoSat is proposing to launch a constellation of only 78 satellites. By contrast, *Space Data* proposed to launch thousands of balloon-based repeaters.²⁴ Second, when LeoSat's end-of-life satellites ultimately reenter the Earth's atmosphere (either more than 100 years or approximately 25 years after being placed in their disposal orbits depending on whether LeoSat uses a high or low disposal orbits, respectively), they will almost entirely disintegrate upon reentry. At most, only minute amounts of certain materials may reach the Earth's surface. By contrast, *Space Data*'s thousands of balloons were expected to all fall back to Earth intact.

The small number of satellites in LeoSat's constellation relative to *Space Data*'s proposed massive fleet of balloons and the negligible amount of resulting debris that may reenter the earth's atmosphere when the satellites ultimately de-orbit decades from now will result in only a minimal risk that any debris will land on environmentally protected lands and no meaningful likelihood that any such debris will have an adverse effect. Thus, LeoSat's satellites are not subject to the Commission's environmental processing rules, which to date have not been applied to other LEO satellites.

²³ *Space Data Corp.*, Memorandum Opinion and Order, 16 FCC Red 16421, ¶¶ 24-27 (WTB 2001).

²⁴ *See id.* ¶ 2.

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Should the Commission require additional information about the foregoing or otherwise in connection with the PDR, please contact the undersigned.

Sincerely,

/s/ Phillip R. Marchesiello

Phillip R. Marchesiello
Lynne M. Montgomery

Counsel to LeoSat MA, Inc.

Cc: Joseph (Cliff) Anders, Founder and President, LeoSat

ATTACHMENT A: RESULTS OF ITU SOFTWARE EPFD ANALYSIS

ATTACHMENT A

RESULTS OF ITU SOFTWARE EPFD ANALYSIS

1. Introduction

LeoSat is filing in electronic form concurrently herewith the orbit data, PFD and EIRP masks in a database that can be used with ITU Software to conduct an EPFD analysis of the LeoSat System's compliance with applicable EPFD standards. A summary of the results of such an analysis conducted by LeoSat based on the inputs is set forth in Section 2 below. They generally demonstrate LeoSat's compliance with the Article 22 EPFD limits. However, in the case of some of the EPFD_{down} results for smaller GSO antenna sizes, the ITU Software suggests that LeoSat's operations do not comply with the Article 22 EPFD values. As explained in Section 3 below, and in the Technical Appendix attached to LeoSat's PDR,²⁵ this issue is caused by the overly pessimistic modeling of NGSO FSS systems with steerable beams by the ITU Recommendations and the current ITU Software's implementation of that model. LeoSat notes that the ITU Working Group Party 4A is revising recommendation S.1503-2 to address this issue. The new approach created by WP4A is expected to introduce new technical parameters, including an NGSO earth station minimum tracking duration that allows for the protection of GSO satellite networks without significant constraints on NGSO operations. A more detailed description of how LeoSat's proposed operations comply with the Article 22 EPFD limits is provided below in Section 3.

2. ITU Software Simulation Results

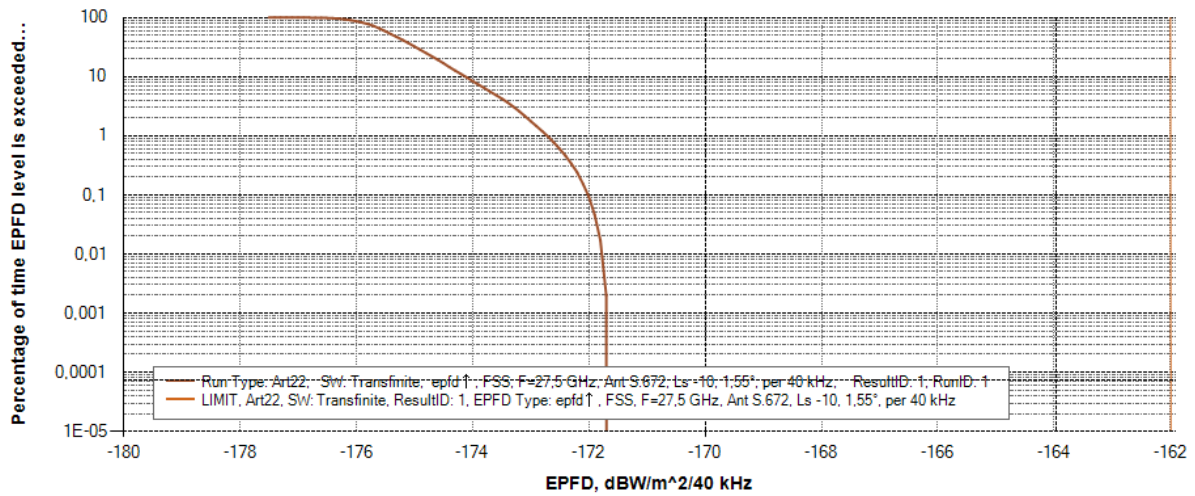
a. EPFD_{up} and EPFD_{is}

The EPFD_{up} and EPFD_{is} results generated from the ITU's EPFD validation computer program for LeoSat's Ka-band operations use the orbit data, PFD and EIRP masks as input data to generate the results below. The results demonstrate LeoSat's compliance with the Article 22 EPFD limits.

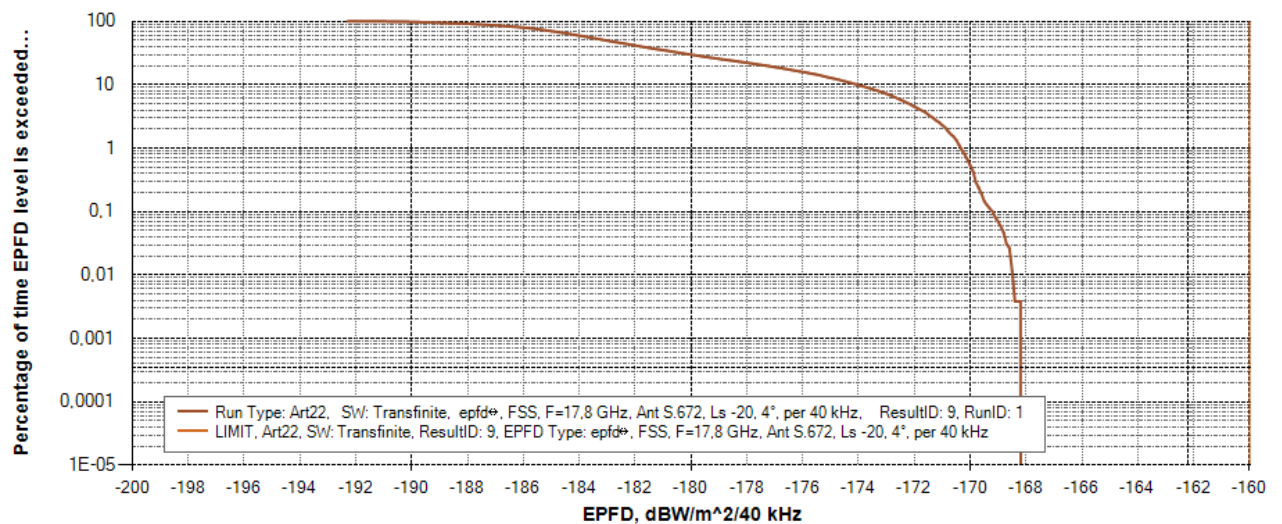
²⁵ LeoSat PDR, Technical Appendix at 28.

ATTACHMENT A: RESULTS OF ITU SOFTWARE EPFD ANALYSIS

EPFD_{up} simulation results



EPFD_{is} simulation results

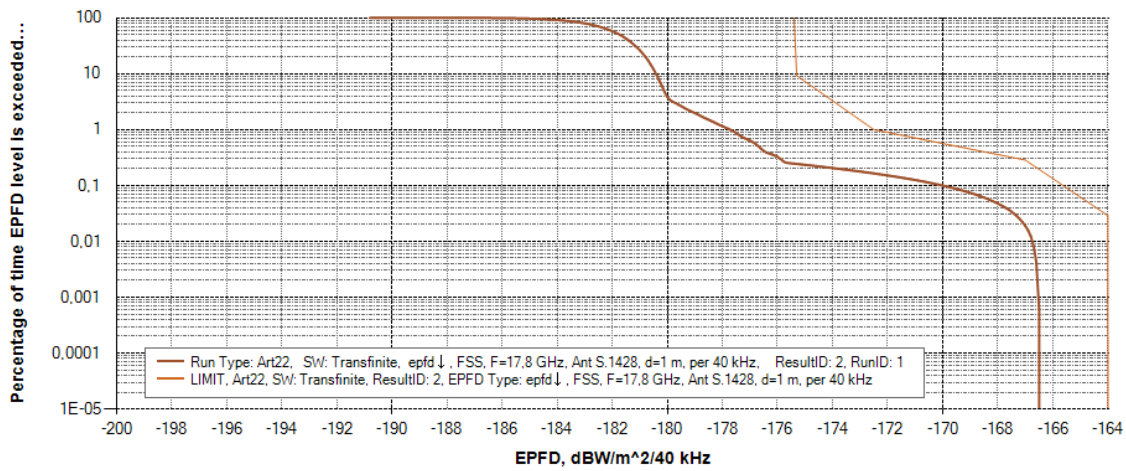


b. EPFD_{down} in the band 17.8-18.6 GHz

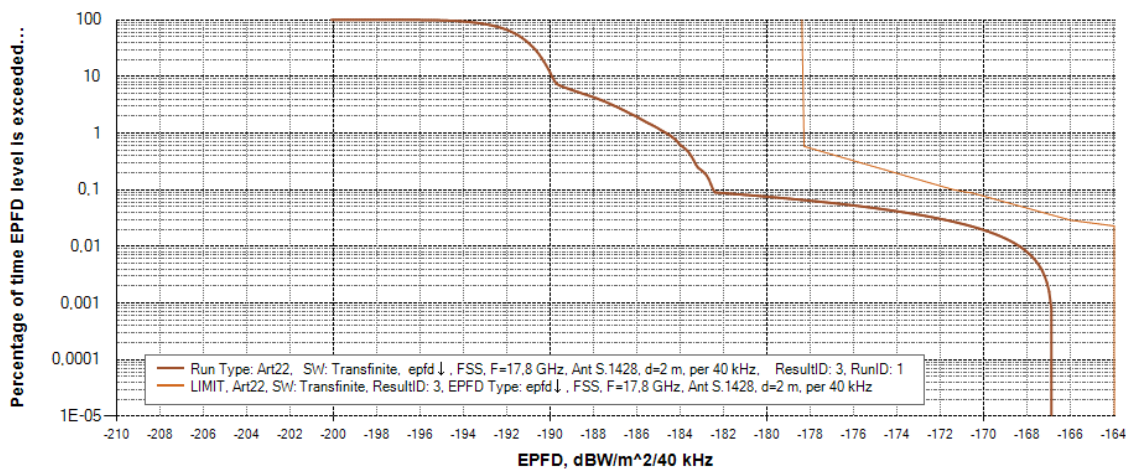
The following figures demonstrate LeoSat's compliance with the single entry EPFD limits with respect to the 17.8-18.6 GHz band. Each plot corresponds to one of the GSO reference earth station antenna sizes from EPFD limits described in ITU RR 22.5C. The labeling of each diagram provides the relevant details for each analysis generated by the software—*i.e.*, the worst case geometry (“WCG”) location and Earth station diameter.

ATTACHMENT A: RESULTS OF ITU SOFTWARE EPFD ANALYSIS

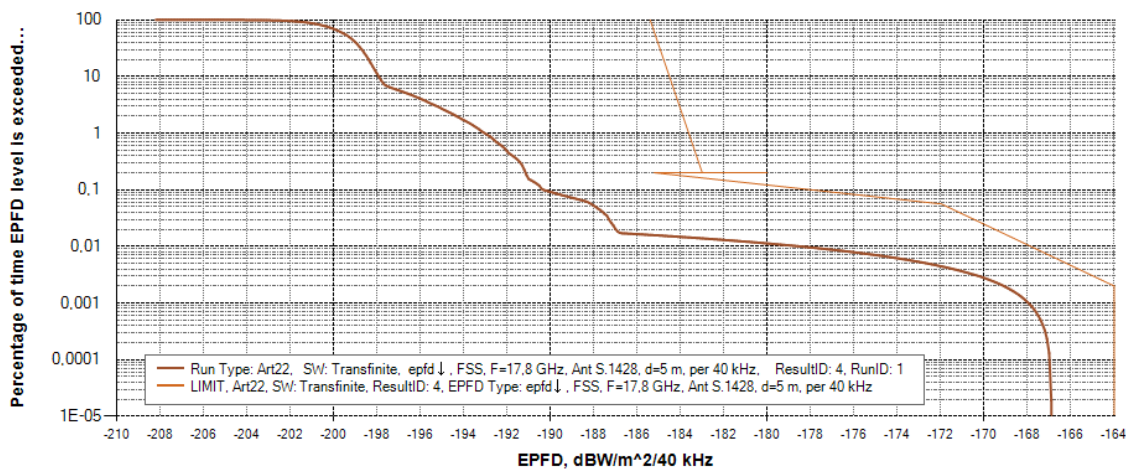
EPFD down simulation results in the bandwidth 17.8-18.6 GHz (1m GSO antenna diameter)



EPFD down simulation results in the bandwidth 17.8-18.6 GHz (2m GSO antenna diameter)



EPFD down simulation results in the bandwidth 17.8-18.6 GHz (5m GSO antenna diameter)

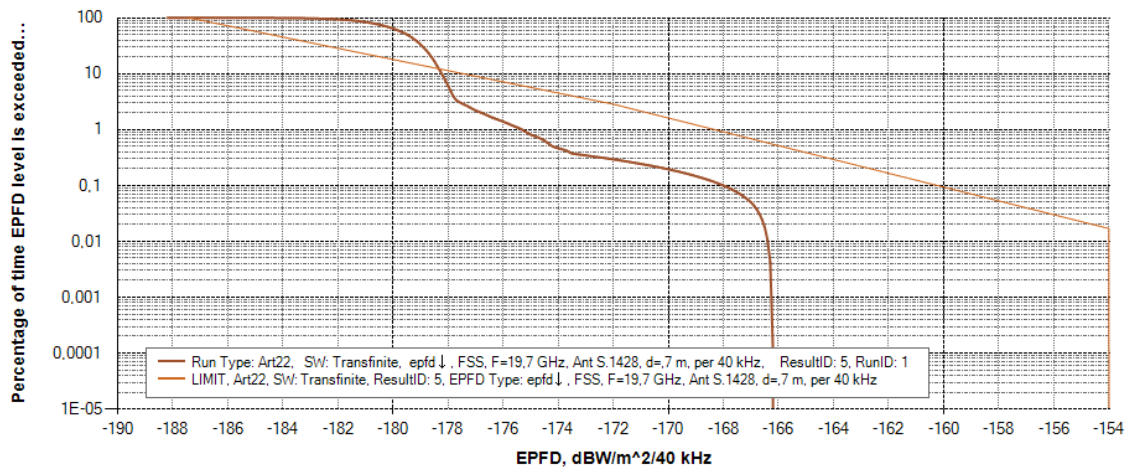


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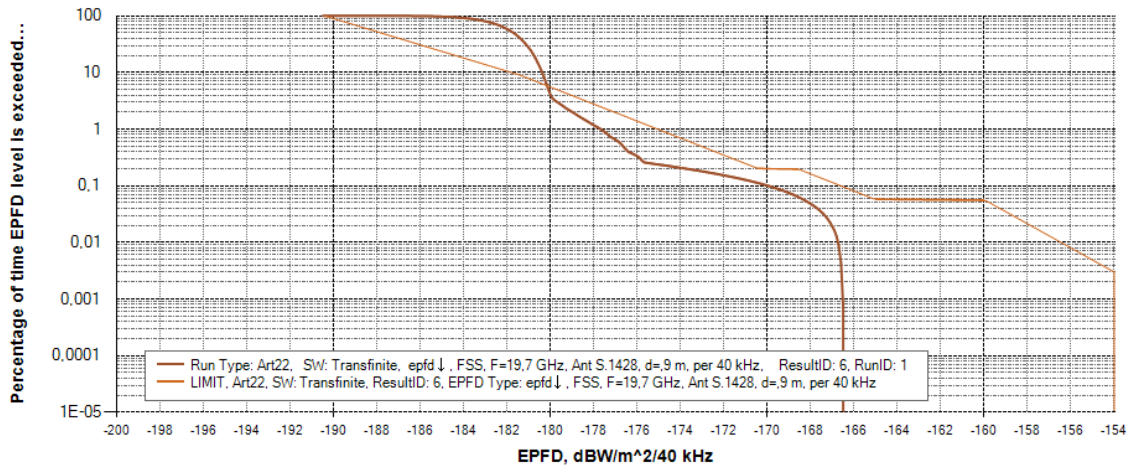
c. EPFD_{down} in the 19.7-20.2 GHz frequency band

The following figures demonstrate LeoSat's compliance with the 5m EPFD limits in the 19.7-20.2 GHz band. However, the current ITU Software results suggest that LeoSat's operations may exceed the EPFD limits for the 0.7m, 0.9m and 2.5m antenna diameter antennas. The labeling of each diagram provides the WCG location and Earth station diameter details for each analysis generated by the software.

EPFD down simulation results in the 19.7-20.2 GHz band (0.7m GSO antenna diameter)

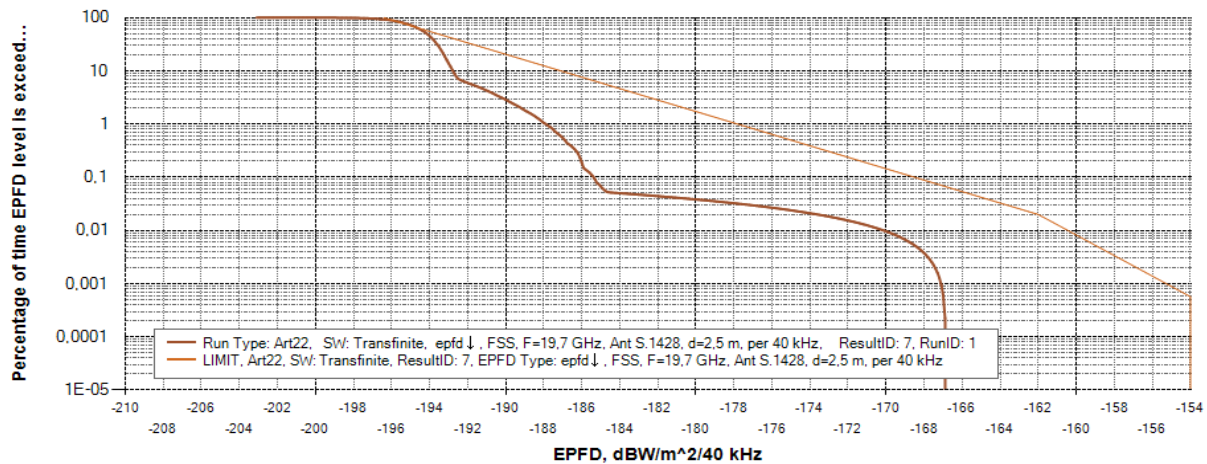


EPFD down simulation results in the 19.7-20.2 GHz band (0.9m GSO antenna diameter)

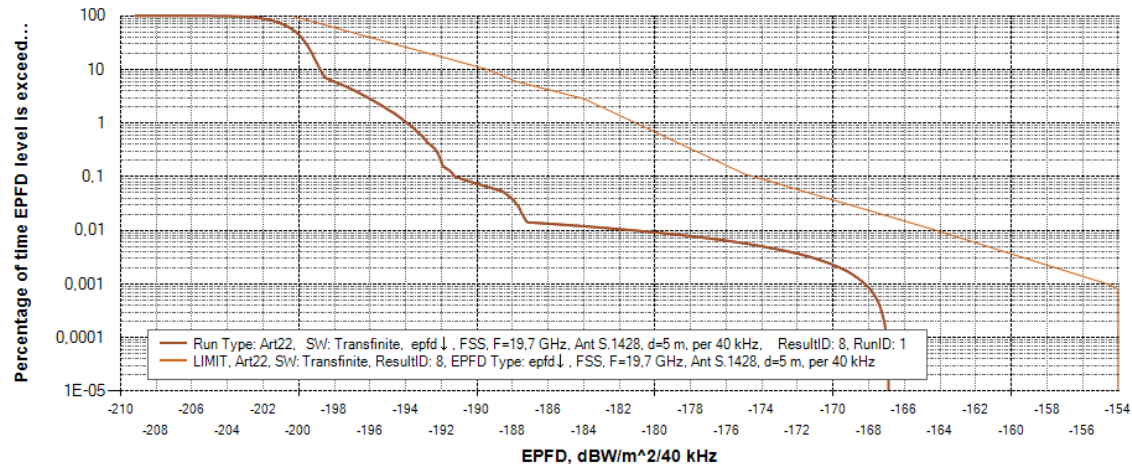


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EPFD down simulation results in the 19.7-20.2 GHz band (2.5m GSO antenna diameter)



EPFD down simulation results in the 19.7-20.2 GHz band (5m GSO antenna diameter)



3. EPFD Results Analysis

This Section 3 studies the 19.7-20.2 GHz simulation results, in particular the 0.7, 0.9 and 2.5 meter antenna diameter results because these are the only cases where the current ITU Software does not clearly demonstrate the compliance of the LeoSat System.

a. Overestimation of interference by the current Recommendation ITU-R S.1503-2 methodology

The current Recommendation ITU-R S.1503-2 methodology considers at each time step the visible NGSO satellite that will cause the worst interference, *i.e.* the satellite with the smallest angular separation to the GSO link. The above simulation results highlight that the WCG locations are located at very high latitudes. The WCG latitudes are -71.13°N, 70.90°N, and 71.43°N respectively for the 0.7, 0.9, and 2.5 meter antenna diameter simulations. At these latitudes, a large number of LeoSat satellites are visible from the ground, and the discrimination

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angle to the victim GSO link is always selected as the smallest among all visible NGSO satellites.

In reality, in the LeoSat System, a NGSO earth station will be served by a single satellite steerable beam in a given frequency band for the minimum duration necessary to maintain the link before the link is handed over to another LeoSat satellite's steerable beam. In other words, the satellite selection strategy in the LeoSat constellation for serving an earth station will decrease interference into a GSO system, compared to the model of ITU-R Recommendation S.1503-2, since the discrimination angle to the victim GSO link will be greater than the worst case for time samples. Therefore, considering the minimum duration that a LeoSat satellite steerable beam tracks its earth station, this approach not only enhances the LeoSat service, but also mitigates any interference to GSO systems. As LeoSat demonstrated in the Technical Appendix of its PDR, the minimum duration necessary to maintain the link is significantly lower at high altitudes.²⁶

In the results set forth herein, the protection criteria are exceeded by 6-7 dB when considering a worst-case satellite selection based on Recommendation ITU-R S.1503-2. However, satellite selection based on Recommendation ITU-R S.1503-2 results in an undue degradation when the number of satellites increases at high latitudes. Working Party 4A concluded that the ITU-R algorithm of Rec. ITU-R S.1503-2 has gaps and therefore does not adequately model steerable beams, as described in the ITU-R WP4A\196\Annex21 Chairman's Report.²⁷ ITU-R Working Party 4A is currently revising the Recommendation ITU-R S.1503 in order to correct these gaps, and introduce a minimum tracking duration parameter. As set forth below, if LeoSat were to run its analysis using revised ITU-R S.1503 parameters, it would meet the EPFD requirements for all relevant GSO earth stations.

b. Results with an improved Recommendation ITU-R S.1503 methodology

The results for the 0.7m, 0.9m, and 2.5m antenna diameters in the 19.7-20.2 GHz bandwidth for the EPFD algorithm described above, and in the Technical Appendix provided in the LeoSat

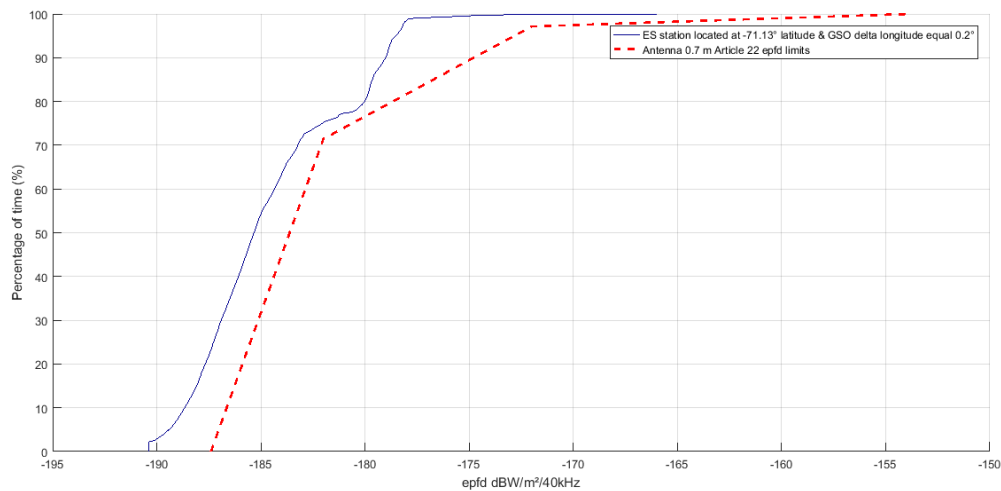
²⁶ Table 1 in LeoSat's Technical Annex of its PDR provides the minimum earth station tracking duration per latitude for the 19.7-20.2 GHz frequency band, which is set at 30 seconds at 0° and 5° latitude. This is compared to lower latitudes where the minimum earth station tracking duration is set at 700 seconds at 65° latitude. PDR, Technical Annex at 28. The minimum earth station tracking duration varies due to the number of satellites available to provide service. Several LeoSat satellites will converge on the poles at once. Given the decreased demand for service at the poles and the relative increase in satellites present to provide service as compared to service at the equator, it is not necessary for an earth station to track one satellite for a long-period of time.

²⁷ Preliminary draft revision to Recommendation ITU-R S.1503: Functional description to be used in developing software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite system networks with limits contained in Article 22 of the Radio Regulations, ITU-R WP4A/TD/161 (May 12, 2017).

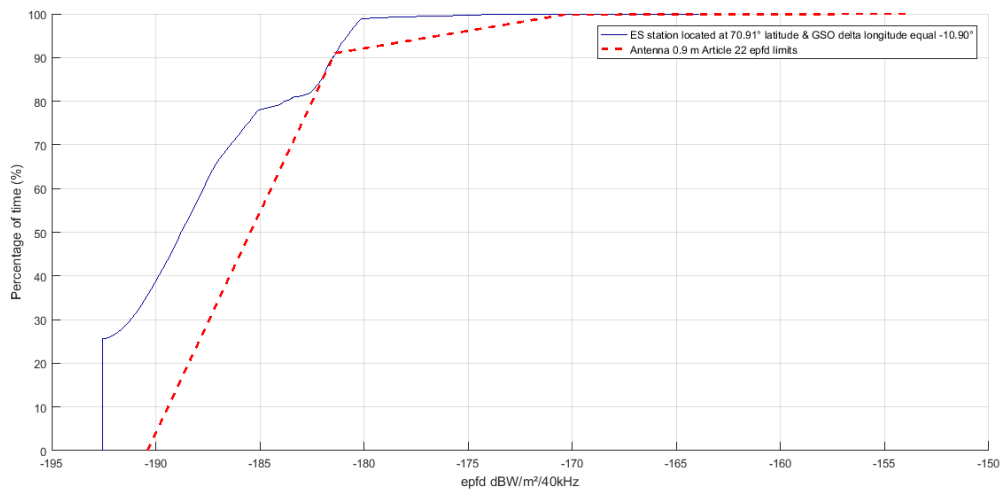
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PDR (*i.e.*, with the additional minimum tracking duration parameter) for the same WCG location demonstrate LeoSat's compliance with the Article 22 EPFD limits as shown in the figures below. The graphs provide the percentage of time during which EPFD values are not exceeded.

EPFD_{down} results with minimum tracking duration parameter (0.7m antenna)



EPFD_{down} results with minimum tracking duration parameter (0.9m antenna)



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EPFD_{down} results with minimum tracking duration parameter (2.5m antenna)

