Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
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Theia Holdings A, Inc.	)	SAT-LOA-20161115-00121
	)	Call Sign S2986
Application for Authority to Launch and Operate a Non-Geostationary Satellite Orbit System in the Fixed-Satellite Service, Mobile-Satellite Service, and Earth Exploration Satellite Service	)))))	

CONSOLIDATED OPPOSITION AND RESPONSE

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CONSOLIDATED OPPOSITION AND RESPONSE

I. SUMMARY AND INTRODUCTION

Theia Holdings A, Inc. ("Theia") hereby submits this Consolidated Opposition and Response to the petitions to deny filed by the GPS Innovation Alliance ("GPSIA"), Telesat Canada ("Telesat"), and ViaSat, Inc. ("ViaSat"), and the comments filed by Hughes Network Systems, LLC ("Hughes"), the National Aeronautical and Space Administration ("NASA"), SES S.A. and O3b Limited (together "O3b"), Space Exploration Holdings, LLC ("SpaceX"), Space Norway AS ("Space Norway"), and Spire Global, Inc. ("Spire") (collectively, such filings the "Pleadings") with respect to the above-referenced application proceeding.[1] Theia demonstrated

[1] *See* Petition to Deny or Defer of the GPS Innovation Alliance, IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("GPSIA Petition"); Petition to Deny of Telesat Canada, IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("Telesat Petition"); Petition to Deny or Impose Conditions of ViaSat, Inc., IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("ViaSat Petition"); Comments of Hughes Network Systems, LLC, IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("Hughes Comments"); Comments of NASA, IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("NASA Comments"); Comments of SES S.A. and O3b Limited, IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("O3b Comments"); Comments of Space Exploration Technologies, Corp., IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("SpaceX Comments"); Comments of Space Norway AS, IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("Space Norway Comments"); Comments of Spire

in its application, which is a part of the Commission's Ku-band/Ka-band processing round (the "FCC Processing Round"),[2] that its proposed operations will comply with applicable Commission rules and International Telecommunication Union ("ITU") regulations or otherwise warrant waivers of those requirements.[3] Moreover, Theia stated expressly in its application that it will coordinate operations in all relevant frequency bands, including specifically the 1215-1300 MHz band allocated for Earth-Exploration Satellite Service (active) and, in fact, had already begun that process. Nothing in the Pleadings rebuts Theia's showings, much less justifies denial of Theia's application or the imposition of any special license conditions, as explained herein.

The Commission should deny the Petition to Deny filed by the GPSIA. The GPSIA sensationally overstates the potential interference of Theia's proposed L-band radar operations in the 1215-1300 MHz band to any Global Navigation Satellite System ("GNSS"), including the Global Positioning System ("GPS"). A number of ITU reports and recommendations, as well as tests performed by the Japan Aerospace Exploration Agency ("JAXA"), the Jet Propulsion Lab, and Theia, demonstrate that space-based L-band radars do not cause harmful interfere to GPS systems in the 1215-1300 MHz band.[4] Furthermore, the JAXA PALSAR-2 has been operating

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Global, Inc., IBFS File No. SAT-LOA-20161115-00121, *et al.* (filed June 26, 2017) ("Spire Comments").

[2] The application is also a part of the Commission's V-band processing round. *See Boeing Application Accepted For Filing In Part; Cut-Off Established For Additional NGSO-Like Satellite Applications Or Petitions For Operations In The 37.5-40.0 GHz, 40.0-42.40 GHz, 47.2-50.2 GHz And 50.4-51.4 GHz Band*s, Public Notice, 31 FCC Rcd 11957 (IB Nov. 1, 2016); *see also* Application, IBFS File No. SAT-AMD-20170301-00029 (filed March 1, 2017).

[3] *See, e.g.*, Theia Holdings A, Inc. Application, SAT-LOA-20161115-00121 at 4 (filed Nov. 15, 2016) ("Theia Application").

[4] *See* ITU, *Pulsed radio frequency signal impact measurements and possible mitigation techniques between Earth exploration-satellite service (active) systems and radionavigation*

since 2014 in a mode almost identical to that planned by Theia (and the PALSAR-2 predecessors were previously in operations since 1992) with no known interference issues.[5]

Although Theia will operate 52 L-band radar satellites, Theia will ensure that its satellites do not illuminate any location that is already illuminated by another L-band radar, whether operated by Theia or another satellite operator. Indeed, doing so is critical to ensure that Theia's L-band radar measurements are accurate.

Contrary to the position of the GPSIA, L-band radar coordination among approximately 60 satellites (52 controlled by Theia) would not be impossible. In fact, such coordination is straightforward and essentially analogous to the coordination of communications links that occur every day among satellite operators. Indeed, coordination of L-band radar operations for approximately 60 satellites would be far easier than the coordination of the thousands of satellites associated with the FCC Processing Round, which itself is nonetheless a manageable task.

Theia is aware that industry, consumers, and governments rely on GNSS-type systems, including GPS. Theia's own services will depend on the continued ability of its customers to receive GNSS-type signals and accurately match location with various Theia geo-physical analytic products. Thus, separate from any regulatory obligations, Theia is strongly motivated and committed to ensuring that its L-band radar operations will not cause harmful interference to GNSS-type operations.

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satellite service systems and networks in the band 1215-1300 MHz, Report ITU-R RS.2311-0 at 19 (Sept. 2014); ITU, *Feasibility of Sharing between Radionavigation-Satellite Service Receivers and the Earth Exploration-Satellite (Active) and Space Research (Active) Services in the 1215-1260 MHz Band*, Recommendation ITU-R RS.1347 at 7 (1998).

[5] *See* ALOS-2 / PALSAR-2, ALOS Research and Application Project of EORC, JAXA, http://www.eorc.jaxa.jp/ALOS-2/en/about/palsar2.htm (last visited July 6, 2017).

Prior to submitting its application in November 2016, Theia initiated discussions regarding its proposed radar operations with multiple GPS stakeholders, including the spectrum management office of NASA, the United States Air Force, and other representatives of the GPS Directorate, contrary to the unsubstantiated statements of the GPSIA otherwise.[6] Similarly, Theia has begun discussions with other interested parties about L-band radar operations, including other commenters to this proceeding, and at this time there do not appear to be any technical reasons why all the identified issues cannot be easily resolved.

With respect to the other Pleadings, the majority of the filings, including the petitions to deny filed by ViaSat and Telesat (both of which are participants in the FCC Processing Round), raise interference, spectrum sharing, and/or international coordination issues applicable to all participants in the FCC Processing Round and request the Commission to deny Theia's application or condition grant of the license on compliance with specified requirements. The Commission has made clear in its recent decision to grant OneWeb's market access request that such broad issues should be resolved in rulemaking proceedings of general applicability,[7] including specifically the *NGSO FSS NPRM* proceeding,[8] and are not a basis for denial or delay

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[6] *See* Theia Application at 18 ("Theia is actively engaged with NASA, the GPS Directorate and other stakeholders regarding spectrum access and compatibility issues."); *id*., Technical Appendix, at 19 n. 10 (coordination process with radio navigation satellite service community are underway); *compare* GPSIA Petition to Deny at 7 ("Theia's proposal does not present any plan to coordinate with the GPS and GNSS stakeholders.").

[7] *See, e.g., In the Matter of WorldVu's Satellite Limited, Petition for a Declaratory Ruling Granting Access to the U.S. Market for the OneWeb NGSO FSS System*, Order and Declaratory Ruling, DA FCC 17-77 ¶ 5 (June 23, 2017) ("*OneWeb Order*") ("[W]e defer matters of general applicability to ongoing or potential future rulemakings.").

[8] *See Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, Notice of Proposed Rulemaking, 31 FCC Rcd 13651 (rel. Dec. 15, 2016) ("*NGSO FSS NPRM*").

in granting applications submitted in the FCC Processing Round.[9] None of these Pleadings provide any basis for deviating from that conclusion.

That same analysis supports rejecting the proposals to impose special license conditions on the grant of Theia's application for other matters of general applicability.[10] In particular, to the extent the Commission believes it should adopt new orbital debris rules regarding satellite design and fabrication reliability and collision avoidance requirements, the Commission should address any such new rules in an appropriate notice and comment rulemaking proceeding. Those issues are of general applicability and could impact other entities that are not a part of Theia's license application proceeding or even the application or market access proceedings of the other participants in the FCC Processing Round.

Nevertheless, Theia recognizes the importance of being a responsible space actor. In its filing on April 14, 2017 in response to a Commission inquiry, Theia revised its orbital debris mitigation plan to enhance physical coordination of the Theia constellation and facilitate fully controlled de-orbit of its satellites from re-entry to disposal into the ocean.[11] That proposal fully addresses the potential de-orbit collision concerns raised by various commenters, as well as the

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[9] *See OneWeb Order* at ¶ 12 (grant of OneWeb market access request prior to the conclusion of the *NGSO FSS NPRM* proceeding is not premature)

[10] Theia does not object to the grant of a license subject to any applicable conditions that the Commission imposed in the *OneWeb Order*.

[11] *See* Letter from Joseph Fargnoli, Chief Technology Officer, Theia Group, Inc. to Jose Albuquerque, Chief, Satellite Division, International Bureau, FCC, File No. SAT-LOA-20161115-00121 (Apr. 14, 2017) ("Theia April 14 FCC Response"); *see also* Letter from Jose P. Albuquerque, Chief, Satellite Division, International Bureau, FCC to Tom W. Davidson, Counsel to Theia Holdings A, Inc., File No. SAT-LOA-20161115-00121 (Mar. 15, 2017) ("FCC March 15 Letter").

Commission.[12] Because Theia's space assets will cost many millions of dollars each to construct and deploy, Theia is highly motivated to ensure the reliability of its satellites in orbit and their ability to avoid collisions with other objects during their mission lifetimes.

For the reasons summarized above and discussed herein, Theia requests that the Commission deny the petitions to deny and reject the requests in the comments to impose special conditions on the grant of Theia's application. Any licensing decision that imposes special conditions on Theia, for factors applicable to other participants in the FCC Processing Round, would be contrary to basic tenets of administrative procedure requiring the Commission to treat similarly situated parties the same.[13]

II. BACKGROUND

Theia Application. On November 15, 2016, Theia timely filed an NGSO FSS satellite application in the FCC's Ku-band/Ka-band processing round.[14] Eleven other entities, including five of the parties filing pleadings regarding Theia's application (*i.e.*, O3b, SpaceX, Space Norway, Telesat, and ViaSat), also filed NGSO FSS applications in the FCC Processing Round.[15]

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[12] In recent discussions with NASA, NASA indicated it was not aware of the Theia April 14 FCC Response. Theia is continuing to work with NASA but believes that filing largely alleviates NASA's concerns, as discussed below.

[13] *See, e.g*., *Melody Music*, *Inc. v. FCC*, 345 F.2d 730, 732-33 (D.C. Cir. 1965).

[14] *See generally* Theia Application.

[15] *See* Application of The Boeing Co., SAT-LOA-20161115-00109 (filed Nov. 15, 2016); Petition for Declaratory Ruling of Kepler Communications Inc., SAT-PDR-20161115-00114 (filed Nov. 15, 2016); Application of SpaceX, SAT-LOA-20161115-00118 (filed Nov. 15, 2016); Amendment of O3b Ltd., SAT-AMD-20161115-00116 (filed Nov. 15, 2016); Application of Audacy Corp., SAT-LOA-20161115-00117 (filed Nov. 15, 2016); Telesat Letter of Intent, SAT-PDR-20161115-00108 (filed Nov. 15, 2016); Petition for Declaratory Ruling of Space Norway AS, SAT-PDR-20161115-00111 (filed Nov. 15, 2016); Petition for Declaratory Ruling of LeoSat MA, Inc., SAT-PDR-20161115-00112 (filed Nov. 15, 2016); Petition for Declaratory

In its application, Theia demonstrated that its proposed operations will comply with applicable Commission rules and policies and sought waivers of Commission rules where necessary.[16] On March 15, 2017, the Commission requested additional information about Theia's constellation and planned operations[17] and Theia timely responded on April 14, 2017.[18] On May 26, 2017, the FCC accepted Theia's application for filing and placed the application on public notice for comment.[19]

Petitions to Deny and Comments. On June 26, 2017, nine parties submitted petitions to deny and comments regarding Theia's application.[20] Viasat and Telesat, both participants in the FCC Processing Round, filed petitions to deny raising concerns related to interference, spectrum sharing, and/or international coordination.[21] Three other participants in the FCC Processing Round, O3b, SpaceX, and Space Norway, filed comments raising similar concerns regarding sharing of spectrum between satellite systems.[22] Hughes, which operates GSO satellites, filed a letter expressing concerns regarding potential interference to GSO networks operating in the Ka-band frequencies.[23]

Ruling of ViaSat, Inc., SAT-PDR-20161115-00120 (filed Nov. 15, 2016); Application of Karousel LLC, SAT-LOA-20161115-00113 (filed Nov. 15, 2016).

[16] *See generally,* Theia Application.

[17] *See* FCC March 15 Letter.

[18] *See* Theia April 14 FCC Response.

[19] *See Cut-Off Established for Additional NGSO-Like Satellite Applications or Petitions for Operations in the 12.75-13.25 GHz, 13.85-14.0 GHz, 18.6-18.8 GHz, 19.3-20.2 GHz, and 29.1-29.5 GHz Bands*, Public Notice, 3 FCC Rcd 4180 (IB May 26, 2017).

[20] *See supra* note 1.

[21] *See generally* Telesat Petition; ViaSat Petition.

[22] *See generally* SES/O3b Comments; SpaceX Comments; Space Norway Comments.

[23] *See* Hughes Comments at 2.

The GPSIA filed a petition to deny based on concerns that Theia's proposed L-band radar operations in the 1215-1300 MHz band could cause harmful interference to the reception of GNSS-type signals, including specifically the GPS L2 signal centered at 1227 MHz.[24] Spire requested that Theia coordinate its use of the 1215-1300 MHz band to protect Spire's satellite use of GNSS-type signals for its radio-occultation operations.[25]

NASA highlighted concerns regarding the proposed orbital altitude, 800 km, for Theia's system and asked that Theia develop a "robust collision avoidance risk analysis process."[26] NASA also raised the general concern, mainly in response to SpaceX's satellite constellation, that participants seeking to deploy a large number of satellites (4,000+) may need to ensure a higher degree of reliability than NASA's current 90% standard.[27] Similarly, Spire raised general orbital debris concerns regarding the post-mission disposal plans of all of the participants in the FCC Processing Round to ensure that the participants adequately protect the operating satellites in the 400-650 km orbital environment, including those of Spire. Spire acknowledged expressly that Theia's revised orbital debris mitigation plan filed on April 14, 2017 addressed its concerns in this regard.[28]

Theia's responses to each of the Pleadings follow.

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[24] *See* GPSIA Petition at 2.

[25] *See* Spire Comments at 5-6.

[26] *See* NASA Comments at 2-3.

[27] *See* NASA Comments at 2.

[28] *See* Spire Comments at 4, n.8.

III. DISCUSSION

1. Response to the GPSIA Petition

As an initial matter, Theia emphasizes that it takes spectrum interference very seriously in all cases, but even more so with respect to GPS and GNSS. Theia fully acknowledges and supports the critical role that GNSS-type systems play in today's society. Virtually every analytic product that Theia will supply to its customers is expected to include a component of geo-referencing. The ability of Theia's customers to obtain accurate geo-referencing through GNSS-type systems and infrastructure typically will be required in order to employ Theia's products. Therefore, any deleterious interference with GNSS-type systems, regardless of the source, is directly in contravention to Theia's business interests. Theia is, and will in the future remain, committed to working with GNSS stakeholders to assure that Theia is fully aligned with them in protecting critical GNSS-type systems and receivers from interference.

That said, extensive analysis, laboratory testing, and on-orbit operations of radar satellites over the last 20 years show that radar operations in the 1215-1300 MHz band are compatible with GNSS and GPS operations. The results of many of these investigations are embodied in ITU-R reports and recommendations, only some of which the GPSIA references. Some of the more relevant ITU analyses and test reports are as follows:

- *Feasibility of Sharing between Radionavigation-Satellite Service Receivers and the Earth Exploration-Satellite (Active) and Space Research (Active) Services in the 1215-1260 MHz Band* (1998) ("Rec. ITU-R RS.1347");[29]
- *Evaluation method for pulsed interference from relevant radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service*

[29] *See* ITU, *Feasibility of Sharing between Radionavigation-Satellite Service Receivers and the Earth Exploration-Satellite (Active) and Space Research (Active) Services in the 1215-1260 MHz Band*, Recommendation ITU-R RS.1347 (1998).

systems and networks operating in the 1164-1215 MHz, 1215-1300 MHz and 1559-1610 MHz frequency bands (2012) ("Rec. ITU-R M.2030"); [30]

- *Calculation method to determine aggregate interference parameters of pulsed RF systems operating in and near the bands 1164-1215 MHz and 1215-1300 MHz that may impact radionavigation-satellite service airborne and ground-based receivers operating in those frequency bands* (2011) ("Rec. ITU-R M.2220-0");[31]
- *Potential interference from Earth exploration-satellite service (active) scatterometers into aeronautical radionavigation service systems in the frequency band 1215-1300 MHz* (2013) ("Report ITU-R RS.2273");[32] and
- *Pulsed radio frequency signal impact measurements and possible mitigation techniques between Earth exploration-satellite service (active) systems and radionavigation satellite service systems and networks in the band 1215-1300 MHz* (2014) ("Report ITU-R RS.2311-0").[33]

As a practical matter, satellite-based radar technologies have operated in the same or adjacent frequency bands as GNSS systems, including GPS, for years and have been shown to co-exist successfully. For example, PALSAR-2 has been operating since 2014 and is the third in a series of JAXA-launched space radar, which have operated in the same spectrum since 1992 (including JERS and PALSAR-1).[34]

Theia's specific responses to the arguments raised in the GPSIA Petition are as follows:

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[30] *See* ITU, *Evaluation method for pulsed interference from relevant radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1164-1215 MHz, 1215-1300 MHz and 1559-1610 MHz frequency bands*, Recommendation ITU-R M.2030 (Dec. 2012).

[31] *See* ITU, *Calculation method to determine aggregate interference parameters of pulsed RF systems operating in and near the bands 1164-1215 MHz and 1215-1300 MHz that may impact radionavigation-satellite service airborne and ground-based receivers operating in those frequency bands*, Recommendation ITU-R M.2220-0 (Oct. 2011).

[32] *See* ITU, *Potential interference from Earth exploration-satellite service (active) scatterometers into aeronautical radionavigation service systems in the frequency band 1215-1300 MHz*, Report ITU-R RS.2273 (Sept. 2013).

[33] *See* ITU, *Pulsed radio frequency signal impact measurements and possible mitigation techniques between Earth exploration-satellite service (active) systems and radionavigation satellite service systems and networks in the band 1215-1300 MHz,* Report ITU-R RS.2311-0 (Sept. 2014).

[34] *See* ALOS-2 / PALSAR-2, ALOS Research and Application Project of EORC, JAXA, http://www.eorc.jaxa.jp/ALOS-2/en/about/palsar2.htm (last visited July 6, 2017).

A. **<u>GPSIA contends that essentially any radar in the 1215-1300 MHz frequency bands, and specifically one below 1260 MHz, will cause unacceptable interference to GNSS-type receivers</u>**. With respect to the signal powers involved, the GPSIA states that the Theia radar signals would arrive with "100,000,000x" the power of GNSS-type signals[35] and give the Theia radar an "80dB advantage" over the GNSS-type signals.[36] Those sensational statements omit the massive coding gain and interference rejection achieved by GNSS-type receivers against noise sources, including those from a space-based L-band pulsed radar at the L2 frequency, a gain which, under lock conditions, amounts to as much as 175dB or more. In fact, the impact of a PALSAR or Theia-type radar signal is under 0.5dB, typical in the overall C/N_0 budget of the GNSS-type receiver, as fully substantiated in Report ITU-R RS.2311-0, which the GPSIA concedes.[37]

Theia presents three cases here to rebut the GPSIA's claim of unacceptable interference. First, using the same assumptions as Rec. ITU-R RS.1347, and assuming that the GNSS-type receiver does not saturate until -70dBW (the contrary assumption is discussed below), saturation will not occur given that the direct beam signal from a direct illumination by a Theia radar is -80.5dBW. The GNSS-type receiver will at most suffer some minor receiver-dependent degradation in C/N_0, as discussed further below. The background of this analysis is found in Theia's Schedule S, Rec. ITU-R RS-1347 and Report ITU-R RS.2311-0.[38]

The second case is where the GNSS-type receiver is not capable of handling a -70dBW input before saturating and has no saturation avoidance capability (also called "blanking").

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[35] GPSIA Petition at 4.

[36] GPSIA Petition at 5.

[37] *See* Report ITU-R RS.2311-0 at 20, Table 5; GPSIA Petition at 5.

[38] Both ITU documents apply directly to the Theia L-band radar.

These receivers sample the down-converted bandwidth near the noise floor, as the navigation signal is well below the noise level before de-spreading. The model for this case includes terms for interfering noise present on a continuous basis as well as during the pulse.[39] For the radar payload, there is no continuous source of noise.[40] Under the condition where the radar signal is present in the passband of the GNSS-type receiver, the receiver's analog to digital converter (ADC) will be saturated during the pulse interval and a short recovery period afterwards. The model for this case from ITU-R Recommendation M.2030 along with the calculation methodology from M.2220 results in an expected degradation of between 0.23dB and 0.45dB. If the radar chirp waveform does not completely overlap the GNSS receiver passband, then the result will be less degradation, proportional to the fractional part that overlaps the passband.

The third case is where the GNSS-type receiver is not capable of handling a -70dBW input before saturating but does have blanking capability. In this type of receiver, the blanker nullifies both the signal and noise components during the pulse interval and a recovery period afterwards. This model also includes continuous interference if present, but does not apply here, because the radar has no continuous noise term. As with the second model, it is assumed that the radar pulse levels are above the noise floor and dynamic range of the ADC, so un-blanked ADC outputs would have been saturated. As expected, the result of this model shows somewhat less C/N_0 degradation than the model for saturating receivers without blanking. Again, the same statement can be made that if the radar chirp pulse does not fully overlap the GNSS signal bandwidth, the degradation will be reduced by the fractional overlap ratio.

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[39] *See* Rec. ITU-R M.2030 at 5-6.

[40] *See* Rec. ITU-R M.2030 at 11.

Results from Theia's calculations (based on ITU models), as well as the measurements provided in the ITU documents for radars very similar to Theia's, show degradations of less than 0.5dB for C/N_0. To put this in context, typical GPS receivers operating with commercial code (not the L2 code which is more robust at rejecting interference) operate at C/N_0 nearly always exceeding 20dB, and often as high as 35dB or higher.

Comparing the degradation due to the presence of the Theia space-based radar emission against other more common signal losses is instructive. Consumer grade GNSS-type receivers such as those found in smartphones have very poor antennas whose orientation is not well controlled and often experience C/N_0 losses exceeding 10dB, without apparent degradation in overall performance. In conclusion, on the matter of interference of one Theia L-band radar, Report ITU-R RS.2311-0 and Rec. ITU-R RS-1347 unmistakably conclude that space-based pulsed L-band radars such as Theia's, can operate in the 1215-1300 MHz spectrum without causing loss of capability in a GNSS-type receiver.

Further, PALSAR-2 has been operating successfully since 2014 in a mode almost identical to that planned by Theia and is the third in a series of JAXA-launched space radar which have operated in the same spectrum since 1992 (including JERS and PALSAR-1).[41] The PALSAR-2 space-borne radar system has a selectable center frequency of 1236.5, 1257.5 or 1278.5 MHz that can be stretched to bandwidths of 84, 42, 28 or 14 MHz.[42] There have been no

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[41] *See* Yukihiro Kankaku *et al*., *The Overview of the L-band SAR Onboard ALOS-2*, Progress In Electromagnetics Research Symposium Proceedings, Moscow, Russia 735, 739 (Aug. 18-21, 2009); *see also* Ake Rosenqvist, *et al*., *ALOS PALSAR: Technical outline and mission concepts, 4th International Symposium on Retrieval of Bio- and Geophysical Parameters from SAR Data for Land Applications*, Innsbruck, Austria (Nov. 16-19, 2004).

[42] *See* Yukihiro Kankaku *et al*., *The Overview of the L-band SAR Onboard ALOS-2*, Progress In Electromagnetics Research Symposium Proceedings, Moscow, Russia 735, 739 (Aug. 18-21, 2009).

substantiated complaints to Theia's knowledge about harmful interference from these radars since the start of the JAXA L-band radar missions in 1992.

B. **GPSIA contends that Theia should have undertaken an analysis of interference**. As noted above, the JAXA PALSAR-2 radar is materially indistinguishable from Theia's proposed L-band radar with respect to the signals they each employ to illuminate the earth.[43] Because ITU documents conclude that the PALSAR-2 radar does not interfere with GNSS-type signaling, potential interference details were not previously presented in Theia's application.[44] Nevertheless, Theia has performed such simulations, produced results and reached the same conclusions as the ITU studies identified above.[45]

C. **GPSIA contends that it will be impossible for Theia to coordinate its 52 L-band radar satellites with each other and with the other operational L-band radar satellites such that the C/N_0 degradation that might be caused by one radar does not accumulate as might be the case if multiple radars illuminate the same place on earth**.[46] The GPSIA concedes that a single Theia satellite would generate less than approximately 0.5dB degradation in C/N_0.[47] This value is not materially different from Theia's calculations. GPSIA erroneously argues, however, that because Theia will have 52 L-band radars in operation, any interference possibly caused by one will be multiplied because it will be impossible for Theia to coordinate its radar satellites (either within its own constellation, or in coordination with other existing L-

[43] *See* Theia Application, Technical Narrative at 18-19.

[44] *See, e.g.,* Rec. ITU-R RS.2311-0; Rec. ITU-R RS.1347.

[45] *See supra* Section III.1.A.

[46] *See* GPSIA Petition at 7.

[47] *See* GPSIA Petition at 5.

band radars already deployed in space) to avoid multiple active L-band radar signals illuminating the same point on earth at the same time.[48]

GPSIA's argument fails to recognize that the orbital and planned operational elements of the Theia satellites result in approximately 11 hours revisit time over most of the earth, meaning there is no less than 11 hours between the times when a Theia radar-equipped satellite sweeps its beam by the same place on earth again.[49] In their primary operating mode, Theia radar satellites are not randomly pointing at different spots according to a tasking queue, but rather are simply continuously strip mapping along a track, with a look angles less than 20 degrees off nadir. Strip mapping mode is the most benign radar operating mode. The radar beam is effectively dragged across the earth's surface and is not maintained on a fixed patch on the ground. Thus, a single location on the ground would be illuminated by a beam for less than one second.

Because Theia satellites will operate in sun-synchronous orbits, the satellite orbit paths will converge at the polar region, creating limited regions where there is a possibility of two Theia radar-equipped satellites illuminating the same place at the same time. However, per the system design, Theia will shut down all but one radar as its radar-equipped satellites approach orbit convergence points. Theia must do this regardless of any GNSS-type interference issues, because multiple radars illuminating the same place at the same time would amount to Theia's radar instruments jamming each other. Moreover, only victim receivers inside the narrow beam would suffer the stated degradation of less than 0.5dB in C/N_0, and even then for less than one second, as discussed above.

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[48] *See* GPSIA Petition at 7 ("Theia's proposal ... does [not] deal with the practical impossibility of coordinating [its] proposed extensive and continuous SAR emissions with existing and planned systems.").

[49] *See* Theia's original orbital elements filing and technical description.

More generally, GPSIA's argument that Theia cannot possibly coordinate its 52 satellites in regular planned orbits with a small number of NASA or other U.S. Federal satellites (or any other plausible number of satellites, for that matter) is simply illogical. To the contrary, such coordination is straightforward and essentially analogous to the coordination of communications links that occur every day among satellite operators. Indeed, coordination of L-band radar operations for approximately 60 satellites would be far easier than the coordination of the thousands of satellites associated with the FCC Processing Round, which itself is, nonetheless, a manageable task.

Theia has already extensively simulated the orbits of the small number of other L-band radar satellites and understands the limited potential for illumination of the same place on earth with multiple beams from different satellites. Because Theia knows the precise orbits and fields-of-view for every other L-band radar satellite in space, Theia can ensure that Theia's satellites will not purposely illuminate the same place on earth at the same time as any of the other operator's L-band radar assets and, as indicated above, has a commercial incentive not to have multiple radars illuminating the same place at the same time.[50]

D. **GPSIA contends that Theia should move its radar primary frequencies to another band much higher in frequency than L-band**. As a preliminary matter, the 1215-1300 MHz spectrum is specifically allocated for EESS (active) under both the ITU and U.S. Table of Frequency Allocations.[51] Accordingly, Theia is well within its rights to request authority to deploy an L-band radar system. The fact that there are EESS (active) allocations in

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[50] Even without direct knowledge of any other operator's particular radar tasking plan moment-by-moment, Theia can carve out a Theia "do-not-illuminate" zone consisting of the other satellite's field-of-view, as they move over the earth in their orbits.

[51] *See generally* 47 C.F.R. § 2.106; ITU RR Art. 5.

other frequency bands is irrelevant and ignores the critical scientific and technical basis for employing the L-band frequencies. Like the L-band radars of other operators, Theia's L-band radar is responsive to soil properties, water content of soils, root density in agriculture, forests and grasslands, and other sub-surface phenomena related to minerals and oil and gas deposits and water aquifers. In contrast, higher frequency radar cannot penetrate surface foliage and soils and, thus, cannot be used to study soil and sub-surface phenomena in the same way possible with an L-band radar. Information that an L-band radar contains, but other higher frequency radars do not, is also critical to understanding water and carbon cycles on earth, which are directly associated with global warming at a macro level, and the ability of small-hold farmers to successfully grow food at the micro level.

Theia is already working with scientists who lost an initial capability to produce ground-breaking research in these areas due to the loss of NASA's SMAP L-band radar capability which transmitted at 1260 MHz.[52] A core benefit to the public of Theia's system involves the ability of Theia to support agriculture and underground natural resources exploration, which requires the L-band radar specifically. In short, it is not possible for Theia to support basic science, NASA researchers and many of its core business products if the company were to move to other radar frequency bands.

In conclusion, the GPSIA's major contentions regarding interference can be addressed by straightforward coordination or simply do not apply to Theia's situation. Theia has established in multiple ways – including by simple calculations recommended by the ITU, ITU's own published conclusions, and comparison to the nearly identical operating L-band space-based

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[52] *See* News | NASA Soil Moisture Radar Ends Operations, Mission Science Continues (Sept. 2, 2015), https://www.jpl.nasa.gov/news/news.php?feature=4710 (last visited July 7, 2017).

radars – that the Theia L-band radars will not interfere with GNSS-type systems. Accordingly, Theia respectfully requests the Commission to deny the GPSIA Petition.

2. Response to Telesat Petition

Telesat, which is a participant in the FCC Processing Round, requests that the Commission deny the Theia application, as well as all the other applications or market access requests submitted in the FCC Processing Round, based on general interference and spectrum sharing concerns and the relative ITU priority of Telesat's proposed system.[53] The Commission should reject Telesat's request.

This license application proceeding is not the appropriate forum to address the generic interference and spectrum sharing concerns that Telesat has raised, as the Commission made clear in the *OneWeb Order*.[54] Issues of general applicability should be resolved in appropriate rulemaking proceedings, such as the *NGSO FSS NPRM* proceeding, which Telesat effectively concedes.[55] Moreover, such general issues are not a basis for denial or delay in granting applications submitted in the FCC Processing Round.[56]

An applicant's relative ITU priority is also not a basis for denial or delay in granting a license application. The Commission has stated on numerous occasions, including recently in the *OneWeb Order,* that "[c]ompliance with ITU coordination procedures is a requirement of the

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[53] *See generally* Telesat Petition.

[54] *See OneWeb Order* ¶¶ 5, 12.

[55] *See* Telesat Petition at 2, n.4 (acknowledging that the Commission is developing spectrum sharing rules in the pending *NGSO FSS NPRM* proceeding and that participants in the FCC Processing Round will need to comply with those rules).

[56] *See OneWeb Order* ¶¶ 5, 12. Without prejudice to Theia's rights to contribute to, or oppose, rules which may be adopted in the future, Theia does not object to the grant of a license subject to any applicable conditions that the Commission imposed in the *OneWeb Order*.

ITU Radio Regulations, which hold the force of treaty to which the United States is a party."[57] Moreover, a licensee's participation in the international coordination process is required expressly under the Commission's rule, 47 C.F.R. § 25.111(b). While Theia has no objection to a license condition that simply reiterates its existing obligations under the Commission's rules, Theia submits that imposing such a license condition is unnecessary and processing such a request is a waste of Commission resources. To the extent that Telesat seeks to expand Theia's responsibilities as codified in 47 C.F.R. § 25.111(b), the Commission should deny that request as unjustified.[58]

Nevertheless, for completeness, Theia submits that coordination of the Theia system with the Telesat system should be readily achievable. Theia has run simulations of the proposed constellations, which show that coordination will be straightforward without any deleterious effects on either constellation. Assuming a protection angle of 5 degrees for the purpose of this rebuttal, the percentage of time that an in-line interference event would occur between Theia and Telesat constellations is less than 1% over most of the earth. In other words, less than 1% of the time, Theia and Telesat space stations will be in positions such that any coordination is required to avoid interference at co-located earth stations. A chart showing the in-line event frequency from an earth-station perspective is shown below in Appendix A. This chart shows the

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[57] *See OneWeb Order* at ¶ 9, n.35. ITU Radio Regulations require that both parties to a coordination must "make every possible mutual effort to overcome [coordination] difficulties." *See* ITU RR No. 9.53.

[58] *See Intelsat North America LLC*, Order and Authorization, 24 FCC Rcd 7058, 7061 ¶ 19 (IB May 26, 2009) (rejecting proposal to impose unjustified license condition to expand an applicant's international coordination responsibilities).

protection angle along the horizontal axis and the percentage of time an earth station at the indicated latitude would see in-line interference between Theia and Telesat.[59]

3. Response to ViaSat Petition

ViaSat, which also submitted an application in the FCC Processing Round, requests that the Commission deny essentially all of the applications and market access requests submitted by the other participants in the FCC Processing Round.[60] ViaSat primarily contends that technical parameters that the Commission has proposed in the pending *NGSO FSS NPRM* proceeding are inadequate to protect GSO systems sharing the Ka-band frequencies. As an alternative to the denial of the applications, ViaSat proposes that the grants of authority be conditioned on (i) compliance with applicable future rules and (ii) the requirement that each and every NGSO operator be responsible for the aggregate interference caused by NGSO systems until an aggregate limit is established. The Commission should reject ViaSat's requests.

As discussed above, this license application proceeding is not the appropriate forum to address broad interference and spectrum sharing concerns, as the Commission made clear in the *OneWeb Order*.[61] Such issues should be resolved in appropriate rulemaking proceedings, such as the *NGSO FSS NPRM* proceeding, which ViaSat effectively concedes.[62] Moreover, as the OneWeb Order makes clear, these issues are not a basis for denial or delay in granting applications submitted in the FCC Processing Round.[63]

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[59] Theia has run other simulations as well, producing similar results.

[60] ViaSat Petition at 1. ViaSat did not file a Petition to Deny OneWeb's application.

[61] *See OneWeb Order* ¶¶ 5, 12.

[62] *See* ViaSat Petition at 3 (requesting that the Commission condition grant of any licenses on compliance with sharing rules developed in the *NGSO FSS NPRM* proceeding).

[63] *See OneWeb Order* ¶¶ 5, 12.

4. Response to SpaceX Comments

SpaceX argues that Theia's proposed use is not well justified, Theia's EIRP for its uplinks is too high and will interfere with SpaceX, and Theia's de-orbit reliability is deficient. Theia responses are as follows:

A. **SpaceX argues that its proposed use of spectrum is superior and Theia' proposed use of the spectrum is not well justified**. While Theia is aware of no Commission requirement to demonstrate that its proposed use of spectrum is superior to that of any other applicant in an FCC satellite processing round, such as SpaceX, or is otherwise justified, for completeness, Theia respectfully disagrees with SpaceX's unsubstantiated position. Theia has proposed a revolutionary remote sensing and communications satellite system intended to accelerate solutions to multiple social and economic problems, and promote creative disruption in multiple physical industries, such as natural resources exploration and development, agriculture, infrastructure, insurance and finance, global physical trade, and commercial intelligence and security. To provide such transformational solutions, Theia's satellite constellation will be generating and downlinking nearly 8.4 petabytes of data per day, as explained below.

Machine-to-Machine ("M2M") and Internet of Things ("IoT") network demand is expected to surge in the coming years. According to Cisco, approximately 46% of all networked devices in 2020 will be Machine-to-Machine (M2M) or Internet of Things (IoT) devices.[64] The NTIA and the U.S. Department of Commerce consider IoT to be the fourth industrial revolution,

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[64] *See* Press Release, Cisco, Cisco Visual Networking Index Predicts Near-Tripling of IP Traffic by 2020, https://newsroom.cisco.com/press-release-content?type=press-release&articleId=1771211 (last visited July 6, 2017).

as important as the steam engine, and even as important as the internet itself,[65] but separate from it. In studies performed for the US government, MITRE Corp. states that "IoT is poised to become the largest contributor to network traffic in the next five years."[66] IDC projects that network data volume for IoT data will be growing 5 times as fast as all other network data. The National Telecommunications and Information Administration (NTIA) observes:

> The prospective benefits of IoT to personal convenience, public safety, efficiency, and the environment are clear… between the years of 2015 and 2020, the number of [IoT] connected devices in the United States will nearly double from 2.3 billion to 4.1 billion… the expected increase in connected devices associated with IoT will dramatically increase demands upon the nation's information and communications infrastructure… IoT will depend upon both public and private communications networks, and will use various wireline and wireless modes, including satellite, often in combination or on an interdependent basis.[67]

By any measure, including the U.S. government's own formal findings, IoT-type devices already number approximately 10 times greater in the U.S. alone than the number of people, and the data volumes and connectivity associated with IoT are growing many times faster than traditional human-associated devices such as smart-phones and PCs. This has led the NTIA to further formally find, and take action on its own findings. Specifically, the Department of Commerce will enable infrastructure availability and access by:

> [c]oordinat[ing] with the private sector, as well as federal, state, and local government partners, to ensure the infrastructure to support IoT continues to expand, that access to infrastructure is inclusive and affordable, and that the

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[65] *See* U.S. Dep't of Commerce, Fourth Industrial Revolution, https://www.commerce.gov/sites/commerce.gov/files/media/images/2016/fourthindustrialrevolution.png (last visited July 6, 2017).

[66] *See* RAMSON WINDER & JOSEPH JUBINSKI, THE MITRE CORP., INTERNET OF THINGS EXAMINATION 6 (2016), https://www.mitre.org/sites/default/files/publications/16-3415-iot-examination.pdf (last visited July 6, 2017).

[67] *See* INTERNET POLICY TASK FORCE & DIGITAL ECONOMY LEADERSHIP TEAM, U.S. DEP'T OF COMMERCE, FOSTERING THE ADVANCEMENT OF THE INTERNET OF THINGS 1, 4, 16 (Jan. 2017), https://www.ntia.doc.gov/files/ntia/publications/iot_green_paper_01122017.pdf.

> infrastructure remains innovative, open, secure, interoperable, and stable. This includes promoting adoption and usage to encourage deployment and investment, and engaging in technical assistance and research and development . . . [and] [c]ontinu[ing] to innovate in spectrum management to increase access to spectrum that will help facilitate IoT growth and advancement.[68]

Theia believes it is important that the Commission differentiate between traditional Internet and M2M/IoT networks. M2M and IoT connections and devices are largely driven by machine and sensor behavior and the needs of regular sensor data collection or regular machine directives issuance, and in any event exhibit dramatically different traffic patterns than traditional internet service, which is largely driven by human behavior. Mature traffic models are beginning to emerge for both the "bits-and-bytes" of small sensor and event-driven M2M/IoT activities,[69] as well as for the continuous "megabits-and-megabytes" interchanges associated with complex machines such as jet engines in flight and oil-rigs deployed to remote locations around the world, and it is clear those traffic models are more demanding on communications links in many respects than traditional internet. In fact, significant companies are rolling out networks which are completely separated from traditional networks, specifically for that reason.[70]

Throughout its application materials, Theia referred to the underlying market and need for the satellite spectrum access requested with M2M and IoT references.[71] Unfortunately, though it deserves a separate category, there is no separate M2M/IoT communications type defined yet in ITU and Commission nomenclature or even in general technical use. While some

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[68] *Id*. at 23.

[69] *See, e.g.*, HARISH VISWANATHAN, *ET AL*., MODELING AND ANALYSIS OF CELLULAR WIRELESS MACHINE-TO-MACHINE COMMUNICATION TRAFFIC (Mar. 2012).

[70] *See, e.g.*, Coverage | Sigfox, https://www.sigfox.com/en/coverage (last visited July 6, 2017).

[71] *See, e.g.*, Theia Application at 1-2, 3, 7, 8, 13-15, 22-29.

associate M2M/IoT applications with traditional internet, when considering the use-case and dramatically different traffic model compared to traditional internet, the general EESS type-category is actually the closest analog to M2M/IoT. Furthermore, M2M/IoT uses are very closely related to the historic definition of EESS uses – both are sensing the world directly, and both are subsequently used to feed-back information extracted from sensors and remote-sensing data sets to machines. Nearly all M2M/IoT traffic is directly linked to some information, data or directive directly impacting the physical world, without necessarily any involvement on the part of a human. In contrast, the traditional internet use model and functionality is nearly always disconnected from direct access to the physical world - it is part of a virtual world where information has become available "on-line" because humans put it there in human-recognizable form.

Search engines today organize and process the on-line world, categorizing and indexing whatever has been stored there for ready access by anyone. In a similar manner, Theia's constellation will continuously capture data regarding the physical world and process and decode the raw data sets for information: time-relevant decision-grade analytic answers for physical industries. While the previous two waves of the information age – computing and communications – did little to change the core underlying business models of major physical industries, the third wave of the information age – remote sensing analytics – promises to transform mankind's understand of, and relationship to, the physical world, and enable the physical industries which underpin modern civilized life to become dramatically more efficient. Improving the efficiency of major physical industries in the physical world is critical. Over the next 30 years, the world needs to increase food production by 70% as the population grows toward 10 billion, while the amount of arable land will only expand by 5% during the same period.[72] Global warming will also render existing farmland less viable. On top of that, the demand on many of the world's physical industries will grow, as 55% of those who presently live a subsistence existence will rise up to become consumers,[73] putting 55% greater demand on infrastructure, raw materials, energy resources, and related industries.

Transforming physical industries requires two critical communications functions at the beginning and the end of the physical analytics activity ecosystem. The first critical function involves collecting in-situ sensor data and calibration data. On the other end of the activity chain, the critical communication function required is that of getting the information or decision product back into the physical industry as close as possible to the use or decision point. Traditional internet and on-line activities are driven by humans, which thus tends to concentrate use, need and bandwidth where humans live. Approximately 95% of mankind lives on about 10% of the land,[74] resulting in a dramatic geographic concentration of traditional internet terrestrial network capacity. Meanwhile, the critical communications requirements of M2M/IoT and physical industries in general are geographically spread much more evenly over the globe, including places where there is little or no terrestrial communications capacity deployed, and likely never will be.

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[72] *See* FOOD AND AGRICULTURE ORGANIZATION, UNITED NATIONS, GLOBAL AGRICULTURE TOWARDS 2050, High-Level Expert Forum (Oct. 12-13, 2009), http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf (last visited July 7, 2017).

[73] *See* David Rohde, *The Swelling Middle*, REUTERS (2012), http://www.reuters.com/middle-class-infographic (last visited July 7, 2017),

[74] *See* European Commission, Joint Research Centre (JRC), European Commission, *Urbanization: 95% Of The World's Population Lives On 10% Of The Land* (Dec. 19, 2008), *reproduced in* ScienceDaily, https://www.sciencedaily.com/releases/2008/12/081217192745.htm (last visited July 7, 2017).

As Theia further develops physical-world M2M/IoT applications, Theia's direct-to-endpoint satellite links will be employed to perform tasks as simple as collecting ground sensor and calibration data from remote places, to more complex tasks such as delivering real-time maps with situational awareness annotations to cars and trucks anywhere or delivering weekly high resolution precision farm directives to every farmer in the world. These types of M2M/IoT/EESS applications are numerous, growing dramatically and are profoundly important to the future mankind. Most importantly, they cannot be served well by terrestrial networks – they require a LEO satellite constellation to provide the necessary infrastructure.

Aside from the demands of these applications on direct-to-endpoint links, with respect to Theia's gateways and overall EESS downlink capacity, Theia's constellation will produce 8.4 petabytes per day of high resolution, high signal-to-noise ratio data in visible, non-visible and ground penetrating radar wavelengths, all of which will be put into Theia's data center for processing into various physical industry analytics to produce important and useful information.

While Theia agrees that everyone in the world should have access to the internet and the world information, it is even more important that everyone in the world first have food, water and access to the basics goods that form the foundations of civilized life. Along with others, those are the types of fundamental physical-world problems that Theia is directly addressing with its constellation, and for which it needs the requested spectrum.

SpaceX argues that Theia is not making efficient use of spectrum and has not justified its request for spectrum.[75] As a purely technical matter, Theia's link implementation includes modern spectrum-efficient features, such as power control and direct electronic beam steering with "point-and-shoot" technology. Although Theia's direct-to-endpoint communications

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[75] *See* SpaceX Comments at 1.

system could provide traditional internet service, it is designed to more effectively serve an M2M/IoT traffic model. For example, Theia's design includes direct-to-endpoint beams, which are not continuously illuminating broad swaths of the earth, but are only transmitting (or receiving) narrow beams when and as needed directly to (and from) earth terminals, minimizing the contribution by Theia's system to the in-band noise floors which created the need for the so-called "3.5 system limit." Theia's communications links are designed with many other spectrum efficient features as well.

Further, Theia meets FCC requirement §25.210(f) as demonstrated by the following excerpt from Theia's Technical Narrative:

> §25.210(f) – Full frequency re-use: Section 25.210(f) of the Commission's rules requires the space station to employ state-of-the-art full frequency reuse. The TSN satellites fully comply with this requirement. Ku-band user links employ four color frequency reuse on the uplink distributed through the 169 uplink beams in the satellite footprint, an effective frequency reuse of more than 42 times. These user links employ both polarizations. Similarly, for the Ku-band downlink, the TSN satellites employ as many as 40 simultaneous downlink beams with full downlink data rate, providing a 40 times reuse factor. Gateways are planned for locations at relatively high latitudes, affording simultaneous access to a number of satellites. This simultaneous access as well as the ability to communicate on both polarizations at Ka-band provides significant reuse of this spectrum as well.

With respect to Theia's spectrum needs, Theia satellite constellation will be generating and downlinking nearly 8.4 petabytes of data per day from its remote sensing sensors. Even with extensive data compression and data reductions, the data generated from the constellation will require heavy use of the spectrum requested. Furthermore, a satellite that can effectively operate anywhere within the Ku and Ka bands will have maximum flexibility to share and coordinate with other co-frequency NGSO systems.[76] Accordingly, SpaceX's assertion that Theia's proposed use of the requested spectrum is unsupported and totally without merit.

B. **SpaceX argues that Theia's EIRP is too high and will interfere with SpaceX's proposed operations.** SpaceX argues that the EIRP density of a Theia earth station is higher than that of a SpaceX earth station and will therefore cause unacceptable interference to its uplinks.[77] While Theia recognizes that uplink interference for NGSO spectrum sharing is an issue that requires further consideration, SpaceX's analysis is flawed.

In the first scenario, SpaceX estimates a 25% $\Delta T/T$ increase assuming that one of their satellites is within the main beam of a Theia earth station uplink. In this scenario, SpaceX points its uplink beam 30 degrees away to achieve 32.13 dB of isolation. However, the Theia uplink EIRP density is at maximum power with 12-19 dB of rain margin (depending upon link conditions). Given that this scenario has the SpaceX satellite within a Theia uplink beam and that Theia intends to implement uplink power control, there is no credible scenario where a SpaceX satellite would receive such power levels from a Theia uplink earth station. If a Theia earth station is transmitting at these maximum EIRP density levels, it is to combat a significant rain fade and any interferences received by the SpaceX satellites would benefit from a nearly identical amount of rain attenuation.

SpaceX further claims that such an interference level would render spectrum unusable anywhere within the satellite footprint during the in-line interference event. Based on this assertion, the uplink interference from GSO earth stations, which typically generate much higher

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[76] Inexplicably, SpaceX criticizes OneWeb for a lack of payload flexibility yet argues here that such flexibility is unwarranted for Theia's constellation. *See* SpaceX Petition to Deny, IBFS File No. SAT-LOI-20160428-00041 at 13-14 (filed Aug. 15, 2016).

[77] *See* SpaceX Comments at 2.

EIRP density, should be more problematic than from NGSO earth stations. If the SpaceX system cannot tolerate the uplink EIRP density from the proposed NGSO systems, it is not clear how their design will handle spectrum sharing with GSO systems.

In SpaceX's second scenario, the SpaceX satellite is exactly 10 degrees away from the boresight of a Theia uplink beam pointed towards zenith. Each system is servicing earth stations for their respective systems that are co-located. In this scenario, SpaceX estimates a 230% $\Delta T/T$ increase due to the sidelobe isolation from the Theia earth station and no sidelobe isolation from the SpaceX receive beam. Again, this analysis assumes the Theia earth station is operating at maximum power, which would only occur a very small fraction of the time during extremely heavy rain events. In addition, the analysis assumes that the interference from the Theia earth station sidelobe toward the SpaceX sidelobe, at only 10 degrees angular separation, would experience no rain fade, which is a highly improbably event.

Furthermore, it is unclear what particular levels of $\Delta T/T$ SpaceX suggests should be the protection criteria for co-frequency NGSO systems. Theia expects that Recommendation ITU-R S.1323-2 Recommends 6 would be the most likely source for an NGSO-NGSO protection criteria.[78] If this is true, it seems that SpaceX should not be worried about a particular worst-case increase in the noise floor due to the cumulative distribution function of allowable interference very similar to the EPFD curves used to protect GSO system from NGSO interference.

At bottom, the constellation proposed by Theia complies with applicable FCC rules and ITU regulations or otherwise warrant waivers of those requirements.[79] Theia acknowledges the

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[78] *See* ITU, *Maximum Permissible Levels of Interference in a Satellite Network (GSO/FSS; non-GSO/FSS; non-GSO/MSS Feeder Links)* in the Fixed-Satellite Service Caused by Other Codirectional FSS Networks Below 30 GHz,* Recommendation ITU-R S.1323-2 (Sept. 2002).

[79] *See generally* Theia Application.

pending *NGSO FSS NPRM* proceeding and that operators may need to modify their systems in the future to comply with any spectrum sharing rules that are adopted in the future. Further, Theia understands that sharing among NGSO systems will involve good faith coordination between all the operators and welcomes the opportunity to coordinate with SpaceX and the other participants in the FCC Processing Round.

C. **SpaceX argues that Theia's de-orbit reliability is deficient**. Attached as Appendix B is Theia's prior response to a Commission inquiry regarding Theia's disposal plan.[80] In that response, Theia commits to taking leadership in the reduction of orbital debris and de-orbit collision risk by affirmatively de-orbiting its satellites at end-of-life, under control, in nominally 3 days from 800 km mission altitude to re-entry into the ocean.

At a minimum, Theia's system will meet NASA's 90% de-orbit success probability requirements.[81] While Theia has not yet finalized the exact failure statistics and will be unable to do so until later in its development cycle, Theia presently estimates that the rate of failure of the critical control systems on its satellites will result in less than 0.3 satellites failing to maintain controllability over 15 years at 800 km orbit.

5. Response to Spire Comments

Spire requests that the Commission require all NGSO operators to provide end-of-life disposal plans with details on the risks of their transits across 400-650 km orbital regime.[82] Theia has previously supplied updated information in regards to disposal plans for its satellites at

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[80] *See* FCC March 15 Letter; *see also* Theia April 14 FCC Response.

[81] *See generally* Theia April 14 FCC Response.

[82] *See* Spire Comments at 4.

end-of-life in its response to a Commission request for information, which is attached hereto as Appendix B.[83]

In summary, Theia will employ very high reliability systems for ensuring that its satellites remain controllable to end-of-life re-entry, and will dispose of its satellites under full control from atmospheric re-entry to disposal into the ocean. The controlled transition from mission orbit to atmospheric re-entry and disposal will take no more than approximately 3 days. Theia's system poses no uncontrolled risk to any satellite constellations below it, and disposal activities will be fully coordinated with all satellites in orbits below Theia's orbit altitude during the brief disposal period, including Spire's satellites.

Spire also requests that Theia be required to coordinate its use of the 1215-1300 MHz band with Spire in regards to Spire's radio occultation application. Theia has had initial discussions with Spire and plans to continue with coordination efforts with Spire. At this time, Theia believes there are no technical reasons why a satisfactory resolution to concerns Spire has raised have cannot be resolved between the parties. As discussed above, Theia is also more generally in discussions with a broader group of GNSS and GPS stakeholders.[84]

6. Response to O3b Comments

O3b recommends adopting certain conditions that would be applicable to all applicants in the FCC Processing Round.[85] Theia supports treating similarly situated parties the same with

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[83] *See generally* Theia April 14 FCC Response; *see also* III.4.

[84] *See supra* Section III.1.

[85] *See* O3b Comments at 8-10.

respect to the adoption of any license conditions and does not object to the grant of a license subject to any applicable conditions that the Commission imposed in the *OneWeb Order*.[86]

O3b also proposes that the Commission should not consider ITU filing priority in the matter of setting priority of spectrum use when in-line events need to be resolved between NGSO systems.[87] Although this license application proceeding is not the appropriate forum to address O3b's position in that proceeding, Theia agrees with O3b that ITU filing priority should not be considered in matters of setting priority of spectrum use when in-line events need to be resolved between NGSO systems.

7. Response to Space Norway Comments

Space Norway does not specifically address issues in Theia's application.[88] Instead, Space Norway asks that Theia and essentially all participants in the FCC Processing Round be required to comply with the interference-avoidance approach that Space Norway proposed in its various filings in the *NGSO FSS NPRM* proceeding.[89]

This license application proceeding is not the appropriate forum to address its position in that proceeding. Indeed, the Commission recently clarified in the *OneWeb Order* that issues of general applicability should be resolved in appropriate rulemaking proceedings, such as the *NGSO FSS NPRM* proceeding.[90] Such issues also are not a basis for denial or delay in granting applications submitted in the FCC Processing Round.[91]

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[86] *See generally OneWeb Order*.

[87] *See* O3b Comments at 7.

[88] *See* Space Norway Comments at 1.

[89] *See Id*.

[90] *See OneWeb Order* ¶¶ 5, 12.

[91] *See id*.

8. Response to Hughes Comments

To the extent the Hughes Comments relate to Theia's application, Hughes' comments support adopting aggregate EPFD limits as the Commission proposed in the *NGSO FSS NPRM* proceeding.[92] As discussed above, these matters are more appropriately addressed in that pending proceeding.[93]

9. Response to NASA Comments

Theia began coordinating with NASA on a number of matters before filing its NGSO FSS satellite application, including on the orbital debris matters on which NASA commented. For example, Theia recently met with NASA and went over its April 14, 2017 response,[94] which NASA had indicated that it had not yet seen prior to submitting its comments. As a result of these efforts, Theia believes NASA's concerns are now largely, if not completely, resolved.

With respect to constellation operations in the 800 km orbital altitude, Theia has followed NASA's recommendation and consulted aerospace experts, including constellation operators and NASA itself, to develop a state-of-the-art system and a robust collision avoidance risk analysis process.[95] For example, Theia invested in simulation and analysis capabilities for deterministic orbit de-confliction and has already operated its constellation in a virtual scenario for 30 days in the current space object environment. Theia commits to continued coordination with experts and stakeholders to ensure safe, collision-free activities in space.

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[92] *See, e.g.*, Hughes Comments at 3-4; *see also NGSO FSS NPRM* ¶ 19.

[93] *See supra* Section III.2.

[94] *See generally* Theia April 14 FCC Response.

[95] *See* NASA Comments at 2.

IV. CONCLUSION

For the reasons stated in this Consolidated Opposition and Response, Theia requests that the Commission deny the petitions to deny and reject the requests in the comments to impose special conditions on the grant of Theia's application. Theia's system complies with the applicable Commission rules and ITU regulations or otherwise warrant waivers of those requirements. The issues raised by various parties that are pending in ongoing rulemaking proceedings (*e.g.*, in-line interference and sharing between GSO and NGSO systems) should be resolved in those proceedings. Similarly, issues that are beyond the scope of this license application proceeding should be addressed in appropriate rulemaking proceedings. Theia has addressed all the interference issues raised by the parties and appreciates that it will need to coordinate its operations in all relevant frequency bands, including for its L-band radar operations. Accordingly, there is no basis for denial of Theia's application or the imposition of any special license conditions.

Respectfully submitted,

/s/ Joseph D. Fargnoli

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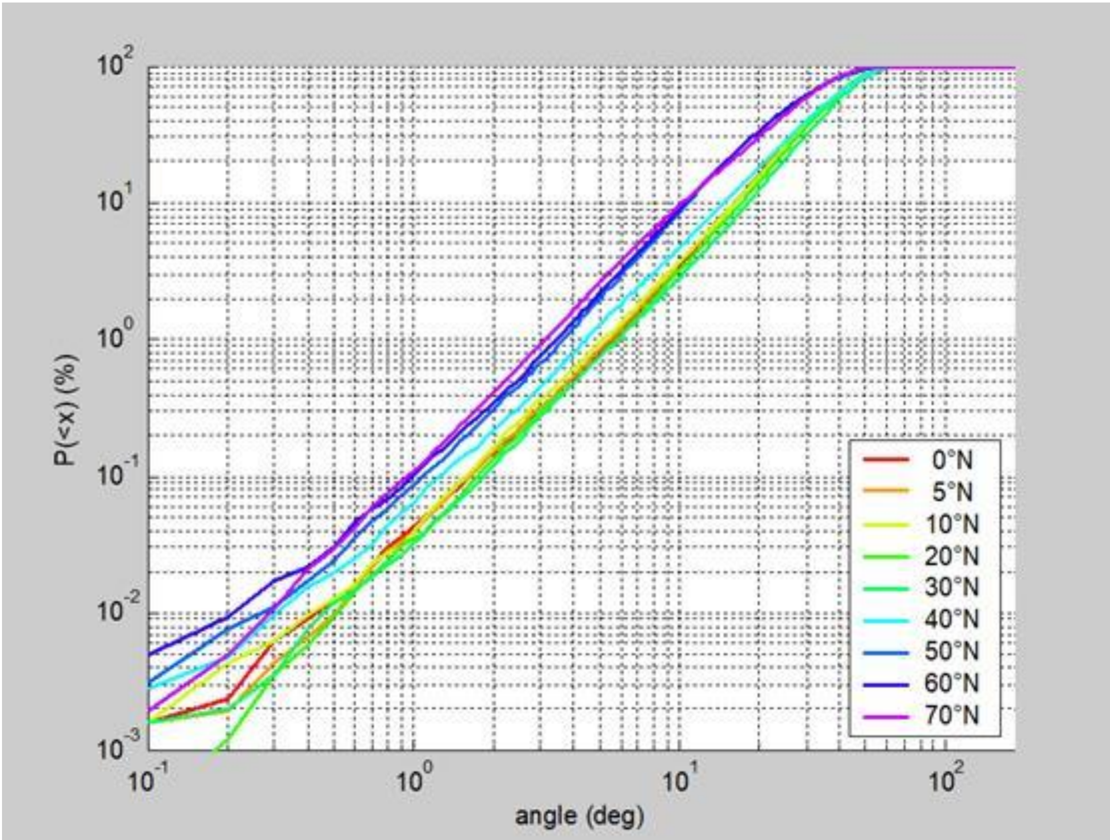
Dated: July 7, 2017

APPENDIX A



PROBABILITY OF IN-LINE INTERFERENCE BETWEEN TELESAT AND THEIA COMMUNICATIONS SATELLITES VERSUS BORESIGHT SEPARATION ANGLE, FOR AN EARTH STATION AT VARIOUS LATITUDES ON THE EARTH'S SURFACE

<u>APPENDIX B</u>

Letter from Joseph Fargnoli, Theia Group, Inc., to
Jose Albuquerque, International Bureau, Federal Communications Commission,
File No. SAT-LOA-20161115-00121 (Call Sign S2986) (April 14, 2017).

Joseph Fargnoli
Chief Technology Officer
Theia Group, Inc.
1600 Market Street
Suite 1320
Philadelphia, PA 19103

April 14, 2017

Jose P. Albuquerque
Chief, Satellite Division
International Bureau
Federal Communications Commission
Washington, D.C. 20554

Re: Response of Theia Holdings A, Inc.
File No. SAT-LOA-20161115-00121 (Call Sign S2986)

Mr. Albuquerque,

Please find attached the response of Theia Holdings A, Inc. ("Theia") to the questions provided in your letter of March 15, 2017.[1]

As described in the attached response, Theia has concluded that a minor change to the satellites in the Theia Satellite Network ("TSN") would substantially enhance the physical coordination of the TSN constellation with other NGSO systems and space objects. Specifically, Theia believes that it can and should de-orbit its satellites under affirmative control. To facilitate the controlled de-orbit of its satellites, Theia seeks to include additional propellant in the existing oversized fuel tank on the spacecraft. This minor change does not affect the DAS analysis included with Theia's original application.

Theia intends to develop and submit an application amendment at the appropriate time to effect this minor change to its satellite design. Other participants in the Commission's NGSO processing rounds may consider similar improvements to their constellation or satellite designs as a result of developments within the processing rounds. Accordingly, Theia respectfully requests Commission guidance on the following matters:

i. Whether the FCC will afford applicants within an NGSO processing an opportunity to submit application amendments by a uniform date certain (to be determined later) to effect proposed changes that may result from processing round comments, consultations,

[1] See Letter from Jose P. Albuquerque, Satellite Division, International Bureau, to Tom W. Davidson, Akin Gump Strauss Hauer & Feld LLP, File No. SAT-LOA-20161115-00121 (Call Sign S2986) dated March 15, 2017 ("FCC Letter").

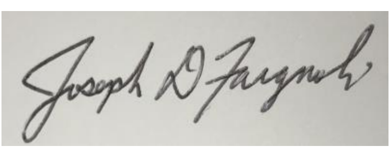
negotiations or other factors, along with any supporting argumentation and appropriate waiver requests, as it has done in prior satellite processing rounds;[2] and

ii. Whether the Commission should or must grant a waiver or forbear from applying of Section 1.65, Section 25.116 or such other provisions of the Commission's rules as necessary to permit applicants considering changes to their proposed systems to file a consolidated amendment on a uniform date certain, rather than potentially filing multiple application amendments throughout the processing round as potential changes are developed.

Theia submits that these approaches in the Commission's pending NGSO processing rounds would serve the interest of administrative convenience and preserve scarce Commission resources, while at the same time serve the public interest by enabling applicants to make necessary improvement to the proposed satellite systems and giving full effect to the Commission's application processing and amendment rules.

Finally, while this response does not constitute an amendment to its pending application, Theia would note that its desire to implement the change described herein could potentially implicate Section 1.65's continuing accuracy and completeness of information requirements and Section 25.116(c)'s amendment provisions. Theia believes that there is good cause to accept this response as an update of information of decisional significant under Section 1.65 and that the addition of fully controlled de-orbit capability should not be considered a major amendment under Section 25.116(c) because it would significantly improve physical coordination of the TSN constellation without requiring changes to the basic spacecraft design. Nonetheless, Theia reserves the right to formally request a waiver of the Commission's rules and other appropriate relief while the Commission considers the important application processing issues noted above.

Respectfully submitted,



Joseph Fargnoli
Chief Technology Officer
Theia Group, Inc.

[2] *See, e.g.*, Public Notice, *International Bureau Invites Applicants to Amend Pending V-Band Applications*, Report No. SPB-199, DA 04-234 (January 29, 2004).

THEIA HOLDINGS A, INC.
RESPONSES TO FCC QUESTIONS

The Federal Communications Commission's ("FCC" or "Commission") letter of March 15, 2017 poses a number of questions. The Commission's questions and responses of Theia Holdings A, Inc. ("Theia") follow below.

1. **Please provide an analysis of collision risk for satellites during the passive disposal phase, i.e., after all propellant is consumed. Recognizing that satellites in this phase are planned for varying initial orbits, please provide an analysis for both a worst case (all satellites at 540 km perigee) as well as an anticipated range of orbits. 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 Theia satellites would transit the ISS orbit.**

In Theia's November 15, 2016 application,[1] end-of-life disposal of satellites from the Theia Satellite Network ("TSN") was described as a series of orbit lowering maneuvers, culminating in the final disposal orbit with 610 km apogee and 540 km perigee. This plan meets FCC and NASA regulations and guidelines for satellite disposal, with a fully passivated satellite with a remaining lifetime of less than 10 years,[2] and a probability of collision with orbital debris of 0.00078.[3] Additional analysis shows that the average number of conjunctions between a Theia satellite in disposal orbit and the International Space Station ("ISS") to within 10 km is less than one event throughout the full term of the remaining satellite orbit.

Notwithstanding Theia's compliance with established FCC and NASA rules, and in recognition of the issue of the proliferation of orbital debris and the attendant increase in collision risk, Theia has concluded that it should adopt an updated plan to deorbit all satellites fully under control to atmosphere. The fully controlled deorbit plan requires an additional 145 kg of propellant on each TSN satellite, which can be accommodated in the existing tank and design.

The additional fuel will permit a fully controlled descent though a series of 5 Hohmann transfers, with a transition from a next-to-final orbit with a 170 km perigee into a final orbit with a 30 km perigee, resulting in targeted atmospheric re-entry. Further, the additional fuel permits this fully controlled descent to avoid the ISS, the Hubble Space Telescope, and all other active or passive space objects whose orbits are known. This plan obviates any ISS avoidance maneuvers and effectively eliminates collision risk with orbital debris. As the propellant tank in the original design is of sufficient volume to accommodate the additional propellant, Theia is able to make the addition of the fuel without modification to the basic architecture of the spacecraft.

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[1] Theia Holdings A, Inc., IBFS File No. SAT-LOA-20161115-00121 (Call Sign S2986) at Technical Narrative, Appendix 4.

[2] *See id.* (analysis employing NASA Debris Assessment Software 2.0.2).

[3] *See id*.

2. **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**.

Theia has examined the collision risk at mission altitude using the NASA Debris Assessment Software ("DAS"), the Analytical Graphics Incorporated Systems Tool Kit ("STK") and the Aerospace Debris Environment Protection Tool ("ADEPT"), a proprietary software package. Reasonable agreement was achieved among all of them.

Should a Theia satellite in mission orbit fail in a manner that would result in the inability to perform collision avoidance procedures, and other measures are not employed to remove the unmaneuverable satellite from orbit, then the satellite would undergo orbital decay and descend out of the mission "shell"[4] in a period of between 20 and 25 years from failure. A failed Theia satellite would continue its orbital decay over a substantial period of time, and ultimately re-enter the atmosphere in an uncontrolled manner. DAS has limitations that prevent full lifetime and collision risk assessment for this scenario, however the results of the studies employing the other tools indicate lifetimes prior to re-entry of between 165 and in excess of 200 years, depending on assumptions about the drag-state of the satellite under consideration. Collision risk with an operational Theia satellite is negligible because operational satellites can readily perform avoidance maneuvers.

The collision risk of 1%, 5% and 10% of the TSN constellation (120 operational satellites and in-orbit spares) becoming unmaneuverable and subsequently beginning natural decay was studied (1, 6 and 12 satellites, respectively). For a single satellite, within an initial 30-day period of becoming unmaneuverable, the probability of a collision in the existing space environment is approximately 0.00009 (9×10^{-5}). The collision risk for one satellite which is unmaneuverable over its natural decay lifetime of approximately 165 years was found to be approximately 0.26 (26%), assuming that no other large LEO constellations ("LLCs") were in deorbit.

Theia also considered the collision risk for one TSN satellite which is unmaneuverable over its natural decay lifetime in a more complex space environment posed by the inclusion of the other LLCs proposed in this processing round. In this case, our study assumed that during LLC operations (a) 2% of the satellites in the LLCs fail, and then (b) during disposal transition 5% of the remaining LLC satellites fail to complete a maneuver to drop the LLC satellites down to a 5-7 year coasting re-entry, leaving approximately 93% of the satellites from the LLCs in a 5-7 year coasting re-entry profile, all of which would be available for consideration of collision with the unmaneuverable TSN satellite, and that (c) the LLC constellations are continuously refreshed for at least 165 years. In that case, the probability of collision with a single TSN satellite which was unmaneuverable and left to natural decay rose to approximately 0.54 (54%).

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[4] The mission orbit "shell" is the range of nominal stationkeeping accuracy of +/- 10 km of nominal mission altitude.

The collision risk statistics for 1, 6 and 12 TSN satellites, for 30 day, average annual and decay lifetime, and both with and without the space environment including the LLCs, is presented in Table 1.

TABLE 1 - PROBABILITY OF AN UN-MANEUVERABLE TSN SATELLITE COLLISION FOR VARIOUS TIME PERIODS AND CONDITIONS	NUMBER OF UN-MANEUVERABLE THEIA SATELLITES								
	1			6			12		
	PERIOD OF CONSIDERATION			PERIOD OF CONSIDERATION			PERIOD OF CONSIDERATION		
	FIRST 30 DAYS	365 DAY AVERAGE	165 YEAR DECAY LIFETIME	FIRST 30 DAYS	365 DAY AVERAGE	165 YEAR DECAY LIFETIME	FIRST 30 DAYS	365 DAY AVERAGE	165 YEAR DECAY LIFETIME
COLLISION RISK ASSUMING NO PROPOSED LLCs ARE PLACED IN THE SPACE ENVIRONMENT	**0.00009** (0.009%)	**0.00130** (0.130%)	**0.26** (26%)	**0.00054** (0.054%)	**0.00777** (0.777%)	**0.83579** (84%)	**0.00108** (0.108%)	**0.01549** (1.549%)	**0.97304** (97%)
COLLISION RISK ASSUMING ALL PROPOSED LLCs ARE IN SPACE WITH DEORBIT TO A 5-7 YEAR COASTING PHASE TO RE-ENTRY	**0.00011** (0.011%)	**0.00270** (0.270%)	**0.54** (54%)	**0.00066** (0.066%)	**0.01609** (1.609%)	**0.990526** (99%)	**0.00132** (0.132%)	**0.03192** (3.192%)	**0.99991** (100%)

The Commission may note that there are already many other objects of comparable size to the TSN satellites studied, which are presently in space with similar uncontrolled orbits and similar decay lifetimes. The statistics in Table 1 are computed specifically for the TSN satellites, but are not directionally unique – any satellite in LEO orbit at or below 800 km, or which enters the sub-800 km region, and which either is, or becomes, not affirmatively maneuverable would experience similar risks of collision, adjusted for satellite cross-sectional area.

Theia has not performed an analysis of the consequences of Theia satellites being unable perform collision avoidance maneuvers prior to orbit injection, because a launch provider has not yet been selected, and therefore the conditions prior to orbit injection are unknown at this time.

In the design of the Theia satellites, Theia has carefully considered, and will continue to carefully consider, the risk of an unmaneuverable satellite at mission orbit. In the satellite design, Theia has included redundancy for critical components, and elements that enhance survivability and reliability. Theia continues to examine the space debris and deorbit issue, and is investigating additional measures to reduce the probability of, as well as limit the consequences of, on-orbit satellite sub-system failures, including potentially the addition of dedicated independent deorbit thrusters, ultra-reliable electrical and attitude control systems, improved tracking, telemetry, and control ("TT&C") communications, and the potential implementation of automated deorbit programs, if certain satellite conditions are present.

In the matter of collision risk, Theia's interests are aligned with those of the U.S. Government and the space community as a whole. Theia continues to keep the reliability of safe, controlled deorbit as a priority in its satellite and mission design.

3. **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.**

While Theia's deorbit procedure as described in the original application is compliant with FCC and NASA regulations and guidelines, Theia is acting to further reduce human casualty risk resulting from atmospheric re-entry of Theia satellites. As described in Theia's response to Question 1 above, Theia has concluded that it should adopt a deorbit plan for the rapid, controlled descent to a target area in the South Pacific Ocean within nominally less than 3 days from deorbit initiation.

The initial target area proposed for disposal is indicated in Figure 1. The re-entry will take place in the direction of travel indicated by the red arrow, and will nominally conclude on the ascending portion of the disposal orbit. The region indicated in blue is approximately 7% of the earth's surface area (36,000,000 square km), is also of a length exceeding 26% of the earth circumference (10,500 km), and contains less than 100 people on average per day. In addition, the buffer between the initial proposed target area and any settlements with over 100 people are more than 1200 km in the cross-track direction, and in excess of 5,000 km along the orbit track in each direction.

The choice of the transition of the second to last orbit at a 170-km perigee to a final orbit with a 30-km perigee also provides for a steep descent into the atmosphere on re-entry. A steeper descent results in a higher accuracy of targeting and a smaller debris field than shallower orbits. The sun synchronous orbits of the TSN satellites naturally take every satellite nearly precisely along the disposal track, further enhancing the ease of implementing and assuring the deorbit plan.

Initial Monte Carlo simulations performed indicate a less than a 1:1,125,000 chance of a satellite's reentry debris field falling outside of the indicated zone. This assumes that the satellite remains within nominal functional limits, and the reentry orbits prior to the final atmospheric capture orbit are known to accuracies commensurate with present-day tracking capabilities. Theia is continuing to study the reentry debris field spread and statistics.

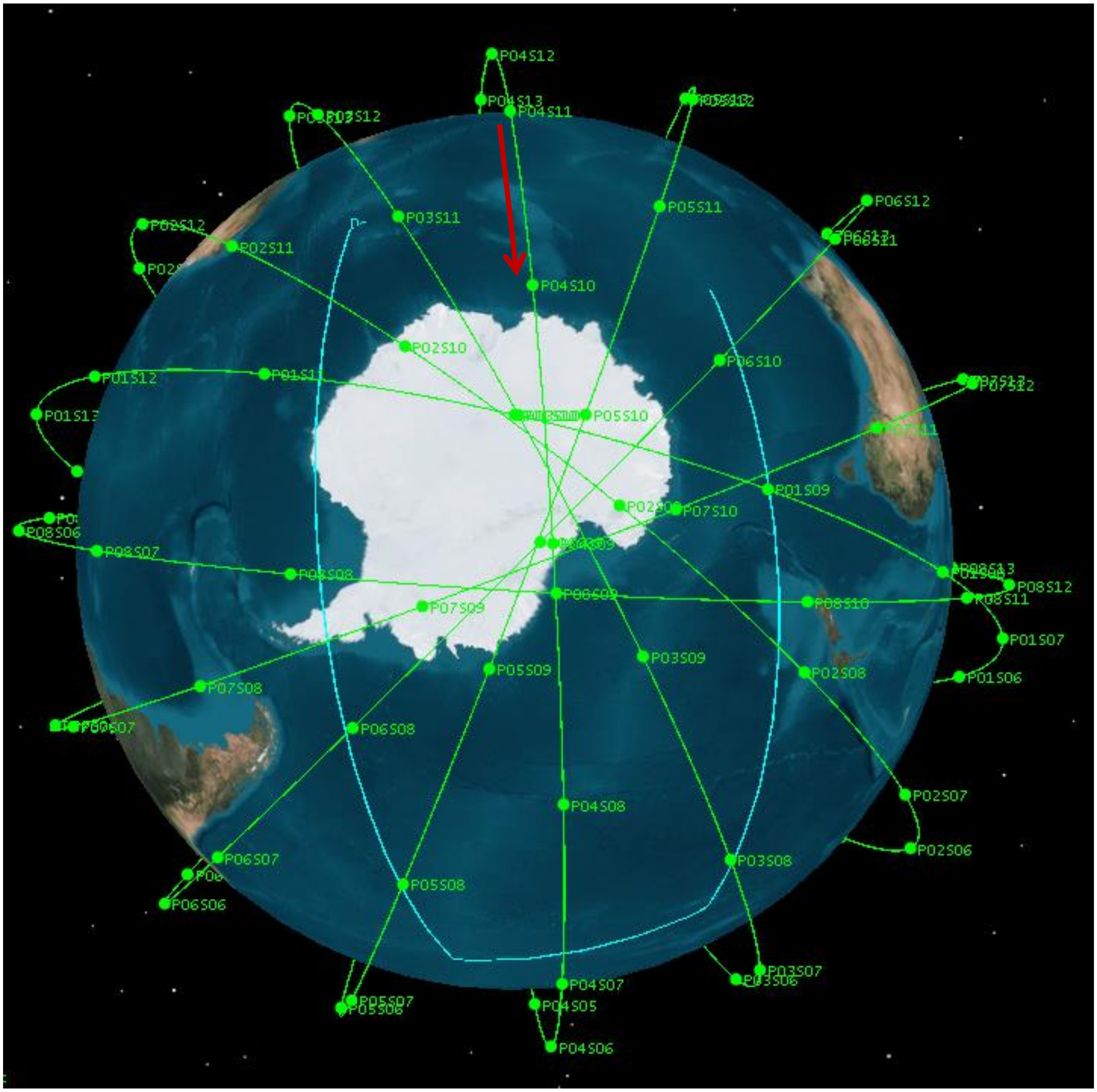

Figure 1 – Theia Satellite Deorbit Target Region

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

<u>THEIA RESPONSE:</u>

With respect to 47 CFR 1.1301-1.1309 of the National Environment Protection Act of 1969, ground infrastructure facilities for the TSN include: gateways, satellite operation centers, network operation centers or supporting data centers. Although locations for these facilities have not yet been selected, Theia shall comply with the Commission's environmental processing rules as stated in 1.1307 including:

- No facilities will be located in an officially designated wilderness area, a wildlife preserve area, or a flood plain.
- No facilities will physically or visually affect a property significant in American history that is listed, or is eligible for listing, in the National Register of Historic Places, as determined in accordance with the Nationwide Programmatic Agreement or the Collocation Programmatic Agreement.
- No facilities will affect Native American (Indian) religious sites.
- No facilities will affect listed threatened or endangered species or designated critical habitats; or are likely to jeopardize the continued existence of any proposed endangered or threatened species or likely to result in the destruction or adverse modification of proposed critical habitats.
- No facilities construction will involve significant change in surface features (e.g., wetland fill, deforestation or water diversion).
- Facilities will not be equipped with high intensity white lights and will not be located in a residential neighborhood (as defined by the applicable zoning law).
- No facilities will cause human exposure to levels of radiofrequency radiation in excess of limits defined by the Commission.
- No facilities will be constructed taller than 450 feet above ground level (AGL).

Theia will prepare and Environmental Assessment if a facility operation or transmission would cause human exposure levels of radiofrequency radiation in excess of the limits specified in 1.1210 and 2.1093.

With respect to the issues raised in the Space Data decision cited in this question, the circumstances in the Space Data case were fundamentally different than those presented by the proposed TSN operations. That case involved a circumstance where all of the large number of proposed balloon-borne repeaters would return to Earth at indeterminate locations because they were not under the control of Space Data, but here the TSN satellites burn up upon re-entry and thus would not implicate the same environmental concerns.

Specifically, Theia submits that its relatively small number of NGSO satellites and compliant DAS analysis establish that launch and operation of the TSN do not give rise to material environmental or safety concerns. Moreover, Theia's conclusion that it should adopt a fully controlled re-entry approach further mitigates and potential concern regarding these issues.

5. **For optical inter-satellite links, please provide the wavelength, power, duty cycle, beam diameter at emitter, and beam divergence. In addition, please provide the power margin at the receiver at maximum operating distance.**

THEIA RESPONSE:

The current design of the optical inter-satellite links employs optical systems using a wavelength of 1064 nanometers for the bi-directional communications signal. The transmitted optical power is expected to be approximately 2 watts (33 dBm), and would operate with 100% duty cycle during crosslink activities. The space-borne beam diameter will nominally be 10 centimeters in diameter at the emitter. The beam divergence will be approximately 14.5 micro-radians measured at the 1/e points on the beam, and 29.1 micro-radians at the $1/e^2$ points. At maximum range and data rate, the power margin is expected to be approximately 9.4 dB at beginning-of-life and 5.3 dB at end-of-life.

The same configuration is expected to be used for space-ground bi-directional links, however the ground terminal will have a larger aperture.

In addition, the TSN optical crosslinks and downlinks may include provision for a much lower power beacon at a different wavelength to assist in the acquisition and tracking of the link. If such a beacon is employed, it would also have a larger beam divergence. Studies are ongoing to determine if such a beacon will be necessary.

6. **Please indicate whether optical inter-satellite links will be coordinated with other systems proposed in Commission applications and with the U.S. Department of Defense's laser clearing house, and, if such coordination has commenced, please address the status of coordination.**

Theia has contacted Department of Defense Laser Clearing House, Operations Officer CPT Austin Baker. Theia has been advised that since it is a commercial organization, Theia does not submit to the Registration process. Theia will nevertheless keep the Laser Clearing House advised of the Theia laser-link activities.

Theia commits to coordinate with other applicants, and will pursue the matter further as the processing round progresses.

Technical Certification

I, Joseph D. Fargnoli, hereby certify that I am the technically qualified person responsible for the preparation of the technical information contained in the above Consolidated Opposition and Response, that I am familiar with Part 25 of the Commission's Rules (47 C.F.R. Part 25), and that I have either prepared or reviewed the technical information submitted in this application and found it to be complete and accurate to the best of my knowledge and belief.

/*s/Joseph D. Fargnoli*
Joseph D. Fargnoli
Chief Technology Officer
Theia Holdings A, Inc.

CERTIFICATE OF SERVICE

I, Joseph D. Fargnoli, hereby certify that on July 7, 2017, a true and correct copy of this Consolidated Opposition and Response was sent by United States mail, first-class postage prepaid, to the following:

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