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

In the Matter of	)	
THEIA HOLDINGS A, INC.	)	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	)	File No. SAT-LOA-20161115-00121

COMMENTS OF SPACE EXPLORATION TECHNOLOGIES CORP.

Space Exploration Technologies Corp. ("SpaceX") hereby comments on the application filed by Theia Holdings A, Inc. for authority to launch and operate a non-geostationary satellite orbit ("NGSO") system providing Fixed-Satellite Service ("FSS") in the Ku and Ka bands. The proposed Theia system would consist of 112 LEO satellites operating in low-Earth orbit ("LEO") at an average altitude of 800 km, which would be used to assemble and distribute data collected using those satellites' remote sensing capabilities and provide a machine-to-machine broadband connectivity.[1]

It is unclear, however, whether Theia's proposed constellation will make efficient use of spectrum. Although Theia's application requests authority to operate throughout the Ku and Ka bands, it does not provide any concrete showing that such large amounts of

[1] *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*, IBFS File No. SAT-LOA-20161115-00121, at 5-6, 9 (Nov. 15, 2016) ("Theia Application").

spectrum are necessary for their proposed application. SpaceX and other applicants, which propose to use this spectrum for traditional high-speed Internet access plainly have a pressing need for a significant amount of spectrum. Indeed, there is likely no amount of spectrum that the FCC can make available in the near term that will allow NGSO satellite operators to meet the entire U.S. and global demand for broadband Internet. Accordingly, authorization of such systems is likely in the public interest so long as they are spectrally efficient, would not impose undue burdens on other operators, and would not undermine the safety of space. The Commission should consider, however, whether this calculus might be different for what is essentially an EESS system that has not made any substantive showing that its bandwidth needs truly necessitate the use of so much spectrum, especially in a band full of other operators seeking to address the global digital divide.

In addition, Theia proposes to use very high EIRP earth station uplink beams, which are likely to cause interference to other LEO systems. For example, although Theia proposes to operate at a lower altitude than SpaceX, Theia's uplink beams will transmit at EIRP levels 10-20 dB higher than SpaceX's. With such a large EIRP disparity, the Theia uplink beam would likely degrade SpaceX's or any other LEO satellite's ability to receive any uplink signal in the affected band from *any* location on the Earth, whether or not it is near the transmitting Theia earth station. This would essentially prevent a LEO satellite with steerable beams from using that steering capability to avoid an in-line event, forcing both operators to default to band segmentation.

To illustrate this point, we consider two in-line scenarios involving the NGSO systems proposed by Theia and SpaceX, and use operational parameters from their respective applications to determine the impact (measured as $\Delta T/T$) of these in-line events.

In Scenario 1, the SpaceX satellite is in the main beam of the Theia user terminal uplink beam. In this scenario, SpaceX has the ability to redirect beams to serve areas unaffected by the in-line event. Table 1 sets forth the analysis of the impact on SpaceX in this scenario, where the SpaceX beams have been redirected to achieve 30 degrees of angular separation from the SpaceX satellite's point of view. As this analysis demonstrates, the uplink beam from a Theia earth station would cause a significant increase in noise temperature relative to the desired signal at the receive antenna of SpaceX satellites, with ΔT/T of 25%, even assuming 30 degrees of angular separation.[2]

SpaceX SAT Rx antenna gain at nadir [dB]	37.00	
SpaceX SAT Rx antenna G/T at nadir [dB/K]	9.80	*per FCC filing*
SpaceX SAT Rx antenna G/T at 30º [dB/K]	-32.13	*32-25log(φ) at 30° separation*
Theia ES EIRP [dBW/40kHz]	19.95	*per Theia, 50.46dBW/50MHz, 80cm UT*
Theia ES EIRP [dBW/Hz]	-26.07	
I/N [dB]	**-6.02**	*at 30° separation*
ΔT/T [%]	**25%**	*at 30° separation*

Table 1. Impact of Theia Earth Stations in Scenario 1

In Scenario 2, the SpaceX and Theia earth stations are essentially collocated while their satellites have an apparent angular separation of 10 degrees (*i.e.*, the edge of an in-line event). Here again, the analysis in Table 2 demonstrates that the high-EIRP transmissions from the Theia earth station would cause a significant increase in interference, with ΔT/T of 230%.

[2] For purposes of this analysis, SpaceX used a representative frequency (14.25 GHz) and representative orbital altitude for its system (1,110 km), and EIRP values for Theia earth stations taken from the Technical Narrative submitted with its application. We note that the EIRP masks used for Theia's EPFD_up simulations show much higher EIRP figures, which would have resulted in even greater interference if used in this analysis. I/N is calculated using this equation (where k = Boltzmann constant):

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

SpaceX SAT Rx antenna G/T at nadir [dB/K]	9.80	*per FCC filing*
Theia ES Diameter D [m]	0.80	
Theia ES Gmax [dB]	39.30	*estimated*
Theia ES Gain @ 10º [dB]	7.00	*32-25log(φ), per Rec. ITU-R S.465-6*
Theia ES EIRP @ 10º [dBW/40kHz]	-12.35	
Theia ES EIRP @ 10º [dBW/Hz]	-58.37	
I/N [dB]	**3.61**	*at 10° separation*
ΔT/T [%]	**230%**	*at 10° separation*

Table 2. Impact of Theia Earth Stations in Scenario 2

As these tables show, in Scenario 1, interference is so strong that it would prevent the SpaceX satellite from using its steerable beams to service other users (outside the area subject to the in-line event) using spectrum shared with Theia, and thus essentially prevents SpaceX from using those frequencies anywhere during the in-line event. In Scenario 2, because SpaceX will experience an unacceptable level of interference without a separation angle much larger than 10 degrees, the operators would have to expand the in-line event zone which would negatively impact spectral efficiency and usable capacity for both systems.

Without effective coordination, this pervasive interference will significantly reduce the overall utility of NGSO operations throughout the band. The Commission is currently considering whether to adopt default limits for EIRP density of NGSO uplink transmissions in order to facilitate spectrum sharing among systems,[3] and SpaceX believes that such limits will be critical to efficient and equitable spectrum sharing among non-homogeneous NGSO systems. At a minimum, any grant of Theia's application should be conditioned upon compliance with the outcome of that rulemaking proceeding. The Commission

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

should also consider whether it would be appropriate to impose additional conditions to address this potential interference and enhance the potential for efficient spectrum sharing.

Theia's stated de-orbit reliability also raises concerns. According to the Theia Technical Narrative, "[Theia] satellites are specified with a 92% reliability of de-orbit."[4] With a system comprising 112 satellites, this means that 9 satellites can be expected not to properly deorbit but instead remain in orbit, but out of control, or deorbit in an uncontrolled fashion. This level of reliability becomes an even greater concern were it to become standard across all of the proposed NGSO satellites in these bands. If this level of reliability were to become accepted as the norm for the coming generation of NGSO satellites, it could mean *hundreds* of out-of-control satellites, significantly increasing the risk of collision and orbital debris. Recognizing its role as a steward of safe space operations, SpaceX intends to far exceed 92% reliability, as it explained in its response to the Commission's request for additional information about the SpaceX system.[5] The Commission should consider holding other operators to a higher standard as well.

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4 Theia Application, Technical Narrative at 17.

5 Letter from William M. Wiltshire, Counsel to SpaceX, to Jose P. Albuquerque, Chief, Satellite Division, International Bureau, IBFS File No. SAT-LOA-20161115-00118, at 2-11 (Apr. 20, 2017).

Respectfully submitted,

SPACE EXPLORATION TECHNOLOGIES CORP.

By: */s/ Tim Hughes*
Tim Hughes
Senior Vice President, Global Business and Government Affairs

Patricia Cooper
Vice President, Satellite Government Affairs
SPACE EXPLORATION TECHNOLOGIES CORP.
1030 15th Street, N.W.
Suite 220E
Washington, DC 20005
202-649-2700 tel
202-649-2701 fax

William M. Wiltshire
Paul Caritj
HARRIS, WILTSHIRE & GRANNIS LLP
1919 M Street, N.W.
Suite 800
Washington, DC 20036
202-730-1300 tel
202-730-1301 fax

Counsel to SpaceX

June 26, 2017

ENGINEERING CERTIFICATION

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

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

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

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

Signed:

/s/ Mihai Albulet

Mihai Albulet, PhD
Principal RF Engineer
SPACE EXPLORATION TECHNOLOGIES CORP.

June 26, 2017

Date

CERTIFICATE OF SERVICE

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

Tom W. Davidson
Jennifer L. Richter
Steven A. Rowings
Akin Gump Strauss Hauer & Feld LLP
1333 New Hampshire Avenue, N.W.
Washington, DC 20036
jrichter@akingump.com

/s/ *Sabrina McMillin*
Sabrina McMillin