Technical Narrative—Theia Satellite Network

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1. Scope and Purpose

This Technical Narrative describes the design and operational characteristics of the proposed non-geostationary satellite orbit ("NGSO") Earth-Exploration Satellite Service ("EESS") and Fixed-Satellite Service ("FSS") system of Theia Holdings A, Inc. or LTS Systems II, LLC—the Theia satellite system ("Theia").

The Theia system level design parameters included herein, as well as in Form 312 and Schedule S thereto that pertain to spectrum use, e.g., the effective isotropic radiated power ("EIRP"), antenna gain-to-noise temperature ratio ("G/T"), antenna contours, power flux density ("PFD") and equivalent power flux density ("EPFD"), are the committed performance levels for Theia. These are the values to which the system will be designed, built, tested and operated over its service lifetime. While specific satellite manufacturer(s) and launch provider(s) have not yet been selected by Theia, the overall satellite design and operational characteristics described herein are directly representative of those that will be implemented.

2. System and Description

Theia is an integrated Earth observation and communications network designed to provide unique remote sensing and communications products and services to a variety of users in the United States and worldwide. Theia will employ a constellation of 112 operational satellites in low-Earth orbit ("LEO") that incorporate remote sensing, signal processing and communications payloads. Theia is designed to collect, process and deliver remote sensing information products directly to end users on demand, and to provide broadband communications necessary for the delivery of these products and services, including directly into machines via machine-to-machine ("M2M") communications interfaces. Monitor and control functionality for both the satellites and the ground terminals will ensure that Theia's operations comply with all applicable domestic and international regulatory requirements.

2.1. Theia Services

Theia's products and services will transform a wide range of commercial industries and governmental operations. Global in scope and operating on a 24/7 basis, Theia will provide end users with on-demand, real-time, processed geophysical information—not simply raw remote sensing data. Theia satellites include sensors which capture:

- Contiguous visible (day) and medium wavelength infra-red (night) still and video imagery;
- Hyperspectral imagery;
- L-band active radar imagery; and
- Microwave radiometer measurements.

The remote sensing services provided by Theia involve full coverage of the Earth. The sensors and processed products from the Theia satellites provide services to end users with resolution on the order of 1 meter. Products can be provided for single events or distributed over time (e.g., for monitoring changes).

Because each Theia satellite includes extensive onboard processing power, calibration, correction, processing and analysis may take place directly on the satellites, reducing large data sets to more valuable information products, facilitating spectrum efficiency for data transmission to ground stations and end users and vastly increasing the "value per bit" communicated to end users. Theia products and services will be of significant value to individual, commercial, and government users.

The primary communications functions within the Theia system will be served by a combination of radio frequency ("RF") user and gateway links, as well as high-bandwidth (10

Gbps) free space optical (“FSO”) inter-satellite links (“ISLs”).[1] Theia will also operate user FSS links in Ku-band frequencies and gateway links in Ka-band and V-band frequencies.[2]

2.2. Frequency Bands, Types of Service, and Coverage Areas; and Center Frequencies, Bandwidths, and Polarization Plan

New Theia and LTS seek access to the following frequency bands for Theia operations that the Commission previously licensed to Theia in 2019:

Remote Sensing	Frequency Band
EESS (active)	1215-1300 MHz

[1] Theia hopes to employ FSO gateway links that potentially may reduce the duty cycle of its use of Ka spectrum for RF gateway operations, subject to the resolution of technical and regulatory questions regarding the use of such FSO gateway links.

[2] Ka-band gateway links provide access for high bandwidth communications between Theia satellites and the terrestrial network and as a supplement to the FSO gateway links, particularly in areas where FSO gateway operations may be impractical (e.g., due to climatological conditions), where the Ka-band gateway links may in fact be the primary gateway link.

Gateway Links	Frequency Band
FSS (s-to-E)	17.8-18.3 GHz
FSS (s-to-E)	18.3-18.6 GHz
FSS (s-to-E)	18.8-19.4 GHz
FSS (s-to-E)	19.6-19.7 GHz
FSS (s-to-E)	19.7-20.2 GHz
FSS (E-to-s)	27.5-28.35 GHz
FSS (E-to-s)	28.35-28.6 GHz
FSS (E-to-s)	28.6-29.1 GHz
FSS (E-to-s)	29.5-30.0 GHz
FSS (s-to-E)	37.5-42.0 GHz
FSS (E-to-s)	47.2-48.2 GHz
FSS (E-to-s)	48.2-50.2 GHz
FSS (E-to-s)	50.4-51.4 GHz

User Links	Frequency Band
FSS (s-to-E)	10.7-11.7 GHz
FSS (s-to-E)	11.7-12.2 GHz
FSS (s-to-E)	12.2-12.7 GHz
FSS (E-to-s)	12.75-13.25 GHz
FSS (E-to-s)	14.0-14.5 GHz

Microwave Radiometer (Passive)	Frequency Band
EESS (Passive)	1420-1427 MHz
Space Research (Passive)	1660.5-1668.4 MHz
EESS (Passive)	2655-2690 MHz
EESS (Active)	8.55-8.65 GHz
EESS (Active)	9.3-9.9 GHz
EESS (Passive)	10.6-10.7 GHz

New Theia and LTS request access to the following additional bands:

Gateway Links	Frequency Band
FSS (s-to-E)	19.4-19.6 GHz
FSS (E-to-s)	29.1-29.5 GHz
FSS (s-to-E)	42.0-42.5 GHz

Although the 8.55-8.65 GHz and 9.3-9.9 GHz bands are allocated to active EESS, Theia will only use these bands in a passive mode and will not transmit in any of the bands used by the Microwave Radiometer.

The types of service to be provided by the Theia are described above in Section 2.1. Theia will provide global coverage, including of the contiguous 48 U.S. states, Alaska and Hawaii, and all U.S. Territories. Subject to the licensing requirements and restrictions of national administrations, all locations on the surface of the Earth can be observed and served by Theia.

Specific channel center frequencies, bandwidths and polarizations for all beams (including telemetry, tracking and command beams) are detailed in Schedule S attached to this Application. Furthermore, Theia's operations in each of the foregoing band segments is discussed more fully in Section 3.2.1 Communications Payload, below.

2.3. Section 25.114(d)(1) Overall Description of System Facilities, Operations, and Services and Explanation of How Uplink Frequency Bands Would Be Connected to Downlink Frequency Bands

The Theia satellite payloads are regenerative, that is, all receive signals are down-converted, demodulated, decoded and processed to baseband (digital) data. This received baseband data contains a destination address. The destination address is used to route the data within the satellite to an appropriate destination, possibly for consumption by the satellite itself (e.g., a message addressed to that specific satellite), or to an off-board communications port (e.g., an adjacent satellite FSO ISL). As such, there is no explicit, fixed relationship between satellite input ports and satellite output ports as there are with transponder satellites. Consequently, signals received on any RF or optical port can be translated through this demodulation-baseband-routing-remodulation process and be retransmitted on any other RF or optical port employed by the satellite.

As to specific RF communications for uplink or downlink, for user links or for gateway links, Theia operations are governed by the geographic location of service and the regulations applicable to that location. For example, communications between a Theia satellite and a user terminal ("UT") in the United Kingdom would be governed by UK spectrum access and remote sensing regulations and operational constraints (available frequency bands, power levels, etc.). Theia's operational flexibility enables it to comply with regulations that may vary on a country-by-country basis.

2.4. Theia Constellation

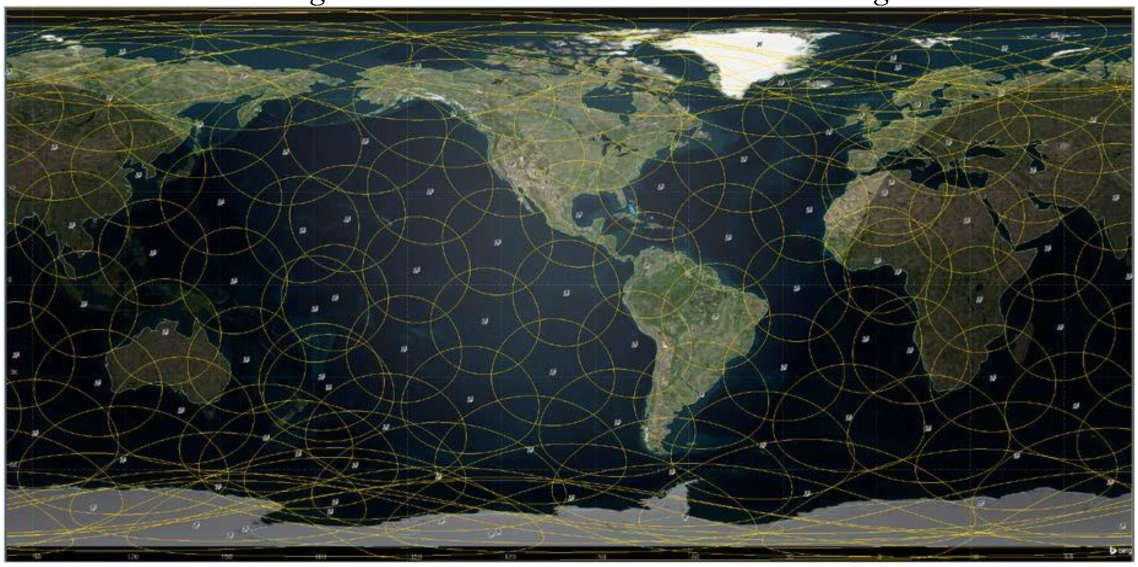
Theia employs a fully integrated constellation of custom satellites optimized to meet mission and safety requirements. The Theia constellation is configured as eight planes of 14 satellites each. All planes operate at a nominal altitude of 800 km, in sun-synchronous orbits, having an orbital period of approximately 6053 seconds and an inclination of approximately 98.6°. The orbital planes are distributed over 180° of right ascension, with 24.5° inter-plane spacing. Complete constellation parameters are provided in Schedule S.

The Theia constellation is capable of global, continuous coverage of the Earth for remote sensing data capture. The satellites in the Theia constellation are interconnected with FSO ISLs that enable dynamic routing and cross-constellation communications with Theia gateways.

Multiple FSO and Ka-band gateways connect Theia to the terrestrial network, enabling global broadband communications capabilities, terrestrial distribution of volume-intensive remote sensing products, and delivery of ground-processed remote sensing products directly to end users. Ku-band user terminals connect directly to the Theia constellation to access communications and remote sensing products and services.

Figure 1 below shows Theia's global coverage. Each satellite and its associated coverage area (yellow circle) are shown in Figure 1. All points on the surface of the Earth are always in the service area of a satellite's sensors. The satellites' orbits are nearly polar, that is, nearly vertical in Figure 1. With the near-polar orbit of the satellites, even the poles are provided with continuous services.

Figure 1 – Theia Constellation Global Coverage



Theia satellites are equipped with 10 Gbps FSO ISLs that connect adjacent satellites within the same plane, as well as adjacent satellites in the neighboring planes (with limited exceptions at the constellation "seam" as described below). This highly interconnected mesh of links provides ample pathways for flexibly routing high-volume Theia traffic.[3] This, in turn, permits Theia to operate far fewer gateways than would otherwise be required.

Figures 2 and 3 show polar and equatorial views of the Theia constellation, depicting the planes as they are arranged around the Earth. The distribution of orbital planes in the constellation results in most satellites traveling in the same direction as their neighbors in adjacent planes. This makes the relative velocities between satellites and their adjacent plane neighbors relatively small, which is conducive to operating FSO ISLs across the inter-plane gap.[4]

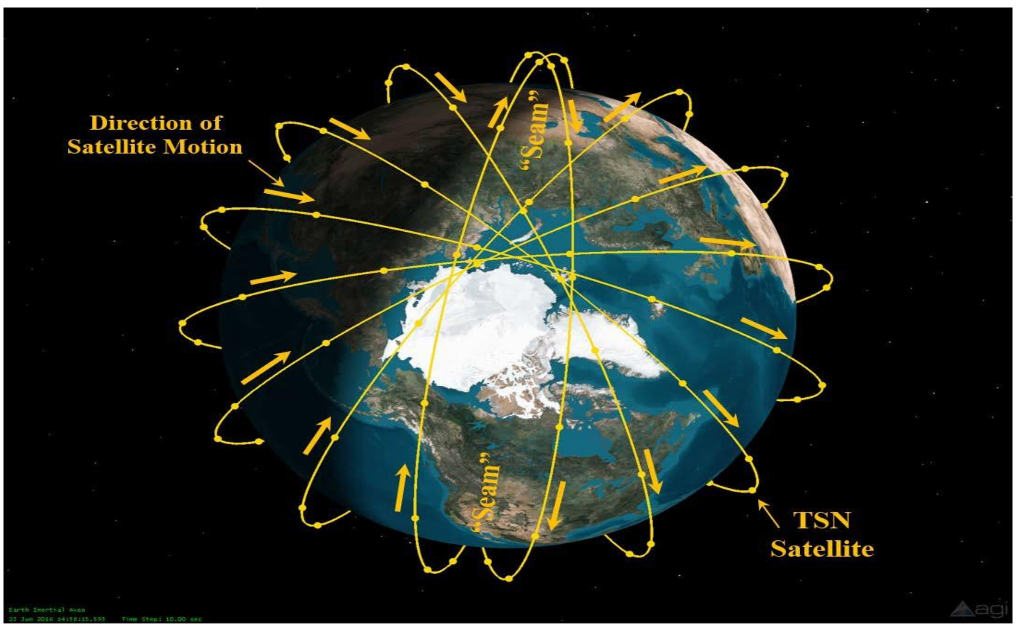
[3] The satellites in the constellation are "highly interconnected" because the majority of satellites have four high bandwidth (10 Gbps) FSO connections to adjacent satellites in orbit; left, right, forward, and aft. All satellites have at least three such connections. This connection geometry is described as a "mesh" network. Since there are so many paths for communications afforded to any satellite, the options available for routing traffic in the event of excess traffic or link failure are still substantial.

[4] Smaller relative velocities permit the FSO terminals on the different satellites to mutually

However, for two planes in the constellation geometry (the first and the last, planes 1 and 8), the satellites in one of the adjacent planes are not traveling in the same direction but rather in opposite (counter-rotating) directions, resulting in high relative velocities that make ISL communications challenging across the inter-plane gap. This inter-plane gap is called the "seam."[5]

Importantly, because a seam only occurs on one side of the two affected planes, FSO links can communicate readily with co-rotating satellites in the other adjacent plane to route traffic across the network as necessary.

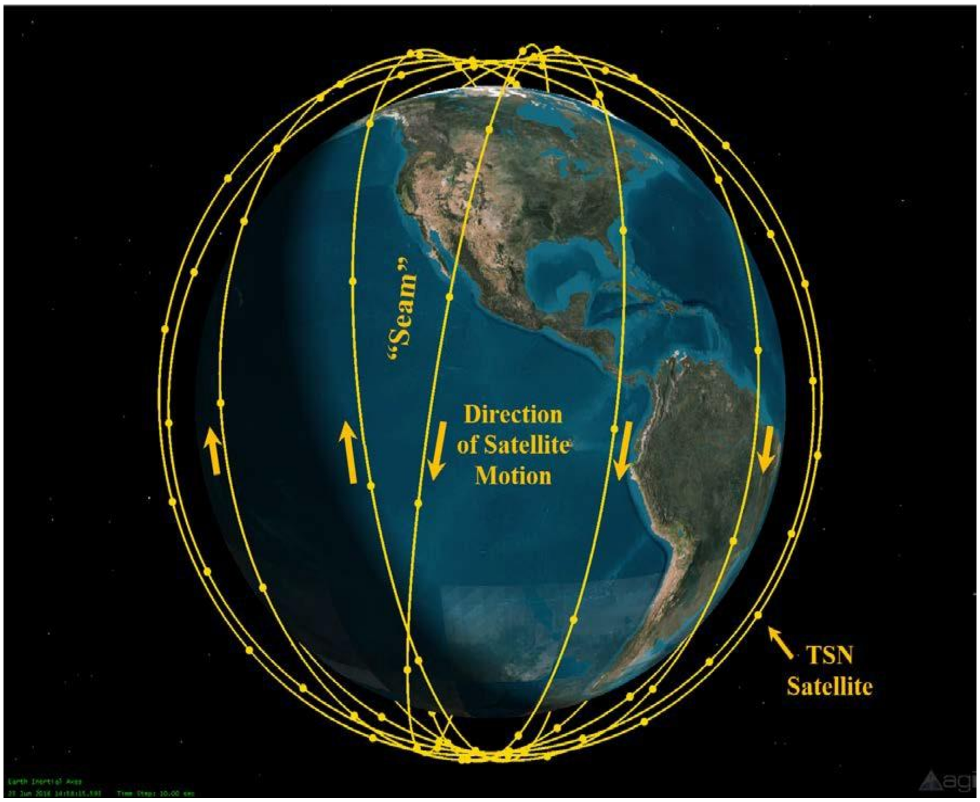
Figure 2 – Polar View of Constellation



acquire one another's signals, lock on, and track their relative motions as they perform their normal communications operations.

[5] This "seam" exists only between the first and last planes (1 and 8) on opposite sides of the Earth from one another and is an unavoidable result of a constellation of this general topology.

Figure 3 - Equatorial View of Constellation



The constellation provides full global coverage at all times with substantially increasing overlap of coverage area at higher latitudes (both North and South) due to converging planes. As Theia satellites approach the poles, the satellites' coverage areas will be reduced dynamically depending on a variety of factors, such as individual satellite health and capability, battery charge state, and service demand.

One spare satellite will be on orbit near each plane at an altitude of approximately 750 km and an orbital inclination of approximately 98.4° (matching the nodal precession of the active planes).

The constellation design has been created for operations in a safe and functional manner, minimizing the risks of damage to the constituent satellites as well as to other systems operating at nearby altitudes. Extensive altitude trades were conducted in the selection of this constellation design, considering such factors as orbital debris density distributions, atmospheric drag effects and the attendant burden of a compensating fuel load, the requirements of the Earth observation sensors as well as presence of other satellite systems that currently occupy, or may occupy, nearby altitudes.

Within each plane, the 14 satellites are equally spaced around the plane. For coverage purposes, the phase relationships of satellite position are staggered from plane to plane by an amount that is close to one-half the in-plane spacing between *satellites*.[6] All Theia satellites are operated to position tolerances of less than +/- 10 km of nominal position in all three axes, radial, in-track and cross-track.

2.5. Section 25.114(c)(6) Orbital Parameters for Theia

All constellation parameters are detailed in Schedule S attached to this Application. Key parameters are summarized here: **Constellation Parameter**	**Theia Value**
Total Number of On-Orbit Satellites	120
Number of Active On-Orbit Satellites	112
Number of On-Orbit Spares (initial deployment, 750 km storage orbit)	8
Number of Planes	8
Number of Active Satellites per Plane	14
Average Altitude – Active Satellites	800 km
Orbit Type	Sun Synchronous

[6] This plane-to-plane phase relationship is not exactly one half the in-plane spacing to prevent satellites from arriving at the polar plane crossings at exactly the same times. These small differences in arrival times represent significant absolute differences in position relative to the size of the satellite control boxes, which effectively eliminates the possibility of collisions among satellites within the constellation without significantly affecting the coverage advantages of the half in-plane spacing arrangement.

Inclination	98.6°
Active Service Arc	Active satellites may be active over their full 360° of true anomaly

2.6. System Implementation

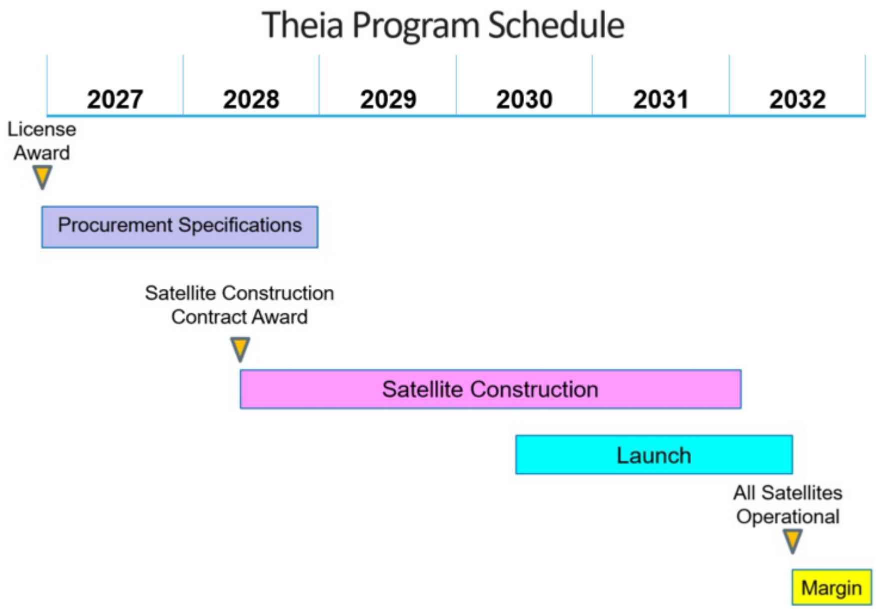
Under Section 25.164(b), the license recipient "must launch 50 percent of the maximum number of space stations authorized for service, place them in their assigned orbits, and operate them in accordance with the station authorization no later than 6 years after the grant of the authorization."[7]

A nominal schedule for procurement, construction, and launch of the Theia constellation is presented below. Note that although the date of license award is indicated as the beginning of 2027, the Theia business plan is not strictly predicated on that specific date. It is simply a representative date for establishing the remainder of the implementation schedule. In any event, Theia will complete launch and operation of the space stations within six years of authorization.

The schedule shown allows for approximately three years from bulk satellite construction contract award to completion of the launch of the entire satellite constellation. It is expected that the first launch of satellites will be 'pathfinder' spacecraft in as little as two years from the beginning of satellite construction, with the next launches following soon thereafter. This additional time period provides a scheduled window for extensive full envelope testing on station to verify satellite design. Following this period, the full production and launch campaign will be

[7] 47 C.F.R. 25.164(b).

completed. As is shown in the schedule, there is a planned margin in the schedule to account for unforeseen issues.



3. Theia Elements

Theia is comprised of the following subsystems:

- Three types of custom satellites with unique remote sensing instrumentation that share an advanced, technically identical communications payload;
- User terminals that communicate with the satellites using Ku-band frequencies;
- Gateway earth stations that provide high-bandwidth links between the satellites and terrestrial networks using Ka-band and V-band frequencies;
- Network operations centers ("NOCs") that perform management functions for user terminal and gateway operations; and
- Satellite operations centers ("SOCs") providing real-time monitoring and control of Theia satellites and the associated tracking, telemetry and control ("TT&C") stations, as well as associated terrestrial communications network that interconnects NOCs, gateways, UTs, as well as SOCs and the TT&C stations.

3.1. Satellites

Theia satellites employ technologies that maximize performance and minimize mass and cost. Each satellite is a three-axis stabilized platform that will be controlled to within +/- 0.1° of nominal in all three axes. Each satellite has a large nadir (Earth-pointing) panel that offers sufficient space to accommodate the earth observation sensors, the RF communications antennas for user terminals, the FSO Terminals for ground communications, and the FSO terminals for the inter-satellite links. RF communication with gateways is provided through deployable, steerable antennas.

The bus subsystem for the Theia satellites employs advanced technologies available for LEO satellites. The core structure constitutes a composite rigid frame assembly to which a number of individual structural composite honeycomb sandwich panels are attached to form the platform shape. The structure subsystem also includes a pair of internal composite honeycomb sandwich panels to support the large fuel tank needed for this design. The electrical power system is designed with deployable rigid panel triple junction gallium arsenide ("GaAs") solar arrays rated at over 30% beginning-of-life efficiency. The solar array wings also include composite yokes and panels, and include a two-axis drive mechanism for each wing. Redundant lithium-ion batteries comprised of individual modular cells are managed by electronic power controllers. These controllers and other avionics support power conditioning, fusing, and spacecraft power distribution for normal operations, as well as for eclipse operations and to serve peak power demands. The SV thermal subsystem encompasses several extremely mature and well-proven elements:

- Redundant thermistors and heaters;
- Multi-Layer Insulation ("MLI") blankets;
- Second Surface Mirrors ("SSMs");

- Paints, coatings and other surface finishes; and
- Heat pipes (embedded in primary structural panels) enabling substantial amounts of heat to be moved from localized heat sources to various nearby radiator surfaces for heat rejection.

Each satellite's propulsion system employs chemical thrusters for orbital relocation, station keeping and end of life disposal. The Theia satellite uses a conventional monopropellant hydrazine blowdown system with the following elements:

- 10 1-N monopropellant hydrazine thrusters
- A large propellant tank sized for the substantial Theia SV delta-V needs; and
- Assorted particulate filters, lines, fill and drain valves, latch valves, and pressure transducers.

Theia satellite command / telemetry, data handling, orbit determination and attitude control are managed by a suite of redundant onboard processors, sensors, actuators, and communications equipment:

- The satellite control processor ("SCP") is an internally redundant radiation-hardened processor unit responsible for managing all bus operations as well as performing all orbit determination and attitude control functions of the satellite. The SCP executes all commands issued to the satellite by the SOC, and the SCP sends all requested telemetry to the SOC.
- Satellite orbit determination and attitude control is performed by the SCP employing a suite of sensors and control mechanisms. The sensor suite includes GPS receivers, star tracker sensors, magnetometers, and sun sensors, as well as positional input data from the FSO terminals in communication with other satellites and the ground gateways.

Actuators include four for three redundant momentum/reaction wheel assemblies and three-axis magnetic torque rods. Thrusters are primarily intended for propulsive delta-V maneuvers. However, they can also be used for selected attitude control purposes, for example periodic de-saturating of momentum wheels should mission tasking induce momentum buildup that the satellite's torque rods cannot remove in the necessary timeframe.

TT&C communication between the SOC and the SCP is achieved in a different manner depending on the mission phase:

- In the case of initial deployment of the satellite, transfer orbit, or satellite anomaly, i.e., where ISL and gateway communication is not available, the TT&C communication is routed through one of two of Ka-band quasi-hemispherically patterned[8] transmit and receive antennas, one at either end of the satellite, to provide full spherical coverage regardless of satellite orientation. Command and data handling is managed through TT&C communications system electronics employing redundant Ka-band transmitters and receivers. These transmitters and receivers operate at the upper edge of the band (see Schedule S for specific frequencies). The TT&C receivers and transmitters interface directly with the SCP for all satellite command and control functions, from normal housekeeping to anomaly management functions for the satellite.

- In the case of normal on-station satellite operations, the satellite is connected into the FSO ISL mesh with other satellites, and connects with gateways from time to time as its orbital position permits. TT&C data are routinely exchanged with the SOCs via the gateway connection / ISL mesh, in the same manner as user traffic, the only difference being that the destination address for the TT&C traffic is the satellite SCP for commands or a SOC for telemetry, rather than a UT or a gateway for user traffic.

3.2. Remote Sensing Payload

The satellites in the Theia carry mission payloads for Earth observation. The remote sensing payloads are distributed as follows:

- All satellites will carry a visible wavelength and mid-IR wavelength optical fixed-staring system which captures a complete picture of the 120° coverage cone of each satellite (approximately 60° half angle from nadir)
- 52 of the satellites will carry a hyperspectral optical sensor with 1.2 meter primary aperture,
- 52 of the satellites will carry an active L-band radar configured both for imaging and soil measurements, with approximately a 36 square meter antenna effective aperture, and
- Eight of the satellites will carry a passive offset microwave radiometer.

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[8] The term "quasi-hemispherically patterned' is employed here to indicate that while there is antenna operation over 2π steradians, the gain is not uniform over that range of operation. The specific antenna patterns are included in Schedule S.

Theia is in the process of obtaining the authority to operate these remote sensing instruments and provide remote sensing products and services from the National Oceanic and Atmospheric Administration ("NOAA"), consistent with U.S. laws, regulations and policies governing commercial remote sensing systems.[9]

Theia will deploy 52 of the 112 satellites that include hyperspectral imagers with nominal 1 meter resolution. The imagers will support hundreds of narrow bands from visible through infrared regions for the capturing of raw visible and non-visible image data.

The L-band RADAR package carried by 52 of the Theia satellites is a system similar in many respects to the JAXA PALSAR-2 payload on the ALOS-2 spacecraft. It provides synthetic aperture radar ("SAR") strip imaging as well as spotlight imaging and sounding on single locations. The RADAR operates day or night, and is not affected by clouds or rain. This RADAR also has ground penetrating capabilities to measure terrestrial and sub-surface metrics.

Appendix 3 – Link Budgets includes the specific RF transmit and receive parameters for the L band radar payload. Further details regarding the emissions are described in Schedule S.[10]

Eight of the Theia satellites will be equipped with a microwave radiometer used to measure thermal electromagnetic surface and atmospheric radiation.

Each satellite is also equipped with a dedicated onboard graphics processing unit ("GPU") with extensive processing power for general use in processing real-time data output from the onboard sensors, including real-time calibration and analytics creation. The processing

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[9] *See* 15 C.F.R. Part 960.

[10] Schedule S contains entries for radar operating channels at 1233, 1240, 1250, 1260, 1270, and 1280 MHz center frequencies, with 32.06 and 16.06 MHz bandwidths. This set of channels is included in Schedule S to encompass the range of candidate operating channels that are under consideration in the coordination processing with the Radio Navigation Satellite Service community. It is anticipated that the actual operating channel will be one or more of these included in Schedule S, based on the results of the coordination agreement.

power in-orbit can also convert certain captured raster data into vector formats for certain types of analytic products, dramatically reducing the amount of information necessary to be transmitted to users, thus maximizing efficient use of spectrum.

The remote sensing payloads are tasked through authorized order instructions for certain Theia products and services received directly from end user terminals, as well as through commands from the Theia NOC via gateway links. Analyzed remote sensing products are delivered directly to user terminals (for relatively small amounts of data) or via gateway links (for larger data packages), which can then be routed to users via terrestrial communications.

Because some users may not have access to appropriate terrestrial connectivity, end user links may be the only communications path available to receive remote sensing products and associated communications services. This diverse suite of passive and active sensors uniquely provides the ability to integrate a global picture of nearly any man-made or natural process or event. Analytic data integration processes using the raw and processed data from each of the remote sensing capabilities will provide a detailed comprehensive image of individual events, locations, processes and activities.

3.2.1. Communications Payload

Theia satellites are capable of multiple modes of communications. Each satellite employs Ku-band antennas for user terminal communications, Ka-band and V-band steerable dish antennas for gateway communications, and Ka-band quasi-hemispherical antennas for TT&C communications. In addition, each satellite is equipped with FSO ISL terminals for inter-satellite connectivity, and a FSO gateway terminal for optical gateway connectivity. Theia satellites are all digitally regenerative satellites rather than "bent pipe" repeaters.

Communications into the various ports are reduced to baseband data before they are routed digitally within the satellite or processed onboard.

Each satellite will be equipped at launch with six FSO terminals—four for ISL communications (one forward in-plane, one aft in-plane, one each left and right adjacent plane)[11] one for gateway communications and one spare. The nominal data throughput for each of the FSO terminals is 10 Gbps.[12] 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 Theia 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. Theia will coordinate with the Department of War Laser Clearing House as well as other known operational systems to address and mitigate possible interference, and will obtain all required permits from the Federal Aviation Administration.

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[11] Note there is only one adjacent plane supporting ISL communications for planes 1 and 8 because those planes are next to the counter-rotating seams.

[12] Theia provides the foregoing information because the FSO terminals are an integral part of the NGSO space stations to be licensed by the Commission.

The Ku-band and Ka-band payload equipment suites are comprised of a number of different antennas and electronics modules.

The Ku-band communications suite includes:

- A multi-beam receive antenna with 169 fixed-pointed, dual-circularly polarized beams (approximately half LHCP, half RHCP), full bandwidth downconverters and analog-to-digital converters;
- Receive digital signal processing electronics with variable bandwidth, spectrum de-spreading and demodulation, decoding and de-interleaving;
- A baseband digital signal interface to an onboard router, which provides data distribution within the satellite itself;
- Transmit digital signal processing electronics with variable bandwidth, coding and interleaving, modulation and spectrum spreading; and
- Transmit electronics with digital-to-analog converters, upconverters and an associated multi-beam antenna with shaped, steerable circularly polarized beams.

The Ka-band and V-band communications suite includes:

- Two steerable transmit / receive parabolic reflector antennas, each with a dual circularly polarized fixed geometry beam.
- Full bandwidth downconverters and analog-to-digital converters;
- Receive digital signal processing electronics with variable bandwidth, spectrum de-spreading and demodulation, decoding and de-interleaving;
- Baseband digital signal interface to the onboard router;
- Transmit digital signal processing electronics with variable bandwidth, coding and interleaving, modulation and spectrum spreading; and
- Transmit electronics with full bandwidth digital-to-analog converters, upconverters and amplifiers connected to the two steerable parabolic reflector antennas.

The satellite payload also performs baseband digital signal distribution within the satellite via a router to/from, any of the FSO ISL, the FSO gateway link, the gateway Ka-band or V-band link, the Ku-band user terminal links, the onboard remote sensing payload or the onboard satellite control processor itself.

3.2.1.1. Section 25.114(c)(4)(ii) Maximum EIRP and Maximum EIRP Density for Transmitting Beams

All beams are identified, and EIRP and EIRP density for transmitting beams are detailed in Schedule S attached to this Application for each frequency band in which the transmitting antenna would operate.

3.2.1.2. Section 25.114(c)(4)(v) G/T and SFD for Receive Beams

All receive beams are identified, and G/T at beam peak and minimum and maximum saturation flux density ("SFD") at beam peak are detailed in Schedule S attached to this Application[13] Because SFD is a concept most applicable to bent-pipe transponder payloads and the Theia satellite payload (including command beams) is regenerative, an explanation of the minimum and maximum SFD value included with the Schedule S is described herein for clarification.

The values provided for minimum and maximum SFD reflect the received flux-density to achieve the threshold bit error rate ("BER") performance for the lowest spectral density modulation/coding (for minimum SFD) and the highest spectral density modulation/coding (formaximum SFD) intended to be received by that beam. In both cases, these are minimum operating targets. User uplink will tend to operate a few dB above these levels to provide for power control error and tracking bandwidth while command uplinks will operate significantly above these levels to assure high link reliability (during the rare events when the backup TT&C uplink is employed).

[13] At the time of this writing, the instructions in document 'Instructions for Schedule S vApr2016.pdf' indicate that SFD values should be entered in Schedule S in units of dBW/m2/MHz. The 'FCC Schedule S System' online software for data entry specifies units of dBW/m2. Further, the reporting of data values previously entered into this software is similarly specified with units of dBW/m2. Consequently, we have elected to enter the values into the Schedule S online system in units of dBW/m2 to reflect the software specification.

Link budgets are included as Appendix 3 to this Application. The link budgets show representative RF parameters (including G/T) for the nadir and edge of coverage (EOC) cases for all link types (user terminal, beacon, gateway and TT&C).

3.2.1.3. Contour Maps for Receive and Transmit Beams

Beam contour diagrams are provided as part of Schedule S of this Application.

3.2.1.4. Section 25.114(d)(12) Applications for NGSO FSS in the 10.7 - 30.0 GHz Bands Must Provide All Information Specified in Section 25.146

Internationally, Theia is designed to provide interference protection to Ku-band and Ka-band GSO satellite networks required under Article 22 of the ITU Radio Regulations. Within the United States, Theia will revert to the methods described in Section 25.146(a)(3) in order to ensure compatibility with operational GSO networks operating in the 10.7-12.7, 17.3-18.6, or 19.7-20.2 GHz bands.[14]

Appendix 1 to this Technical Narrative, Ku-band and Ka-band EPFD Compliance Analysis, provides the prior Ka- and Ku-band EPFD findings associated with Theia's prior ITU filing, USASAT-NGSO-4.

3.2.1.5. Section 25.202(e) Frequency tolerance, space stations.

Section 25.202(e) of the Commission's rules provides that "[t]he carrier frequency of each space station transmitter authorized in these services shall be maintained within 0.002 percent of the reference frequency." This requirement is well within common standards of practice. Theia satellites will comply with this requirement.

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[14] *See Modernizing Spectrum Sharing for Satellite Broadband*, Report and Order, SB Docket No. 25-157; FCC 26-26 (May 1, 2026).

3.2.1.6. Section 25.202(g)(2) Frequencies, polarization and coding of TT&C transmissions must be selected to minimize interference into other satellite networks.

Theia seeks to operate gateway and other high-capacity links in Ka-band and V-band frequencies. The Theia gateways may communicate with the constellation via one or more Ka-band, V-Band or FSO links. V-band communications with Theia satellites are designed to minimize interference with other satellite networks. TT&C information will be communicated between the SOC and Theia satellites through two primary means: (i) gateway communication, or (ii) TT&C sites communicating with Theia satellites through onboard Ka-band quasi-hemispherically patterned antennas. In all cases, communication between the SOC and satellite is secured.

For TT&C information communicated via means (i) above, between the SOC and the satellite over a conventional gateway link, this link may be achieved with Ka-band or V-band RF. Should this be the case, this link would not be established at band edge like those Ka-band only links established between TT&C sites and satellites via means (ii) above. Rather, this gateway communication (means (i)) would use normal gateway Ka-band or V-band RF frequencies (not specifically the Ka band edges) and would be processed in a manner indistinguishable from other gateway traffic.

For TT&C information communicated via means (ii) above the SOC command is routed through the terrestrial communications network to an appropriate TT&C site. This TT&C site sends the command to the target satellite directly, via a band edge Ka-band RF link. Telemetry data is similarly downlinked to the TT&C site. It is the SOC's responsibility to manage contact times and TT&C site selections for individual satellite communications. This is particularly important for satellites that are not yet part of the constellation mesh, such as satellites just deployed in the launch sequence, or spare satellites in holding orbits.

Ka-band RF communications with Theia satellites are designed to minimize interference with other satellite networks. The Theia TT&C sites are planned for high latitude locations, to provide for better access to a larger number of satellites at any one time. The higher latitude locations limit or eliminate any interference with GSO systems, as the difference in pointing angles between the Theia satellite downlink and a victim earth station GSO downlink (the 'alpha angle') is expected to be very large, and as with any site, any interfering NGSO direct line of sight occurrence will be managed through the standard procedures established with the other operator.

Note that in the first communication method described above, with TT&C information communicated between the SOC and the satellite over a conventional gateway link, this link may be achieved with Ka-band RF. Should this be the case, this link would not be established at band edge like those links described in the second method above. Rather, this gateway communication would use normal gateway Ka-band RF frequencies away from the band edges and would be processed in a manner indistinguishable from other gateway traffic. To require strict compliance with this requirement would place an undue operational burden on the Theia network. It would force all TT&C traffic to be carried via direct communications between the TT&C earth stations and each of the 112 satellites in the constellation individually. Under current design, the number of TT&C sites is limited. Further, the data rate of the direct TT&C link is relatively low, only permitting the minimum needed communications for the limited functions for those satellites operating out of the constellation (e.g., spares or in transition).

Specific Ka-band TT&C uplink and downlink frequency ranges are provided in the associated Schedule S to this Application.

3.2.1.7. Section 25.207 Cessation of Emissions

Each active satellite transmission chain (element drivers and associated solid state power amplifier) can be individually or collectively turned on and off by ground command, thereby satisfying the Section 25.207 cessation of emissions requirement.

3.2.1.8. Sections 25.114(c)(8) and 25.208 Power Flux Density Limits

As discussed in detail in Appendix 2, Theia Power Flux Density Compliance, Theia will comply with the PFD requirements of Sections 25.114(c)(8) and 25.208 of the Commission's rules.

3.2.1.9. Section 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 Theia satellites fully comply with this requirement. Ku-band user links employ four color[15] 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 Theia 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 and V-band provides significant reuse of this spectrum as well.

[15] A 'color' in this context is a portion of the dual polarization radio frequency spectrum that is reusable within a given satellite's footprint. So, four color reuse means that the entire available spectrum is divided into four portions, and those portions are reused throughout the footprint, without any two adjacent areas of the footprint having the same 'color', or portion of the spectrum, and hence without interference.

3.3. User Terminals

Theia user terminals are the equipment employed at customer sites that access Theia products and services directly from the Theia constellation. For users that have no appropriate terrestrial connectivity options available, the user terminal is the only viable means of service delivery. In other instances, user terminals may nevertheless be the best means of obtaining Theia products and services given latency requirements, traffic routing issues and other factors.

Theia user terminals will operate in Ku-band frequencies and will be available in fixed and Earth-station-in-motion ("ESIM") configurations. Fixed user terminals are designed for installation and long-term operation at a customer facility and will be equipped with standard interfaces such as USB and Ethernet to enable communication with local computer and/or routing equipment. ESIMs are designed for installation on a movable apparatus, such as an automobile, boat, or airplane.

Transportable user terminals will have similar operational features, but will be designed for short-term use at a customer site and add optional wireless connectivity (e.g., Bluetooth, Wi-Fi) for local interface with the customer computer and routing equipment. Finally, given the Commission's well-settled rules governing Ku-band ESIMs,[16] Theia anticipates deploying ESIMs user terminals for applications such as communications to operational farm and mining equipment, as well as security/surveillance, unmanned systems support, and other applications.

Theia user terminals are fully enclosed weatherproof systems, which can be mounted on an appropriate skyward facing location. The user terminals are fully compliant with all regulatory requirements for human safety and appropriate operating instructions and labeling

[16] *See* 47 C.F.R. § 25.228.

will be provided to ensure that no excessive exposure to RF radiation will occur.[17] User terminals will include all capabilities required to operate with Theia, including such functions as satellite acquisition and tracking, link acquisition and maintenance (e.g., timing and Doppler compensation, demand assignment management, power control, etc.), and authentication functionality. Of course, the antenna and associated Ku-band electronics for communicating with Theia satellites will also be included in the user terminal.

The Theia design incorporates user terminals with 40 cm and 80 cm equivalent aperture antennas and currently anticipates the use of electronically steered arrays.[18] The 40 cm and 80 cm UT are representative of the types of user terminals expected to operate in the Theia network. While these are the principal UT classes, others are anticipated. See the link budgets in Appendix 3, which include information applicable to the expected performance of these UT.

Because the Theia satellites move across the sky relative to a user's location, user terminals will track the Theia satellite during its service period to that location and then acquire the next serving satellite. Theia anticipates a very brief switch-over period between serving satellites that will be consistent with the service requirements of its customers. Tracking of Theia satellites will be achieved through beacons and transmission of relevant ephemeris data to user terminals via the terrestrial communications network and/or satellite links, as appropriate, combined with positional information of the user terminal. Because all user terminals will know their own locations, the positions of relevant satellites, and emissions restrictions imposed by

[17] Maximum permissible exposure (MPE) analysis has been performed to indicate that adequate safety margins can be achieved with conventional UT design and manufacturing methods.

[18] Although Theia anticipates filing earth station applications with the Commission that fully detail the characteristics of the Theia user terminals at the appropriate time, at this time Theia can confirm that all user terminals will comply fully with applicable Ku-band earth station performance standards.

local regulations prior to commencing transmissions, it will be possible for the user terminal antenna to acquire and track the serving satellite without interference with other satellites or services.

Theia user terminals will operate at data rates up to the following rates depending on the specific needs of the user and/or geospatial/geophysical product being delivered:

Equivalent Antenna	**Direction**	**Bandwidth**	**Data Rate**
40 cm	Uplink	50 MHz (10 dBW RF Power)	38.2 Mbps
40 cm	Downlink	500 MHz	62.6 Mbps
80 cm	Uplink	500 MHz (10 dBW RF Power)	76.7 Mbps
80 cm	Downlink	500 MHz	234.7 Mbps

Further, user terminals are expected to be located within differing rain regions, requiring different levels of rain margin for the links in order to operate with adequate availability for Theia services. The combination of variation of user data rate along with variation in rain region results in the need for a variety of different sizes of outdoor antennas for the user terminals.

In operation, the UTs and Theia satellites will monitor the link performance continuously. Adaptive power control as well as adaptive coding and modulation ("ACM") schemes will be employed to ensure that the maximum error-free data transmission rates can be achieved through all atmospheric conditions. The specific Ku-band frequencies to be used by Theia user terminals in proposed operational regions are discussed in Section 2.2.

3.3.1. Section 25.209 Earth Station Antenna Performance Standards

All user terminal, gateway and TT&C earth station antennas will comply with Section 25.209 and other applicable earth station performance standards for all operations.

3.4. Gateway Earth Stations

Theia gateway earth stations link the Theia constellation and terrestrial communications networks. Traffic carried by these earth stations includes user traffic requiring terrestrial backhaul, management and control information for handling user traffic and TT&C communications.

Gateways may be located at high latitudes. High latitudes afford the gateway the opportunity to make contact with a greater number of Theia satellites simultaneously, as the planes of satellites converge near the poles. The links between a gateway facility on the ground and the constellation of Theia satellites are each very high bandwidth, whether FSO or RF. These high bandwidth links connect into the ISL mesh within the satellite constellation in space, and on the ground, the links connect to the terrestrial communications network to permit communications to users as well as control centers (NOCs and SOCs). As a result of this architecture, it is not expected that a large number of gateways will be required to support Theia operations. The specific number and location of gateways will be optimized when the final constellation is authorized by the Commission.

Gateway earth stations may operate FSO links, Ka-band links, V-band links, singly or together depending on location, network loading and other factors. The Ka-band and V-band gateway links will function as primary, high-bandwidth connections to the terrestrial network or back-up for the FSO gateway links (where optical links can be employed effectively). Theia gateway sites will be fully coordinated pursuant to applicable Commission procedures. V-band high-capacity links will serve the needs of a limited number of large customers. Given the limited number of gateway earth stations needed to serve the inter-connected Theia constellation and the potential use of FSO gateway links, Theia anticipates coordinating Ka-band and V-band gateway operations will be relatively straightforward.

Theia's gateway earth stations will vary in size among 1.6m, 3.2m, and 4.8m equivalent circular aperture sizes depending on specifics of climate, throughput, link availability requirements, and other factors. Each gateway earth station will employ multiple, steerable antennas to allow make-before-break connectivity with the Theia constellation. Specific RF parameters such as EIRP and G/T for the gateways are provided in detail in Schedule S.

3.5. Network Operations Centers ("NOCs")

User operations throughout the Theia network are managed through a hierarchical arrangement of NOCs. The global NOC coordinates all user traffic operations, sets policies, rates, performs quality of service management, coordinates updates, and manages or supervises the management of all UTs. One of the key functions of the NOC is the coordination of Theia operations with other NGSO and GSO systems. This coordination ensures that Theia operates according to regional and global regulations, and in a manner consistent with sharing agreements.

Regional and national operation centers will be established as needed to serve the specific requirements of securing and maintaining "landing rights" within certain geographic areas, including responsibility for compliance with national regulations in each jurisdiction.

The NOC, regional, and national operations centers will be interconnected through a secured terrestrial communications network. The gateways will be interconnected with the same terrestrial network.

3.6. Satellite Operations Centers (SOC) and Tracking, Telemetry, and Control (TT&C) stations

The Theia SOC will provide 24x7 monitoring & control of all satellites: operational, spare, in launch, deployment and transit, as well as decommissioning, deorbit and disposal. The SOC not only performs normal day-to-day operations functions for all satellites, but also manages anomalous events should they occur. Personnel at the SOC will also provide Engineering and Analysis services to support all manner of routine and anomalous activities. The SOC provides constellation ephemeris data to the Theia network for managing satellite acquisition and tracking. The SOC coordinates with government entities such as the Joint Space Operations Center and the United States Strategic Command to ensure that space situational awareness needs are maintained. The SOC maintains communications with other satellite operators to perform timely coordination for collision and interference avoidance as needed.

SOC facilities will be sited in a variety of dispersed locations. The primary satellite operations center is planned for an urban location, to be manned 24 hours per day with qualified satellite operations personnel. A backup SOC will also be installed, geographically separated from the primary SOC. It will be equipped identically to the primary SOC. The backup SOC includes all necessary elements and infrastructure to take over from the primary SOC at any time. All necessary data are mirrored and backed up in order to enable the backup to take over at any time with no warning. It will be staffed with sufficient personnel to operate the satellites, but in a prolonged outage of the primary SOC, the operators from the primary would need to relocate to the backup.

Communications between the satellites and the SOCs are provided in one of two ways. For the constellation of connected, operational satellites, commands and telemetry are exchanged between SOCs and satellites through Theia gateways. For the satellites that are not part of the connected ISL constellation (spares, launch, deployment and transit, decommissioning, deorbit and disposal, and those otherwise operational satellites which have suffered anomalies and are in 'safe mode'), communications are maintained through dedicated TT&C sites.

The TT&C sites are typically located at high latitude to permit access to a larger number of satellites at any one time. The sites are equipped with multiple 1.6 to 4.8 meter[19] transmit/receive antennas and associated electronics that communicate with Theia satellites through the spacecraft's Ka-band omni antennas. Attachment 3 – Link Budgets provides details for representative TT&C communications links.

The primary and backup SOCs are connected to a terrestrial communications network that includes connectivity with the Theia gateways and the TT&C sites. Similarly, as noted above, the NOCs and gateways are connected to the terrestrial communications network as well.

The terrestrial communications network will provide easily accessible communications services among the ground components of the Theia network. It is made up of links of both the public Internet as well as private leased lines as required. The network operations centers and gateways carry substantial volumes of traffic, and will likely require private leased lines for much of the network. User terminal traffic accessing gateways may be more economically served by direct connection to the public Internet. In all cases, Theia communications are performed over secured, encrypted protocols to ensure data security.

4. Sharing with Other Services

4.1.1. EESS (s-to-E): 1215-1300 MHz

The U.S. Table of Allocations provides that the band 1215-1300 MHz is allocated to Federal EESS (active) operations on a primary basis and non-Federal EESS operations are

[19] Antenna sizes will be chosen consistent with climate conditions at TT&C sites.

secondary.[20] Specifically, in the 1215-1240 MHz band, non-Federal EESS operations are permitted on a secondary basis to Federal EESS, radiolocation, radionavigation-satellite ("RNSS") and SRS operations.[21] Additionally, in the 1240-1300 MHz band, non-Federal EESS operations are secondary to Federal EESS, radiolocation, SRS, and aeronautical radionavigation operations, as well as non-Federal aeronautical radionavigation operations.[22]

In the band 1215-1300 MHz, Theia will not cause harmful interference to, claim protection from, or otherwise impose constraints on operation or development of the radiolocation service, the RNSS and other services allocated on a primary basis.[23] Further, in the 1240-1300 MHz band, Theia will not cause interference to, claim protection from, or otherwise impose constraints on operation or development of the aeronautical radionavigation service.[24]

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[20] Federal radiolocation in the 1215-1300 MHz band is primarily for the military services; however, limited secondary use is permitted by other Federal agencies to support experimentation and research programs. *See* United States Table of Frequency Allocations, 47 C.F.R. § 2.106, footnote G56.

[21] 47 C.F.R. § 2.106. The 1215-1240 MHz band is used by Federal agencies for operating various types of long-range radar systems, as well as various radionavigation-satellite systems. See National Telecommunications and Information Administration, Office of Spectrum Management, 1215-1240 MHz 1 (2015), https://www.ntia.doc.gov/files/ntia/publications/compendium/1215.00-1240.00_01DEC15.pdf.

[22] 47 C.F.R. § 2.106. The 1240-1300 MHz band is used by Federal agencies for operating various types of long-range radar. *See* National Telecommunications and Information Administration, Office of Spectrum Management, 1240-1300 MHz 1 (2015), https://www.ntia.doc.gov/files/ntia/publications/compendium/1240.00-1300.00_01DEC15.pdf.

[23] 47 C.F.R. § 2.106 nn. 5.332 and 5.335A; *see also id.* at n. G56. In the same vein, Note G132 states: "Use of the radionavigation-satellite service in the band 1215–1240 MHz shall be subject to the condition that no harmful interference is caused to, and no protection is claimed from, the radionavigation service authorized under ITU Radio Regulation No. 5.331. Furthermore, the use of the radionavigation-satellite service in the band 1215– 1240 MHz shall be subject to the condition that no harmful interference is caused to the radiolocation service. ITU Radio Regulation No. 5.43 shall not apply in respect of the radiolocation service. ITU Resolution 608 (WRC–03) shall apply." *Id.* at n. G132.

[24] *Id.* nn. 5.5332. 5.335.

Theia shall operate the SAR System as follows:

1. At all times the SAR System shall be operated in a manner, both with respect to an individual SAR and the constellation, including with respect to space-borne L-band radars operated by others, such that the Theia SAR System does not cause harmful interference to RNSS receivers. This operational requirement shall supersede any and all operating metrics of Theia's SAR, including those indicated below.
2. Theia shall operate the SAR System such that, when the calculation of the interference degradation relative to the interference-free noise level to a RNSS receiver is performed according to Equations 1-1 and 1-2 in the ITU Document with NLIM=1, the resulting degradation to a non-blanking RNSS receiver is less than 0.2 dB. An example of a combination of parameters that may be employed to achieve the 0.2 dB requirement is as follows:
    - Peak transmitter power = 37.3 dBW
    - Transmitter antenna gain = 34.9 dB
    - Pulse Width = 12.8 μsec
    - Pulse repetition frequency = 1490 Hz
    - Transmit duty cycle = 1.91 %

   An example of the calculation cited using the above parameters is found in Appendix B for blanking and saturation mode receivers.

3. Theia's SAR transmit antenna shall have sufficiently low side-lobes such that the SAR beams from multiple SARs operating nearby each other do not act to create additive interference. An example of a combination of antenna beam parameters that could be employed to achieve this requirement is as follows:

(a) the main radar beam -1 dB contour is 12.3 km +/- 10% in diameter on the surface of the Earth at nadir,

(b) the main radar beam -3 dB contour is 21.2 km +/- 10% in diameter on the surface of the Earth at nadir, and

(c) at 2.6 degrees angle off of boresight, the antenna gain is less than -60 dB relative to the beam peak on boresight and is monotonically reduced further thereafter.

4. Theia shall not permit more than one of the Theia constellation SARs to illuminate the same region on the Earth's surface at any given time, defined such that the -3 dB contours of any two SAR transmit antenna beams shall (a) never overlap and (b) remain separated by at least 70 km on the Earth's surface at all times.

5. Theia shall proactively work with other space-borne L-band radar operators to avoid illuminating the same region on the Earth's surface in the L-band radar frequencies at any given time in a manner in which interference could become additive between the two L-band radars. In the event that another L-band SAR operator is non-cooperative, Theia shall avoid the entire field of regard of that operator's L-band SAR system, thereby ensuring there shall be no additive interference risk to RNSS receivers in the relevant area.

6. Theia shall employ center frequency diversity to manage the bandwidth overlap between the SAR System and the GPS L2 signal, limiting the interference degradation to less than 0.2 dB, as calculated relative to the interference-free noise level to a RNSS receiver according to Equations 1-1 and 1-2 in the ITU Document and using the effective pulse-width method with partial overlap, as specified on p. 17 of the ITU Document, with NLIM=2. The interference degradation is a function of

the bandwidth of the chirped pulse and the overlap with the L2 signal. The applicable ranges of center frequencies[4] for the Theia SAR for a 28 MHz SAR chirp and a 14 MHz SAR chirp are as follows:

- 28 MHz SAR chirp: 1243.0 MHz – 1285.0 MHz.
- 14 MHz SAR chirp: 1241.5 MHz – 1292.0 MHz.

Thus, for the 28 MHz chirp mode, the bandwidth overlap with the GPS L2 signal would be at most 11.46 MHz (when the center frequency of the Theia SAR is at 1243.0 MHz), resulting in a less than 0.2 dB degradation for all receiver types. An example interference analysis appears in Appendix C.

Theia consents to the adoption of the above-enumerated SAR Conditions as conditions to the grant of the Theia Application.

4.2. Ka-Band Gateway Operations

4.2.1. Uplink Bands (Earth-to-space)

Article 22 of the ITU Radio Regulations sets forth standards for interference protection of GSO satellite networks from NGSO satellite systems. As demonstrated in this Technical Narrative, Appendix 1, Theia's earth station transmissions in the following bands will protect Federal and non-Federal space station receive operations by complying with all applicable $EPFD_{up}$ limits contained in Article 22 of the ITU Radio Regulations.[25]

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[25] *See In re contactMEO Communications, LLC*, 21 FCC Rcd. 4035, 4043-44 (2006) (holding that compliance with the ITU's EPFD limits provides a sufficient basis for an NGSO FSS system to operate on a non-interference basis in a band in which GSO FSS systems are primary).

The NSF uses portions of the 27.5-30.0 GHz band for the radio astronomy research of various spectral-lines and continuum measurements.[26] Theia will undertake coordination and consultation with NSF and Federal stakeholders as required to accommodate these operations.

4.2.1.1. FSS (E-to-s): 27.5 GHz – 29.1 GHz

4.2.1.1.1. 27.5 GHz – 28.35 GHz

In the 27.5-28.35 GHz band, the FSS (Earth-to-space) is secondary to the Upper Microwave Flexible Use Service ("UMFUS"). Theia will comply with the Commission's rules for UMFUS in the 27.5-28.35 GHz band.

Theia's proposed gateway operations in the 27.5-28.35 GHz band are consistent with the Commission's view that FSS gateway operations that would not cause harmful interference to primary UMFUS stations in the band.

Theia intends to choose sites for its gateway earth stations in this band and coordinate with existing UMFUS licensees in accordance with the limitations and processes set in the applicable Commission rules. With respect to GSO FSS operating in the 27.5-28.35 GHz band, Theia will comply with the Section 25.146 to ensure compatibility with these GSO FSS systems. Theia will comply with Section 25.261 in order to protect NGSO FSS systems authorized in prior processing rounds.

4.2.1.1.2. 28.35 GHz – 28.6 GHz

The Commission's rules and Ka-band Plan[27] provide that in the 28.35-28.6 GHz (Earth-to-space) band, GSO FSS systems operate on a primary basis and NGSO FSS systems must

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[26] *See* National Telecommunications and Information Administration, Office of Spectrum Management, Federal Spectrum Use Summary 71 (2010), https://www.ntia.gov/files/ntia/Spectrum_Use_Summary_Master-06212010.pdf ("NTIA Federal Spectrum Use Summary").

[27] *Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the*

protect GSO FSS operations and are subject to Section 25.146(a). Theia demonstrates in this Technical Narrative that it can operate gateway earth stations without causing harmful interference to authorized spectrum users and agrees to accept any harmful interference from duly authorized GSO FSS operations in the 28.35-28.6 GHz band.

4.2.1.1.3. 28.6 GHz – 29.1 GHz

The 28.6-29.1 GHz (Earth-to-space) band may be used by NGSO FSS systems on a primary basis and by GSO FSS systems on a secondary basis.[28] Theia intends to use this band pursuant to this primary allocation. Theia will comply with Section 25.261 in order to protect NGSO FSS systems authorized in prior processing rounds.

4.2.1.2. FSS (E-to-s): 29.1 GHz – 29.5 GHz

The U.S. Table of Allocations permits use of the entire 29.1-29.5 GHz band on a primary basis for the FSS feeder links of NGSO Mobile-Satellite Service ("MSS") systems. In the 29.1-29.25 GHz portion of this band, that allocation is co-primary with LMDS service.[29] In the 29.25-29.5 GHz portion of this band, that allocation is co-primary with GSO FSS service.[30] Theia intends to use the 29.1-29.5 GHz band for c feeder links for its system.[31] While some Theia operations meet the definition of FSS because Theia earth stations will be operated at fixed

27.5-29.5 GHz Frequency Band, to Reallocate the 29.5-30.0 GHz Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services, First Report and Order and Fourth Notice of Proposed Rulemaking, 11 FCC Rcd. 19005 (1996) ("*Ka-band Plan R&O*").

[28] *SeeUpdate to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, Report and Order and Further Notice of Proposed Rulemaking, 32 FCC Rcd. 7809 (2017).

[29] 47 C.F.R. § 2.106 n. NG166.

[30] 47 C.F.R. § 2.106 n. NG535A.

[31] The Theia network will also utilize vehicle-mounted earth stations ("VMES") operating pursuant to the blanket licensing provisions of Section 25.226 of the Commission's rules. 47 C.F.R. §25.228.

"given positions,"[32] it will also support ESIM applications that are comparable to MSS.[33] Thus, Theia's access to this spectrum comports with the spirit of the U.S. Table of Allocations and Part 25 of the Commission's rules. Theia will coordinate with existing and future MSS feeder links operating in the band. Additionally, and in accordance with Section 25.258, Theia will coordinate with operators of GSO FSS earth stations in the 29.25-29.5 GHz band in order to ensure compatibility with GSO FSS operations, as well as with LMDS providers in the 29.1-29.25 GHz band. Theia requests a waiver for good cause (the similarity between ESIM and MSS operations) to the extent necessary to permit such operations.

Theia will also follow the procedures established by Section 25.261 of the Commission's rules to ensure compatibility with NGSO system authorized in processing rounds earlier than the one determined by the Commission as the appropriate processing round for the Theia system.[34] Finally, Theia will immediately terminate any gateway operations upon notification that such operations are causing harmful interference to any lawfully authorized radio system in the 29.1-29.5 GHz band operating in conformance with the U.S. Table of Allocations.

4.2.1.3. FSS (E-to-s): 29.5 GHz – 30.0 GHz

The U.S. Table of Allocations and Ka-band Plan provide that in the 29.5-30.0 GHz (Earth-to-space) band, GSO FSS systems operate on a primary basis and NGSO FSS systems on

[32] *See* 47 C.F.R. § 25.103 (defining "Fixed-Satellite Service" to include "radiocommunication service between earth stations at given positions, when one or more satellites are used; the given position may be a specified fixed point or any fixed point within specified areas").

[33] 47 C.F.R. § 25.103 (defining "Mobile-Satellite Service" as "radiocommunication service: (i) Between mobile earth stations and one or more space stations, or between space stations used by this service; or (ii) Between mobile earth stations, by means of one or more space stations," and a "Mobile Earth Station" as "[a]n earth station in the Mobile-Satellite Service intended to be used while in motion or during halts at unspecified points").

[34] 47 C.F.R. § 25.261.

a secondary basis.[35] As a secondary user, Theia's proposed NGSO FSS operations in the 29.5-30.0 GHz band must not cause interference to primary GSO FSS systems. Theia will comply with Sections 25.289 and 25.146 to ensure compatibility with GSO FSS networks. Theia will also comply with Section 25.261 of the Commission's Rules to ensure compatibility with NGSO FSS systems.[36]

4.2.2. Downlink Bands (space-to-Earth)

As demonstrated in this Technical Narrative, Appendix 1, Theia's space station transmissions in the following bands will protect Federal and non-Federal GSO earth station receive operations by complying with § 25.146 which provides multiple methods for ensuring the protection GSO FSS networks from unacceptable interference in order to satisfy § 25.289. In addition, as demonstrated in this Technical Narrative, Appendix 1, Theia's space station transmissions in the following bands will protect Federal and non-Federal GSO space station receive operations by complying with all applicable $EPFD_{is}$ inter-satellite limits contained in Article 22 of the ITU Radio Regulations.

Finally, as demonstrated in this Technical Narrative, Appendix 2, Theia's space station transmissions in the following bands will protect Federal and non-Federal terrestrial operations by complying with all applicable PFD limits contained in Article 21 of the ITU Radio Regulations.

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[35] *Ka-band Plan R&O* at 19024 ¶ 42; *see also Redesignation of the 17.7-19.7 GHz Frequency Band, Blanket Licensing of Satellite Earth Stations in the 17.7-20.2 GHz and 27.5-30.0 GHz Frequency Bands, and the Allocation of Additional Spectrum in the 17.3-17.8 GHz and 24.75-25.25 GHz Frequency Bands for Broadcast Satellite-Service Use*, Report and Order, 15 FCC Rcd. 13430, 13443 ¶ 28 ("*Redesignation of Ka-band Plan R&O*").
[36] 47 C.F.R. § 25.261.

According to the NTIA Federal Spectrum Use Summary, NSF uses portions of the 17.8-18.6 GHz and 18.8-20.2 GHz bands for the radio astronomy research of various spectral lines and continuum measurements, and military agencies use this band as a downlink for some satellite networks. Theia will undertake coordination and consultation as required to ensure its proposed operations are compatible with Federal uses. To the extent required, Theia will coordinate its non-Federal gateway earth station operations in this band with Federal FSS systems operating on a primary basis. Additionally, in the event that Theia seeks to operate an earth station at a location allocated for primary Federal operations—that is, Denver, Colorado; Washington, DC; San Miguel, California; and Guam—prior to commencing operations, Theia will assist the FCC with any information it may need in order to complete coordination with NTIA.[37]

4.2.2.1. FSS (s-to-E): 17.8 GHz – 18.3 GHz

The 17.8-18.3 GHz band is allocated to the Fixed Service (FS) on a primary basis and to the FSS, both GSO and NGSO, on a secondary basis. Theia will comply with the PFD levels contained in Article 21 of the ITU Radio Regulations and referenced in Section 25.146 (a)(ii) to ensure the protection of FS. With respect to FSS GSO operations in this band, Theia will comply with the EPFD limits contained in Article 22 of the ITU Radio Regulations. For operations in the United States Theia may engage in coordination with operational GSO operators or use the degraded throughput method described in Section 25.146 (a)(3) to demonstrate compatibility with GSO networks. As for NGSO systems authorized in earlier processing rounds, Theia will comply with Section 25.261 of the Commission's Rules in order to ensure compatibility with these NGSO FSS systems.

[37] *See* 47 C.F.R. § 2.106, n. US334.

4.2.2.2. FSS (s-to-E): 18.3 GHz – 18.6 GHz

The 18.3-18.6 GHz band is allocated to GSO FSS on primary basis, and NGSO FSS on secondary basis, subject to Sections 25.289 and 25.146. Accordingly, Theia will operate its NGSO system on a secondary basis in the 18.3-18.6 GHz band. To ensure that GSO FSS systems do not receive unacceptable interference, Theia will comply with the EPFD limits contained in Article 22 of the ITU Radio Regulations. For operations in the United States Theia may engage in coordination with operational GSO systems or use the degraded throughput method described in Section 25.146(a)(3) to demonstrate compatibility with such networks. As for NGSO systems authorized in earlier processing rounds, Theia will comply with Section 25.261 of the Commission's Rules to ensure compatibility with these NGSO FSS systems.

4.2.2.3. FSS (s-to-E): 18.8 GHz – 19.3 GHz

The 18.8-19.3 GHz (space-to-Earth) band is allocated to NGSO FSS operations on a primary basis, as well as for certain limited Federal uses.[38] Theia will operate in this band in accordance with this allocation.

4.2.2.4. FSS (s-to-E) 19.3 GHz – 19.7 GHz

The Commission's rules allocate this band for primary FSS (space-to-Earth) use for both Federal and non-Federal users, and Theia will operate in this band in accordance with this allocation.[39] Additionally, pursuant to note NG166 to the U.S. Table of Allocations, "[t]he use of

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[38] *See* 47 C.F.R. § 2.106, n. NG165; Ka-band Plan R&O ¶¶ 59-62; *see also Redesignation of Ka-band R&O* at 13433 ¶ 28. Note that low power point-to-multipoint terrestrial fixed systems may continue to be licensed and operate on a co-primary basis with NGSO/FSS in the 18.82-18.87 GHz and 19.16-19.21 GHz bands.

[39] *See Ka-band Plan R&O* at 19030-31 ¶¶ 59-62; *see also Redesignation of Ka-band R&O* at 13443 ¶ 28.

the band 19.3–19.7 GHz by the fixed-satellite service (space-to-Earth) is limited to feeder links for the mobile-satellite service."[40]

As indicated above, the Theia network incorporates FSS ESIM functionalities. Therefore, Theia believes that its use of this band conforms to the requirements of this rule with respect to the ESIM functionalities supported by using spectrum in this band. Theia seeks a waiver to the extent required to allow it to use these feeder links to support additional functionalities of its system, in addition to those explicitly permitted under this rule.

If required, based on the Commission's action on that waiver request, Theia will operate its NGSO system on a non-conforming basis in this band. As is the case with the feeder links operating at 29.1-29.5 GHz, discussed above, there is no incremental risk of interference as a result of Theia's operation of the associated gateways at 19.3-19.7 GHz to support the additional functionalities of the Theia network because the gateways will operate at the same frequencies, locations and power levels as they will to support the services contemplated by the Table of Allocations and the Commission's rules. In that case, Theia will not claim protection from conforming uses of the spectrum and agrees to accept any harmful interference from conforming services.

4.2.2.5. FSS (s-to-E): 19.7 GHz – 20.2 GHz

The Commission's rules allocate this band for primary FSS (space-to-Earth) use for both Federal and non-Federal users, and Theia will operate in this band in accordance with this allocation. More specifically, the Table of Allocations and the Commission's Ka-band Plan provide that the 19.7-20.2 GHz band (space-to-Earth) may be used by GSO FSS operations on a

[40] 47 C.F.R. § 2.106, n. NG166.

primary basis with no designation for NGSO FSS systems.[41] Elsewhere in this Application, Theia seeks a waiver to the extent necessary to allow its NGSO FSS operations in this band and agrees to accept any harmful interference from these services while operating on a non-conforming, unprotected basis.

As described in connection with that waiver request, it is highly unlikely that such operations will interfere with existing conforming uses. There is little to no potential for interference to existing and future GSO systems by Theia's proposed gateway earth station operations. Theia also will immediately terminate gateway operations in the band upon notification that such operations cause harmful interference to any lawfully authorized radio system in the 19.7-20.2 GHz band.

4.3. Ku Band Terminals

4.3.1. Uplink Bands (Earth-to-space)

As demonstrated in this Technical Narrative, Appendix 1, Theia's earth station transmissions in the following bands will protect Federal and non-Federal space station receive operations by complying with all applicable $EPFD_{up}$ limits contained in Article 22 of the ITU Radio Regulations and Sections 25.146 and 25.208 of the Commission's rules, 47 C.F.R. §§ 25.146, 25.208.

4.3.1.1. FSS (E-to-s): 12.75 GHz – 13.25 GHz

The U.S. Table of Allocations identifies conditions for spectrum use by FSS in the 12.75-13.25 GHz band. The Table of Allocations provides that the 12.75-13.25 GHz band is shared on a co-primary basis with terrestrial FS and FSS operations and NGSO system operations are

[41] *See Ka-band Plan R&O* at 19030-31 ¶¶ 59-62; *see also Redesignation of Ka-band R&O* at 13443 ¶ 28.

limited to gateway earth station transmissions.[42] In addition, the Table of Allocations requires that the use of the band 12.75-13.25 GHz (Earth-to-space) by a NGSO FSS system is subject to coordination with other NGSO FSS systems.[43] In the sub-band 13.15-13.2125 GHz, NGSO FSS gateway uplink transmissions shall be limited to a maximum EIRP of 3.2 dBW towards 0° on the radio horizon.[44]

The U.S. Table of Allocations identifies certain types of FS operations considered primary in the 12.75-13.25 GHz band.[45] Theia will not claim protection from lawfully operating GSO FSS networks when operating on a primary basis and will ensure compatibility with other lawfully operating co-primary FSS and FS users. Elsewhere in this Application, Theia has requested a waiver of the Commission's rules to the extent necessary to use this band for non-gateway operations in order to communicate with Theia user terminals and M2M/IoT terminals. As described in connection with that waiver request, it is highly unlikely that such operations

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[42] 47 C.F.R. § 2.106 n. NG57.

[43] 47 C.F.R. § 2.106, n. 5.441. NGSO systems also cannot claim protection from lawfully operating GSO FSS networks, irrespective of the dates of receipt by the Commission of complete coordination or notification information, as appropriate, for the NGSO or GSO networks. *Id.*

[44] 47 C.F.R. § 2.106, n. NG53.

[45] Specifically, in the band 13.15-13.25 GHz, the following provisions apply: (i) the sub-band 13.15-13.2 GHz is reserved for television pickup ("TVPU") and cable television relay service ("CARS") pickup stations inside a 50 km radius of the 100 television markets delineated in 47 C.F.R. § 76.51; and (ii) outside these areas, TVPU stations, CARS stations and NGSO FSS gateway earth stations shall operate on a co-primary basis. In the sub-band 13.2-13.2125 GHz, TVPU stations are co-primary and CARS pickup stations are secondary inside a 50 km radius of the 100 television markets delineated in 47 C.F.R. § 76.51; and outside these areas, TVPU stations and NGSO FSS gateway earth stations operate on a co-primary basis and CARS stations shall operate on a secondary basis. 47 C.F.R. § 2.106 n. NG53; *Amendment of Parts 2, 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band*, Second Memorandum Opinion and Order, 18 FCC Rcd. 2327-31 ¶¶ 7-17 (2003). In addition, the National Science Foundation uses this band for the radio astronomy research of various spectral lines, including the research of the formaldehyde line and quasars. *See* NTIA Federal Spectrum Use Summary at 61.

will interfere with existing conforming uses. If granted the waiver as requested, Theia will operate its NGSO system in this band in such a way that minimizes the possibility of interference to existing conforming uses and rapidly eliminates any unacceptable interference that may occur as a result of the operation of Theia user terminals, including by terminating such operations.[46] Moreover, Theia will comply with any rules that may be promulgated by the Commission in the pending rulemaking concerning this band.[47]

4.3.1.2. FSS (E-to-s): 14.0 GHz – 14.5 GHz

The Commission's rules allocate this band on a primary basis to Ku-band FSS operations. Theia will operate Ku-band user terminals in this band in accordance with these rules,[48] and shall take all practicable steps to protect the activities in this band of radio astronomy observatories, as required by footnotes US113 and US342 to the U.S. Table of Allocations.[49] Specifically, Theia will ensure it coordinates with astronomy observations of the formaldehyde line frequencies in the 14.47-14.5 GHz band and, should its assignment of this band result in harmful interference to these observations, Theia will remedy the situation.[50]

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[46] 47 C.F.R. § 2.106 n. 5.441

[47] *Satellite Spectrum Abundance*, Further Notice of Proposed Rulemaking and Notice of Proposed Rulemaking, 40 FCC Rcd. 3794 (2025).

[48] *E.g.*, 47 C.F.R. § 25.115(c)(1) (governing licensing of earth stations).

[49] 47 C.F.R. § 2.106, nn. US113 and US342.

[50] Theia also acknowledges that Federal civilian and military agencies operate communications satellite earth stations for voice, data, and video signals using commercial GSO satellites in the band. Specifically, in the 14.0-14.2 GHz band, the NOAA utilizes the band for satellite uplinks for the transmissions of meteorological information as part of the automated weather distribution system ("SAWDS") through non-Federal satellite systems. Additionally, NASA uses this band for spacecraft communications downlinks involving space research as well as TDRSS to provide communications to spacecraft, and NSF uses this band for radio astronomy research of various spectral lines, including the research of the formaldehyde line and quasars. NTIA Federal Spectrum Use Summary, at 62. NSF also uses parts of the 14.2-14.47 GHz band for similar purposes. *Id*. at 61-62.

Federal agencies use the 14.4-14.5 GHz band for fixed point-to-point microwave relay communications for voice, data, and video as well as airborne downlink data transmissions. Additionally, NASA conducts research in the 14.47-14.5 GHz band on ground-to ground transmissions of digital data, digital audio, and digital data to and from water mobile telemetry and precision tracking vans.[51] Theia will work to ensure compatibility of any of the above mentioned Federal operations in the 14.0-14.5 GHz band.

4.3.2. Downlink Bands (space-to-Earth)

As demonstrated in this Technical Narrative, Appendix 1, Theia's space station transmissions in the following bands will protect Federal and non-Federal GSO earth station receive operations by complying with all applicable $EPFD_{down}$ limits contained in Article 22 of the ITU Radio Regulations and Section 25.208 of the Commission's rules, 47 C.F.R. § 25.208. In addition, as demonstrated in this Technical Narrative, Appendix 1, Theia's space station transmissions in the following bands will protect Federal and non-Federal GSO space station receive operations by complying with all applicable $EPFD_{is}$ inter-satellite limits contained in Article 22 of the ITU Radio Regulations.

Finally, as demonstrated in this Technical Narrative, Appendix 2, Theia's space station transmissions in the following bands will protect Federal and non-Federal terrestrial operations by complying with all applicable PFD limits contained in Article 21 of the ITU Radio Regulations and Section 25.146 of the Commission's rules, 47 C.F.R. § 25.146.

4.3.2.1. FSS (s-to-E): 10.7 GHz – 11.7 GHz

The 10.7-11.7 GHz band is allocated on a primary basis to FSS operations. Theia proposes to operate its user terminals in the 10.7-11.7 GHz band. Prior to commencing

[51] *Id.* at 62.

operations in the lower portion of the 10.7-11.7 GHz band, Theia will consult with the radio astronomy observatories identified in the Commission's rules in order to achieve a mutually acceptable agreement on the protection of the radio telescope facilities operating in the adjacent 10.6-10.7 GHz band.[52]

Further, Theia acknowledges that Federal, civilian, and military agencies operate satellite earth stations for voice, data, and video signals using commercial geostationary satellites in this band.[53] Additionally, NOAA uses the 10.7-10.8 GHz band for passive sensing of the Earth from space using numerous sensing instruments such as radiometers, imagers, sounders, and temperature and water vapor profilers, etc. Accordingly, Theia will not claim protection from Federal uses in the band and will protect such operations from harmful interference.

4.3.2.2. FSS (s-to-E): 11.7 GHz – 12.2 GHz

The 11.7-12.2 GHz band is allocated on a primary basis to FSS operations and Theia will use this band to support its user terminal operations. Theia acknowledges that Federal, civilian, and military agencies operate communications satellite earth stations for voice, data, and video signals using commercial geostationary satellites and will work to ensure its primary operations are compatible with Federal operations in the band.[54]

[52] 47 C.F.R. § 2.106, n. US131.

[53] NTIA Federal Spectrum Use Summary, at 60 ("Federal civilian and military agencies operate communications satellite earth stations for voice, data, and video signals using commercial geostationary satellites. These Federal agencies operate earth stations that receive voice, data, and video signals. [NOAA] uses the 10.7-10.8 GHz band for passive sensing of the Earth from space using numerous sensing instruments such as radiometers, imagers, sounders, and temperature and water vapor profilers, etc.").

[54] NTIA Federal Spectrum Usage Summary, at 60 ("Federal civilian and military agencies operate communications satellite earth stations for voice, data, and video signals using commercial geostationary satellites. This band is the downlink that is paired with the uplink in the 14.0-14.5 GHz band. The [NSF] uses this band for the radio astronomy research of various spectral-lines, including the research of the formaldehyde line and quasars.").

4.3.2.3. FSS (s-to-E): 12.2 GHz – 12.7 GHz

Pursuant to the Table of Allocations, the 12.2-12.7 GHz band is allocated to the FSS on a primary basis, provided these systems do not claim protection from, and do not unacceptably interfere with broadcasting-satellite service ("BSS") networks.[55] Theia will operate in this band consistent with its primary allocation, will not claim protection from BSS satellite systems, and will rapidly eliminate unacceptable interference that may occur during Theia operations.[56]

Additionally, there are currently 46 grandfathered FS links in the 12.2-12.7 GHz band that have legacy licenses under old FCC allocations. Theia agrees to accept any interference from these 46 legacy FS links and will ensure there is no downlink interference into these 46 legacy FS links.

The Commission has also authorized the Multichannel Video Distribution and Data Service ("MVDDS") for one-way terrestrial wireless transmissions in the 12.2-12.7 GHz band. The technical and service rules for MVDDS in the 12 GHz band specifically state that MVDDS providers will share the 12 GHz band with new NGSO FSS operators on a co-primary basis.[57]

To account for the particular interference mechanisms between MVDDS and NGSO systems, the Commission adopted the following operating requirements for both systems:

<u>*MVDDS Operating Requirements*</u>:

[55] 47 C.F.R. § 2.106, n. 5.487A.

[56] *Id.* at n. 5.441.

[57] *See Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range; Amendment of the Commission's Rules to Authorize Subsidiary Terrestrial Use of the 12.2-12.7 GHz Band by Direct Broadcast Satellite Licensees and Their Affiliates; and Applications of Broadwave USA, PDC Broadband Corporation, and Satellite Receivers, Ltd. To Provide A Fixed Service in the 12.2-12.7 GHz Band*, Memorandum Opinion and Order and Second Report and Order, 17 FCC Rcd. 9614, 9617 ¶ 3(2002) ("*MVDDS Second R&O*").

(i) PFD at a distance: To promote MVDDS and NGSO FSS band sharing, the PFD of an MVDDS transmitting system shall not exceed -135 dBW/m2/4 kHz measured and/or calculated at the surface of the earth at distances greater than 3 km from the MVDDS transmitting site.

(ii) The maximum MVDDS EIRP shall not exceed 14 dBm per 24 MHz, but there is no restriction on the polarization of the MVDDS transmission.

(iii) The MVDDS transmitting antenna may not be installed within 10 km of any pre-existing NGSO FSS receiver unless the affected licensees agree to a closer separation.

NGSO FSS Operating Requirements:

(iv) Later-in-time NGSO FSS receivers must accept any interference resulting from pre-existing MVDDS transmitting antennas.

(v) Low angle PFD limits on NGSO FSS downlinks in 12.2-12.7 GHz band: For elevation angles from 0˚ to 2˚ above the horizontal plane, NGSO FSS downlinks must meet a reduced PFD level of -158 dBW/m^2/4kHz, and for elevation angles from 2˚ to 5˚ degrees above the horizontal plane, a reduced PFD level of -158 + 3.33 (δ-2) dBW/m^2/4kHz, where δ is the elevation angle in degrees.

To allow the sharing mechanisms of (i), (iii) and (iv) above to be implemented the MVDDS and NGSO FSS operators must maintain and share databases of their respective transmitters and receivers, as required by the *MVDDS Second R&O*. Theia is committed to this sharing arrangement and will comply with the Commission's rules regarding coordination between NGSO FSS and MVDDS operations at 12.2-12.7 GHz or any rules that may be established on the pending rulemaking on this subject.[58] Theia will also comply with the

[58] *Expanding Flexible Use of the 12.2-12.7 GHz Band*, Report and Order and Further Notice of

requirements of (v) above concerning the low elevation angle PFD limits in the 12.2-12.7 GHz band, as demonstrated in above.

4.4. Section 25.261 Procedures for avoidance of in-line interference events for NGSO FSS satellite network operations.

Theia will operate in compliance with Section 25.261 for sharing among NGSO space stations. With respect to NGSO systems authorized in the same processing around, Theia will engage in good faith coordination to achieve mutually acceptable conditions for compatibility. Absent a coordination agreement, Theia will demonstrate compatibility using the default procedure described in Section 25.261(c).

With respect to NGSO systems authorized in earlier processing rounds, Theia will also engage in good faith coordination to achieve technical compatibility. Absent a coordination agreement, Theia will demonstrate compatibility using the degraded throughput method described in Section 25.261(d).

The Theia system design is rich with intersatellite connectivity, which provides many degrees of freedom and facilitates coordination with other NGSO systems. Additionally, the Theia payload is highly flexible and can easily accommodate dynamic band segmentation scenarios in case it becomes necessary to fall back on the default procedure described in Section 25.261(c).

4.5. Section 25.272 General inter-system coordination procedures.

The SOCs are equipped with the full suite of hardware and software to monitor space-Earth transmissions in the Theia system. Theia operations shall coordinate transmissions with

Proposed Rulemaking and Notice of Proposed Rulemaking, 38 FCC Rcd. 5283 (2023).

those of other systems to prevent harmful interference incidents, or, in the event of a harmful interference incident to identify the source of the interference and correct the problem promptly.

4.6. V-band Operation

4.6.1. Uplink Band Sharing

4.6.1.1. FSS (E-to-s): 47.2 GHz – 50.2 GHz

The 47.2-48.2 GHz band is allocated to the Fixed, FSS (Earth-to-space), and Mobile services on a primary basis. In this band FSS earth stations are subject to Section 25.136(d), and Theia will address the relevant conditions of that rule in future earth station applications.

The 48.2-50.2 GHz band is allocated to the Fixed, FSS (Earth-to-space), and Mobile services on a primary basis. Footnote US156 sets unwanted emission levels for FSS earth stations operating in the 49.7-50.2 GHz band, and footnote US342 stipulates the need to protect radio astronomy observations in the 48.94-49.04 GHz band from transmitting FSS earth stations. Theia will address these requirements in future earth station applications. Theia will also coordinate with the National Telecommunications and Information Administration ("NTIA") and federal agencies to avoid interference to any of these and other federal government users operating consistent with the U.S. Table of Frequency Allocations.

As for the protection of GSO networks, Theia commits to complying with Section 25.289 of the Commission's rules. In particular, in the 47.2-50.2 GHz band, instead of adopting EPFD limits, WRC-19 adopted ITU Radio Regulations ("RR") Nos. 22.5L and 22.5M. These provisions provide single entry and aggregate criteria for NGSO systems to protect GSO networks respectively. Theia is committed to working with other NGSO operators to ensure that the aggregate criteria in 22.5M are met. With respect to previously authorized NGSO FSS systems, Thea commits to comply with Section 25.261 of the Commission's rules.

4.6.1.2. FSS (E-to-s): 50.4 GHz – 51.4 GHz

The 50.4-51.4 GHz band is allocated to the Fixed, FSS (Earth-to-space), Mobile, and Mobile-Satellite (Earth-to-space) services on a primary basis. Footnote US156 sets unwanted emission levels for FSS earth stations operating in the 50.4-50.9 GHz band. Theia will address this requirement in future earth station applications. Theia will coordinate with NTIA and federal agencies to avoid interference to any federal government uses operating in accordance with the U.S. Table of Frequency Allocations. In this band FSS earth stations are subject to Section 25.136 and Theia will address the relevant conditions of that rule in future earth station applications to the Commission.

As for the protection of GSO networks, Theia commits to complying with Section 25.289 of the Commission's rules. In particular, in the 50.4-51.4 GHz band, instead of adopting EPFD limits, which was done to protect GSO networks in the Ku- and Ka-bands, WRC-19 adopted ITU Radio Regulations ("RR") Nos. 22.5L and 22.5M. These provisions provide single entry and aggregate criteria for NGSO systems to protect GSO networks respectively. Theia is committed to working with other NGSO operators to ensure that the aggregate criteria in 22.5M are met. With respect to previously authorized NGSO FSS systems, Thea commits to comply with Section 25.261 of the Commission's rules.

4.6.2. Downlink Bands

4.6.2.1. FSS (s-to-E): 37.5 GHz – 42.0 GHz

The 37.5-40.0 GHz band is allocated to the Fixed, FSS (space-to-Earth), and Mobile services on a primary basis. The Commission's V-band proceeding adopted Section 25.136 for individually licensed earth stations, and Theia will address the conditions of that rule in future related earth station applications. This band is also allocated to federal users including Fixed, Mobile, Space Research (space-to-Earth), FSS, and Mobile-Satellite (space-to-Earth) services.

Theia will coordinate with NTIA and federal agencies as needed to ensure Theia will operate in a manner that is compatible with these federal services.

The 40.0-42.0 GHz band is allocated to Broadcasting, Broadcasting-Satellite, Fixed, FSS (space-to-Earth), Mobile, and Mobile-Satellite (space-to-Earth) services in various segments on a primary basis. The band is also allocated to federal users including Earth-Exploration Satellite (Earth-to-space), FSS (space-to-Earth), Mobile-Satellite (space-to-Earth), and Space Research (Earth-to-space) services in various segments. Theia will coordinate with NTIA and federal agencies as needed to ensure the Theia network will operate in a manner that is compatible with these Federal services.

In order to protect the terrestrial services in the 37.5-42.0 band, Theia will comply with the PFD limit specified in § 25.208 as detailed in Appendix 2.

As for the protection of GSO networks, Theia commits to complying with Section 25.289 of the Commission's rules. In particular, in the 37.5-39.5 GHz (space-to-Earth) and 39.5-42.5 GHz (space-to-Earth) bands, instead of adopting EPFD limits, WRC-19 adopted ITU Radio Regulations ("RR") Nos. 22.5L and 22.5M. These provisions provide single entry and aggregate criteria for NGSO systems to protect GSO networks respectively. Theia is committed to working with other NGSO operators to ensure that the aggregate criteria in 22.5M are met. With respect to previously authorized NGSO FSS systems, Theia commits to comply with Section 25.261 of the Commission's rules.

4.6.2.2. FSS (s-to-E): 42.0 GHz – 42.5 GHz

The U.S. Table of Allocations provides that the 42.0-42.5 GHz band is allocated as a non-Federal only band to the fixed and mobile services, but there is no FSS allocation in this band. Theia respectfully requests a waiver to operate its FSS feeder link earth stations on a non-conforming basis in the band. Theia agrees to accept any harmful interference from these services while operating on a non-conforming, unprotected basis.

It appears that this band is among the frequencies used by the VLBA for radio astronomy observations,[59] and Footnote US211 of the U.S. Table requires any operations in this band to take all practicable steps to protect radio astronomy in this band.[60] Theia will coordinate its limited earth station receive operations with Federal users and comply with applicable power limits to fully protect all Federal uses of the bands.

In addition, like other V-band downlink spectrum, this band is critical for its proposed operations so FSS access to the band should be preserved. At a minimum, Theia should be permitted to operate in this band outside the United States in accordance with international FSS allocations and applicable regulatory requirements.

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[59] *Federal Spectrum Use Summary* at 77; *Use of Spectrum Above 24 GHz for Mobile Radio Services, et al.*, 31 FCC Rcd. 8014, 8071 n. 388 (noting that VLBA receivers include the 41.0-45.0 GHz band).

[60] *See* 47 C.F.R. § 2.106 n. US211. Regarding radio astronomy usage, Theia would comply with the provisions of Footnote 5.551H and would follow the coordination process described in Resolution 743-2. For radio astronomy sites that confirm observation band capabilities in the 37.5-42.5 GHz band, Theia intends to complete the coordination process to protect observation capabilities at these selected locations and facilities. Theia will also suppress out-of-band emissions above 42.5 GHz to comply with the protection criteria identified in ITU Recommendation RA.769-2 to protect radio astronomy observation in the 42.5-43.5 GHz band.

Appendix 1

Ku-Band and Ka-Band EPFD Compliance Analysis

I. Operations in Ku and Ka bands:

For its operation in the Ku and Ka bands, Theia will rely on the ITU filing USASAT-NGSO-4 (CR/C/4562 IFIC 2990). This ITU filing was fully examined by the ITU for compliance with the applicable EPFD limits in Article 22 of the ITU Radio Regulations,[61] and it received a "Favorable" finding for all beams, as can be shown in the tables below.

Description of EPFD validation and results of examination Input parameters

Mask link data

Mask Id.	*Direction*	*Minimum frequency, MHz*	*Maximum frequency, MHz*	*Linked orbit IDs / Satellite IDs*
1	↓	10700	12750	All
2	↔	10700	12750	All
3	↑	13750	14000	All
4	↑	12750	13250	All
5	↑	14000	14500	All
6	↓	17800	18600	All
7	↓	19700	20200	All
8	↔	17800	18600	All
9	↑	27500	30000	All

Common SNS Data

Common

A.4.b.7.d.1 *Exclusion zone type*	*A.4.b.7.d.1* *Exclusion zone size, degrees*
Y - topocentric angle (earth based)	10

Orbits

Apogee/Perigee/Inclination	*A.4.b.6.d* *Uses station keeping*	*A.4.b.6.e* *Uses specific precession*
809/791/98.6	No keeping	Default

Uplink (Gateway)

A.4.b.7.b *Earth station density (1/km^2)*	*A.4.b.7.c* *Average distance (km)*	*A.4.b.7.a* *number of satellites receiving simultaneously*
4E-06	500	20

Downlink (Gateway)

A.4.b.6.a *Number of satellites transmitting to any latitude within corresponding range*		
From latitude	*To latitude*	*Number*
-90	90	20

[61] The ITU publishes on its website the results of its EPFD examinations for all NGSO filings. https://www.itu.int/net/ITU-R/space/epfd/index.html.

Uplink (User)

A.4.b.7.b *Earth station density (1/km²)*	*A.4.b.7.c* *Average distance (km)*	*A.4.b.7.a* *number of satellites receiving simultaneously*
4E-06	500	1

Downlink (User)

A.4.b.6.a *Number of satellites transmitting to any latitude within corresponding range*		
From latitude	*To latitude*	*Number*
-90	90	1

Group table

Beam(s)	*Direction*	*Minimum frequency, MHz*	*Maximum frequency, MHz*	*A.4.b.7.cbis* *Minimum elevation angle*
RU2U1, RU2U2	R	14000	14500	12
RU2G	R	13750	14500	12
RU1G, RU1U1, RU1U2	R	12750	13250	12
RA2G, RA2U1, RA2U2	R	29500	30000	12
RA1G, RA1U1, RA1U2	R	27500	29100	12
RU2T	R	13750	14500	5
RU1T	R	12750	13250	5
RA2T	R	29500	30000	5
RA1T	R	27500	29100	5
TU2B, TU2G, TU2U1, TU2U2	E	11700	12750	12
TU1B, TU1G, TU1U1, TU1U2	E	10700	11700	12
TA2B, TA2G, TA2U1, TA2U2	E	19700	20200	12
TA1B, TA1G, TA1U1, TA1U2	E	17800	18600	12
TU2T	E	11700	12750	5
TU1T	E	10700	11700	5
TA2T	E	19700	20200	5
TA1T	E	17800	18600	5

Results

B1A *Beam designation*	*B2* *Emi-Rcp*	*BR7a* *Group id./* *Target Group id.*	*GHz*	*Orbital planes id. no.*	*Mask ID*	*Article 22 Limit*	*Result*	*Article 22 Examination*
RA1G	R	320763505 / 117852862 320763506 / 117852863 320763507 / 117852864 320763511 / 117852868 320763512 / 117852869 320763513 / 117852870	27.5-28.5	1 - 8	9	TABLE 22-2	Pass	Favorable
RA1G	R	320763508 / 117852865 320763509 / 117852866 320763510 / 117852867 320763514 / 117852871 320763515 / 117852872 320763516 / 117852873	28.5-29.1	1 - 8	9	TABLE 22-2	Pass	Favorable
RA1T	R	320763517 / 117852874 320763518 / 117852875 320763519 / 117852876 320763523 / 117852880 320763524 / 117852881 320763525 / 117852882	27.5-28.5	1 - 8	9	TABLE 22-2	Pass	Favorable

RA1T	R	320763520 / 117852877 320763521 / 117852878 320763522 / 117852879 320763526 / 117852883 320763527 / 117852884 320763528 / 117852885	28.5-29.1	1 - 8	9	TABLE 22-2	Pass	Favorable
RA1U1	R	320763529 / 117852892 320763530 / 117852893 320763531 / 117852894 320763532 / 117852895	27.5-28.5	1 - 8	9	TABLE 22-2	Pass	Favorable
RA1U1	R	320763533 / 117852896 320763534 / 117852897 320763535 / 117852898 320763536 / 117852899	28.5-29.1	1 - 8	9	TABLE 22-2	Pass	Favorable
RA1U2	R	320763537 / 117852908 320763538 / 117852909 320763539 / 117852910 320763540 / 117852911	27.5-28.5	1 - 8	9	TABLE 22-2	Pass	Favorable
RA1U2	R	320763541 / 117852912 320763542 / 117852913 320763543 / 117852914 320763544 / 117852915	28.5-29.1	1 - 8	9	TABLE 22-2	Pass	Favorable
RA2G	R	320763545 / 117852927 320763546 / 117852928 320763547 / 117852929 320763548 / 117852933 320763549 / 117852934 320763550 / 117852935	29.5-30	1 - 8	9	TABLE 22-2	Pass	Favorable
RA2T	R	320763551 / 117852939 320763552 / 117852940 320763553 / 117852941 320763554 / 117852945 320763555 / 117852946 320763556 / 117852947	29.5-30	1 - 8	9	TABLE 22-2	Pass	Favorable
RA2U1	R	320763557 / 117852957 320763558 / 117852958 320763559 / 117852959 320763560 / 117852960	29.5-30	1 - 8	9	TABLE 22-2	Pass	Favorable
RA2U2	R	320763561 / 117852969 320763562 / 117852970 320763563 / 117852971 320763564 / 117852972	29.5-30	1 - 8	9	TABLE 22-2	Pass	Favorable
RU1G	R	320763565 / 117852981 320763566 / 117852982 320763567 / 117852983 320763568 / 117852984 320763569 / 117852985 320763570 / 117852986	12.75- 13.25	1 - 8	4	TABLE 22-2	Pass	Favorable
RU1T	R	320763571 / 117852987 320763572 / 117852988 320763573 / 117852989 320763574 / 117852990 320763575 / 117852991 320763576 / 117852992	12.75- 13.25	1 - 8	4	TABLE 22-2	Pass	Favorable
RU1U1	R	320763577 / 117852996 320763578 / 117852997 320763579 / 117852998 320763580 / 117852999	12.75- 13.25	1 - 8	4	TABLE 22-2	Pass	Favorable
RU1U2	R	320763581 / 117853004 320763582 / 117853005 320763583 / 117853006 320763584 / 117853007	12.75- 13.25	1 - 8	4	TABLE 22-2	Pass	Favorable
RU2G	R	320763585 / 117853012 320763589 / 117853016	13.75-14	1 - 8	3	TABLE 22-2	Pass	Favorable

RU2G	R	320763586 / 117853013 320763587 / 117853014 320763588 / 117853015 320763590 / 117853017 320763591 / 117853018 320763592 / 117853019	14-14.5	1 - 8	5	TABLE 22-2	Pass	Favorable
RU2T	R	320763593 / 117853020 320763597 / 117853024	13.75-14	1 - 8	3	TABLE 22-2	Pass	Favorable
RU2T	R	320763594 / 117853021 320763595 / 117853022 320763596 / 117853023 320763598 / 117853025 320763599 / 117853026 320763600 / 117853027	14-14.5	1 - 8	5	TABLE 22-2	Pass	Favorable
RU2U1	R	320763601 / 117853035 320763602 / 117853036 320763603 / 117853037 320763604 / 117853038	14-14.5	1 - 8	5	TABLE 22-2	Pass	Favorable
RU2U2	R	320763605 / 117853049 320763606 / 117853050 320763607 / 117853051 320763608 / 117853052	14-14.5	1 - 8	5	TABLE 22-2	Pass	Favorable
TA1B	E	320763337 / 117852520 320763338 / 117852521 320763339 / 117852522 320763340 / 117852523	17.8-18.6	1 - 8	6, 8	TABLE 22-1B TABLE 22-3	Pass Pass	Favorable
TA1G	E	320763341 / 117852528 320763342 / 117852529 320763343 / 117852530 320763344 / 117852531 320763345 / 117852532 320763346 / 117852533	17.8-18.6	1 - 8	6, 8	TABLE 22-1B TABLE 22-3	Pass Pass	Favorable
TA1T	E	320763347 / 117852534 320763348 / 117852535 320763349 / 117852536 320763350 / 117852537 320763351 / 117852538 320763352 / 117852539	17.8-18.6	1 - 8	6, 8	TABLE 22-1B TABLE 22-3	Pass Pass	Favorable
TA1U1	E	320763353 / 117789397 320763354 / 117789398 320763355 / 117789399 320763356 / 117789400	17.8-18.6	1 - 8	6, 8	TABLE 22-1B TABLE 22-3	Pass Pass	Favorable
TA1U2	E	320763357 / 117789401 320763358 / 117789402 320763359 / 117789403 320763360 / 117789404	17.8-18.6	1 - 8	6, 8	TABLE 22-1B TABLE 22-3	Pass Pass	Favorable
TA2B	E	320763361 / 117852563 320763362 / 117852564 320763363 / 117852565 320763364 / 117852566	19.7-20.2	1 - 8	7	TABLE 22-1C	Pass	Favorable
TA2G	E	320763365 / 117852585 320763366 / 117852586 320763367 / 117852587 320763368 / 117852594 320763369 / 117852595 320763370 / 117852596	19.7-20.2	1 - 8	7	TABLE 22-1C	Pass	Favorable
TA2T	E	320763371 / 117852603 320763372 / 117852604 320763373 / 117852605 320763374 / 117852612 320763375 / 117852613 320763376 / 117852614	19.7-20.2	1 - 8	7	TABLE 22-1C	Pass	Favorable

TA2U1	E	320763377 / 117852631 320763378 / 117852632 320763379 / 117852633 320763380 / 117852634	19.7-20.2	1 - 8	7	TABLE 22-1C	Pass	Favorable
TA2U2	E	320763381 / 117852651 320763382 / 117852652 320763383 / 117852653 320763384 / 117852654	19.7-20.2	1 - 8	7	TABLE 22-1C	Pass	Favorable
TU1B	E	320763385 / 117852667 320763386 / 117852668 320763387 / 117852669 320763388 / 117852670	10.7-11.7	1 - 8	1, 2	RR 22.5C4 TABLE 22-1A TABLE 22-3	Pass Pass Pass	Favorable
TU1G	E	320763389 / 117852675 320763390 / 117852676 320763391 / 117852677 320763392 / 117852678 320763393 / 117852679 320763394 / 117852680	10.7-11.7	1 - 8	1, 2	RR 22.5C4 TABLE 22-1A TABLE 22-3	Pass Pass Pass	Favorable
TU1T	E	320763395 / 117852681 320763396 / 117852682 320763397 / 117852683 320763398 / 117852684 320763399 / 117852685 320763400 / 117852686	10.7-11.7	1 - 8	1, 2	RR 22.5C4 TABLE 22-1A TABLE 22-3	Pass Pass Pass	Favorable
TU1U1	E	320763401 / 117789277 320763402 / 117789278 320763403 / 117789279 320763404 / 117789280	10.7-11.7	1 - 8	1, 2	RR 22.5C4 TABLE 22-1A TABLE 22-3	Pass Pass Pass	Favorable
TU1U2	E	320763405 / 117789281 320763406 / 117789282 320763407 / 117789283 320763408 / 117789284	10.7-11.7	1 - 8	1, 2	RR 22.5C4 TABLE 22-1A TABLE 22-3	Pass Pass Pass	Favorable
TU2B	E	320763409 / 117852706 320763410 / 117852707 320763411 / 117852708 320763412 / 117852709	11.7-12.2	1 - 8	1	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D	Pass Pass Pass Pass	Favorable
TU2B	E	320763413 / 117852710 320763414 / 117852711 320763415 / 117852712 320763416 / 117852713	12.2-12.7	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable
TU2B	E	320763417 / 117852714 320763418 / 117852715 320763419 / 117852716 320763420 / 117852717 320763421 / 117852718 320763422 / 117852719 320763423 / 117852720 320763424 / 117852721	12.5-12.75	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable
TU2G	E	320763425 / 117852738 320763426 / 117852739 320763427 / 117852740 320763437 / 117852750 320763438 / 117852751 320763439 / 117852752	11.7-12.2	1 - 8	1	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D	Pass Pass Pass Pass	Favorable
TU2G	E	320763428 / 117852741 320763429 / 117852742	12.2-12.7	1 - 8	1, 2	RR 22.5C4 RR 22.5C8	Pass Pass	Favorable
		320763430 / 117852743 320763440 / 117852753 320763441 / 117852754 320763442 / 117852755				TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass	

TU2G	E	320763431 / 117852744 320763432 / 117852745 320763433 / 117852746 320763434 / 117852747 320763435 / 117852748 320763436 / 117852749 320763443 / 117852756 320763444 / 117852757 320763445 / 117852758 320763446 / 117852759 320763447 / 117852760 320763448 / 117852761	12.5-12.75	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable
TU2T	E	320763449 / 117852762 320763450 / 117852763 320763451 / 117852764 320763461 / 117852774 320763462 / 117852775 320763463 / 117852776	11.7-12.2	1 - 8	1	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D	Pass Pass Pass Pass	Favorable
TU2T	E	320763452 / 117852765 320763453 / 117852766 320763454 / 117852767 320763464 / 117852777 320763465 / 117852778 320763466 / 117852779	12.2-12.7	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable
TU2T	E	320763455 / 117852768 320763456 / 117852769 320763457 / 117852770 320763458 / 117852771 320763459 / 117852772 320763460 / 117852773 320763467 / 117852780 320763468 / 117852781 320763469 / 117852782 320763470 / 117852783 320763471 / 117852784 320763472 / 117852785	12.5-12.75	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable
TU2U1	E	320763473 / 117789295 320763474 / 117789296 320763475 / 117789297 320763476 / 117789298	11.7-12.2	1 - 8	1	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D	Pass Pass Pass Pass	Favorable
TU2U1	E	320763477 / 117789313 320763478 / 117789314 320763479 / 117789315 320763480 / 117789316	12.2-12.7	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable
TU2U1	E	320763481 / 117789331 320763482 / 117789332 320763483 / 117789333 320763484 / 117789334 320763485 / 117789349 320763486 / 117789350 320763487 / 117789351 320763488 / 117789352	12.5-12.75	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable
TU2U2	E	320763489 / 117789299 320763490 / 117789300 320763491 / 117789301 320763492 / 117789302	11.7-12.2	1 - 8	1	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D	Pass Pass Pass Pass	Favorable
TU2U2	E	320763493 / 117789317 320763494 / 117789318 320763495 / 117789319 320763496 / 117789320	12.2-12.7	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable

TU2U2	E	320763497 / 117789335 320763498 / 117789336 320763499 / 117789337 320763500 / 117789338 320763501 / 117789353 320763502 / 117789354	12.5-12.75	1 - 8	1, 2	RR 22.5C4 RR 22.5C8 TABLE 22-1A TABLE 22-1D TABLE 22-3	Pass Pass Pass Pass Pass	Favorable
		320763503 / 117789355 320763504 / 117789356						

Notes:

1. Findings are promulgated as favorable when all applicable limits in Article 22 are met for given group of frequency assignments in all applicable scenarios.
2. The Result column can be either Pass or Fail (see Rec. ITU-R S.1503-2). N/A (Non Applicable) refers to the case when an applicable Article 22 limit is not examined in the current scenario.
3. Qualified Favorable is established due to continuous application of Resolution 85 (WRC-03) on request by the notifying administration.

II. Operations in V-band:

For its operation in the V-band, Theia will rely on the newly prepared ITU filing USASAT-NGSO-4A (Backlog). Theia prepared the following analysis to demonstrate compliance with Article 22 of the ITU Radio Regulations.

1. Introduction

The Theia non-geostationary-satellite orbit fixed-satellite service network operations in the band frequency ranges 37.5-42.5 GHz for space-to-Earth transmissions and 47.2-50.2 GHz and 50.4-51.4 GHz for Earth-to-space transmissions meet EPFD rules as described in the ITU Radio Regulations and the Commission's rules.

These frequency bands are subject to the protection requirements of Article 22 of the ITU Radio Regulations, including No. 22.5L, which applies to non-GSO FSS systems operating in these bands with respect to protection of geostationary-satellite orbit FSS and BSS networks. Theia has been assessed using the methodology of Resolution 770 (Rev.WRC-23), together with the procedures and equivalent power flux-density calculation framework prescribed in the most current version of Recommendation ITU-R S.1503.

The purpose of this analysis is to demonstrate that Theia complies with the applicable single-entry limits in No. 22.5L. The assessment confirms that the interference produced by Theia into GSO reference links remains within the applicable Resolution 770 criteria, namely that Theia does not cause an increase of more than 3% in the time fraction for which the GSO reference links fall below the applicable short-term performance objective, and does not cause a reduction of more than 3% in the long-term average spectral efficiency of the GSO reference links.

The analysis is based on the technical characteristics of the Theia constellation, satellite transmit parameters, earth station transmit parameters, antenna patterns, operational constraints, and service-link assumptions summarized below.

- ITU filing name / satellite network name: USASAT-NGSO-4A
- Downlink frequency range: 37.5-42.5 GHz
- Uplink frequency ranges: 47.2-50.2 GHz and 50.4-51.4 GHz
- Satellite antenna pattern reference: ITU-R S.1528, LN=-30
- Earth station antenna pattern reference: ITU-R S.580
- Maximum satellite EIRP density: 21.9 dBW/MHz
- Maximum satellite PFD mask at the surface of the Earth: -116 dBW/m2/MHz
- Maximum satellite PFD mask at the surface of the Earth when in the GSO exclusion zone: -151 dBW/m2/MHz
- Maximum earth station power density: -71.5 dBW/Hz
- Minimum operational elevation angle: 12 degrees
- GSO avoidance angle: 10 degrees

- Number and distribution of gateway earth stations: 1000 km average spacing, with a density of 0.000001 stations per km^2
- Analysis software and version: Transfinite Visualyse EPFD V.3.923
- Recommendation ITU-R S.1503 version applied: S.1503-4
- Resolution 770 methodology implementation: WRC-23
- Calculated results compared to No. 22.5L criteria: PASS

2. Technical Analysis

Theia operates in high-frequency V-band spectrum where narrow spot beams, controlled antenna patterns, and high-gain earth station antennas are expected to provide substantial discrimination between the intended Theia links and GSO reference links. The Theia system design uses controlled satellite and earth station emissions, defined service areas, and operational constraints to limit the power radiated toward the geostationary arc and toward GSO receiving systems.

For the 37.5-42.5 GHz downlink, the principal interference mechanism is aggregate interference from Theia space stations into GSO FSS earth station receivers. This is assessed through epfd(down) statistics generated in accordance with the applicable ITU-R S.1503 procedures and then applied within the Resolution 770 methodology for the V-band GSO reference links.

For the 47.2-50.2 GHz and 50.4-51.4 GHz uplink bands, the principal interference mechanism is aggregate interference from Theia earth station transmitters into GSO satellite receivers. This is assessed through epfd(up) statistics generated in accordance with the applicable ITU-R S.1503 procedures and applied to the Resolution 770 GSO reference link methodology.

The Theia system has been modelled using the constellation geometry, frequency assignments, antenna patterns, EIRP density limits, and operational assumptions identified in the input parameter table above. The analysis accounts for the time-varying nature of the NGSO geometry, the pointing relationship between Theia satellites, Theia earth stations, and GSO reference systems, and the statistical distribution of interference events over the simulation period.

The following technical assumptions are applied:

- Theia satellite transmissions in the 37.5-42.5 GHz band are limited to the maximum EIRP density and antenna gain patterns submitted for the network.
- Theia earth station transmissions in the 47.2-50.2 GHz and 50.4-51.4 GHz bands are limited to the maximum EIRP density, antenna gain patterns, and pointing constraints submitted for the network.
- Theia operates using beam pointing, beam shaping, and operational constraints that prevent unnecessary radiation toward the GSO arc.
- A minimum elevation angle of 12 degrees and a GSO avoidance angle of 10 degrees is included in the simulation and applied consistently across the analysis.
- The assessment uses the applicable Resolution 770 reference link framework for the relevant Q/V-band frequency ranges.
- The epfd statistics used as input to the Resolution 770 assessment are generated in accordance with the current version of Recommendation ITU-R S.1503.

3. Regulatory Considerations

Article 22 of the ITU Radio Regulations establishes requirements for non-GSO systems to protect GSO networks in certain frequency bands. For V-band NGSO FSS operations in the

37.5-42.5 GHz downlink and 47.2-50.2 GHz and 50.4-51.4 GHz uplink bands, No. 22.5L applies the Resolution 770 framework for protection of GSO FSS and BSS networks.

Resolution 770 establishes the methodology and criteria for assessing the single-entry interference impact of an NGSO FSS system into representative GSO reference links in these bands. The criteria are based on the effect of NGSO interference on GSO link performance rather than on a simple fixed epfd mask alone. Compliance is demonstrated where the NGSO system does not exceed the prescribed degradation criteria for the GSO reference links.

For Theia, the relevant compliance criteria are:

- the increase in the time fraction for which the GSO reference links fall below the applicable short-term performance objective does not exceed 3%; and,
- the reduction in long-term average spectral efficiency of the GSO reference links does not exceed 3%.

Recommendation ITU-R S.1503 provides the functional methodology for calculating epfd statistics for non-GSO FSS systems and for determining conformity with Article 22 limits. For this analysis, the Theia epfd(down) and epfd(up) statistics are calculated using the current version of Recommendation ITU-R S.1503 and then used in the Resolution 770 methodology applicable to the 37.5-42.5 GHz, 47.2-50.2 GHz, and 50.4-51.4 GHz bands.

On this basis, the Theia analysis is aligned with the applicable ITU regulatory framework and provides the required demonstration of compliance with No. 22.5L.

At this stage, however, it is important to note that the ITU Radiocommunication Bureau does not have compliance assessment software available to independently assess compliance with No. 22.5L using the Resolution 770 methodology for the Q/V-band frequency ranges. The present assessment therefore reflects Theia’s good-faith technical analysis using the currently available methodology, the current version of Recommendation ITU-R S.1503, and the Resolution 770 framework as presently published.

Theia acknowledges that the ITU-R methodology, the implementation of Recommendation ITU-R S.1503, and the Resolution 770 compliance procedure may be further developed or modified before the ITU BR publishes or makes available its compliance assessment software. Such future developments may result in changes to the EPFD masks, reference link parameters, input assumptions, calculation procedures, or other parameters required to demonstrate compliance with No. 22.5L.

Accordingly, Theia commits to updating this analysis, including the applicable input parameters, assumptions, EPFD masks, software implementation, and compliance results, at the time of network notification, at such other time as the ITU BR compliance assessment methodology and software become available or at the Commission's request. Any such update would be made to reflect the methodology and parameters applicable at the time of formal ITU assessment.

4. Software and Analysis Method

The Theia compliance assessment was performed using Transfinite Visualyse EPFD version 3.923, applying the methodology prescribed in Resolution 770 and the epfd calculation procedures prescribed in the current version of Recommendation ITU-R S.1503.

The analysis included the following steps:

1. The Theia constellation was modelled using the submitted orbital parameters, including altitude, inclination, number of orbital planes, number of satellites per plane, and phasing.

2. The Theia space station transmit characteristics were modelled for the 37.5-42.5 GHz downlink band, including antenna patterns, maximum EIRP density, beam pointing, and operational constraints.
3. The Theia earth station transmit characteristics were modelled for the 47.2-50.2 GHz and 50.4-51.4 GHz uplink bands, including earth station antenna patterns, maximum EIRP density, gateway distribution, and pointing constraints.
4. The epfd↓ and epfd↑ statistics were calculated using the current Recommendation ITU-R S.1503 methodology.
5. The resulting epfd statistics were applied to the Resolution 770 reference link methodology for the relevant GSO FSS and BSS reference links.
6. The calculated results were compared against the No. 22.5L single-entry criteria.

   Placeholder: Insert software output summary

   • Downlink epfd↓ result for 37.5-39.5 GHz: PASS

• Downlink epfd↓ result for 39.5-42.5 GHz: PASS

• Uplink epfd↑ result for 47.2-50.2 GHz: PASS

• Uplink epfd↑ result for 50.4-51.4 GHz: PASS

• Simulation duration / time step / statistical confidence: 308632807 steps = = 2 years, 134 days, 10:58:59.294

5. **Impact Assessment**

The analysis confirms that Theia satisfies the applicable No. 22.5L criteria for the Q/V-band frequency ranges under consideration.

For the 37.5-42.5 GHz downlink, the calculated epfd(down) statistics demonstrate that aggregate interference from Theia space stations into GSO earth station reference links remains within the Resolution 770 single-entry criteria. The Theia satellite antenna patterns, beam pointing assumptions, and EIRP density limits constrain the power radiated toward GSO receiving earth stations and prevent exceedance of the applicable performance degradation thresholds.

For the 47.2-50.2 GHz and 50.4-51.4 GHz uplink bands, the calculated epfd(up) statistics demonstrate that aggregate interference from Theia earth stations into GSO satellite reference receivers remains within the Resolution 770 single-entry criteria. The Theia earth station antenna discrimination, pointing geometry, maximum EIRP density limits, and any applicable GSO avoidance constraints ensure that the interference contribution from the Theia uplink remains below the applicable thresholds.

The resulting Resolution 770 assessment shows that Theia does not exceed the 3% short-term performance degradation criterion and does not exceed the 3% long-term average spectral efficiency reduction criterion for the applicable GSO reference links. A summary table for these results is shown below,

Table 1: Summary of EPFD Run Results

Direction	**Criterion**	**22.5L Limit**	**Worst Result**	**Margin**
Uplink	DU	3.000%	0.031275%	2.968725 pp
Uplink	DThr	3.000%	0.005256%	2.994744 pp
Downlink	DU	3.000%	0.000000%	3.000000 pp
Downlink	DThr	3.000%	0.068998%	2.931002 pp

For the uplink assessment, the maximum calculated increase in the time fraction for which the GSO reference links fall below the applicable short-term C/N performance objective is 0.031275%, compared with the 3% limit in No. 22.5L. This provides an uplink DU margin of 2.968725 percentage points. The maximum calculated reduction in long-term average spectral efficiency for the uplink cases is 0.005256%, compared with the 3% limit. This provides an uplink DThr margin of 2.994744 percentage points. The controlling uplink criterion is therefore the short-term unavailability criterion.

For the downlink assessment, the maximum calculated increase in the time fraction for which the GSO reference links fall below the applicable short-term C/N performance objective is 0.000000%, compared with the 3% limit in No. 22.5L. This provides a downlink DU margin of 3.000000 percentage points. The maximum calculated reduction in long-term average spectral efficiency for the downlink cases is 0.068998%, compared with the 3% limit. This provides a downlink DThr margin of 2.931002 percentage points. The controlling downlink criterion is therefore the long-term spectral efficiency criterion.

The overall controlling result is the downlink DThr result of 0.068998%, which remains materially below the applicable 3% threshold. Accordingly, the Theia Satellite Network complies with the applicable single-entry limits in No. 22.5L using the Resolution 770 methodology.

6. Conclusion

The Theia Satellite Network has been assessed for compliance with the applicable Article 22 requirements for operation in the 37.5-42.5 GHz downlink band and the 47.2-50.2 GHz and 50.4-51.4 GHz uplink bands.

The assessment was performed using the methodology of Resolution 770 and the EPFD calculation procedures prescribed in the current version of Recommendation ITU-R S.1503. The analysis considered Theia's constellation geometry, transmit power levels, antenna characteristics, beam pointing assumptions, operational constraints, and the applicable GSO reference link methodology.

Based on the presently available methodology and software implementation, Theia complies with the single-entry limits in No. 22.5L of the ITU Radio Regulations. The Theia system does not cause more than a 3% increase in the time fraction for which the GSO reference links fall below the applicable short-term performance objective and does not cause more than a 3% reduction in the long-term average spectral efficiency of the GSO reference links.

This conclusion is subject to the current status of the ITU BR assessment process. The ITU BR does not currently have compliance assessment software available for the independent assessment of No. 22.5L compliance using the Resolution 770 methodology in these bands. In addition, the applicable methodology, including Recommendation ITU-R S.1503 and Resolution 770 implementation details, may be further revised before such software becomes available. These changes may affect the EPFD masks, reference link assumptions, input parameters, or calculation procedures required for formal ITU assessment.

Accordingly, Theia commits to updating this compliance analysis at the network notification stage. Any such update would be made to reflect the applicable ITU requirements, input parameters, masks, and software implementation in effect at the time of formal assessment.

Subject to these commitments, the current analysis demonstrates that Theia's operation in the 37.5-42.5 GHz, 47.2-50.2 GHz, and 50.4-51.4 GHz bands is compliant with the applicable single-entry limits in No. 22.5L using the Resolution 770 methodology.

III. Other EPFD Rules:

Theia confirms that it is not claiming interference protection from GSO FSS and BSS networks operating in accordance with the Commission's Part 25 rules and the ITU Radio Regulations.

Theia confirms it will coordinate with the very large GSO FSS earth stations in the 17.8-18.6 GHz and 19.7-20.2 GHz bands according to 9.7A and 9.7B of Table 5-1 of Appendix 5 of the ITU Radio Regulations.

Appendix 2

Compliance with PFD Limits

(Sections 25.208(b), 25.208(c), 25.208(o), 25.208(r), 25.208(s), 25.208(t), and 25.146(a)(1))

The non-geostationary satellite orbit ("NGSO") system proposed by Theia Holdings A, Inc. ("Theia"), the Theia network, complies with all applicable Federal Communications Commission ("FCC") and International Telecommunication Union ("ITU") power flux density ("PFD") limits, which are designed to protect the terrestrial fixed service ("FS") from downlink interference due to the satellite transmissions.

Downlink PFD Limits in Ku-band

The FCC's Ku-band downlink PFD limits in 10.7-11.7 GHz band, are provided in § 25.208(b) and listed below:

- *-150 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;*
- *-150+(δ-5)/2 dB(W/m$_2$) in any 4 kHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and*
- *-140 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.*

The ITU PFD limits, as shown in Table 21-4 of the ITU Radio Regulations, applicable to NGSO systems in the 10.7-11.7 GHz band with orbit altitude below 18,000 km are identical to the FCC PFD limits[62] described above. Compliance with the FCC/ITU PFD limits is demonstrated below.

The Theia Ku-band downlinks employ power control to create a constant effective isotropic radiated power ("EIRP") density on the Earth's surface over the range of operational user elevation angles from 12° to 90°. At elevation angles below the minimum operational elevation angle, the maximum PFD incident on the Earth's surface reflects the sidelobe energy of a beam scanned to the edge of coverage.

The maximum Ku-band downlink EIRP density for the Theia satellites is -16.6 dBW/4 kHz (7.4 dBW/MHz). The shortest distance from the Theia satellite to the Earth's surface (800 km) gives a worst case (i.e., smallest) spreading loss of 129.05 dB (i.e., $10*\log(4\pi(800x10^3)^2)$). The spreading loss at edge of coverage is 137.94dB. The maximum PFD from the Theia

[62] The ITU PFD limits are defined over a reference bandwidth of 1MHz rather than the 4kHz reference bandwidth for the FCC PFD limit. However, for uniform distribution of power over the assigned frequency band, as is the case with the Theia waveforms, this correspond to the same relative PFD.

satellites will never exceed –145.6 dBW/m^2/4kHz (-121.6 dBW/m^2/MHz) at nadir and will never exceed -154.54 dBW/m^2/4kHz (-130.54 dBW/m^2/MHz) at the minimum operational elevation angle of 12 degrees. This translates to always operating at least 6 dB below the PFD limit at any elevation angle.

The PFD levels at the Earth's surface for all elevation angles are illustrated in Figure 1. These PFD levels for emissions in the 10.7-11.7 GHz band apply to all Theia satellites at any location on the Earth's surface. From this it can be seen that the Theia Ku-band downlink transmissions are compliant with the PFD limit in 47 C.F.R. § 25.208(b) with no less than 6 dB margin.

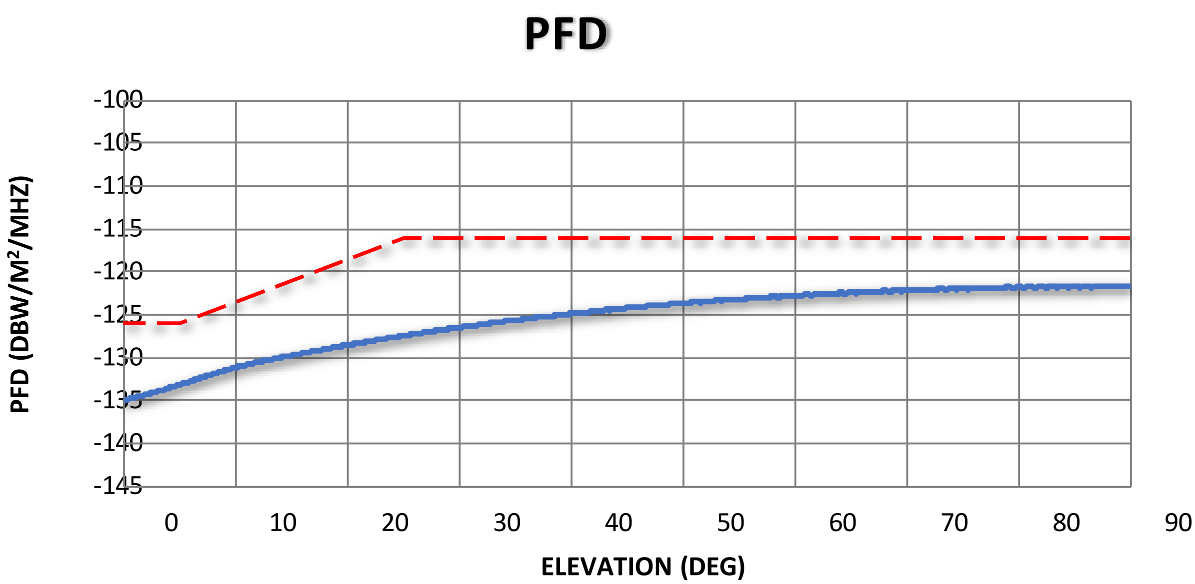

Figure 1. Theia Ku (10.7-11.7 GHz) PFD vs. Elevation Angle

Section 25.146(a)(1) incorporates by reference the PFD limits contained in Article 21, Section V, Table 21-4 of the ITU Radio Regulations. The ITU PFD limits in the 11.7-12.7 GHz band are 2 dB higher (more relaxed) than the FCC PFD limits at every elevation angle in the 10.7-11.7 GHz band. Because the Theia EIRP density profiled for the 10.7-11.7 GHz band is also applicable to the 11.7-12.7 GHz band, Theia will also be compliant with these ITU PFD limits with a margin of at least 8 dB.

The FCC has adopted specific low-elevation PFD limits in 47 C.F.R. § 25.208(o), which apply in the 12.2-12.7 GHz band in order to protect the terrestrial Multichannel Video Distribution and Data Service ("MVDDS"). These limits, which relate to the PFD into an actual operational MVDDS receiver, are defined as follows:

- *-158 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 2 degrees above the horizontal plane;*
- *-158+3.33(δ-2) dB(W/m^2) in any 4 kHz band for angles of arrival δ (in degrees) between 2 and 5 degrees above the horizontal plane.*

Theia compliance with the FCC's low-elevation-angle PFD limits in the 12.2-12.7 GHz band is illustrated in Figure 2. As demonstrated below, the Theia PFD is more than 0.25 dB below the limits set by Section 25.208(o).

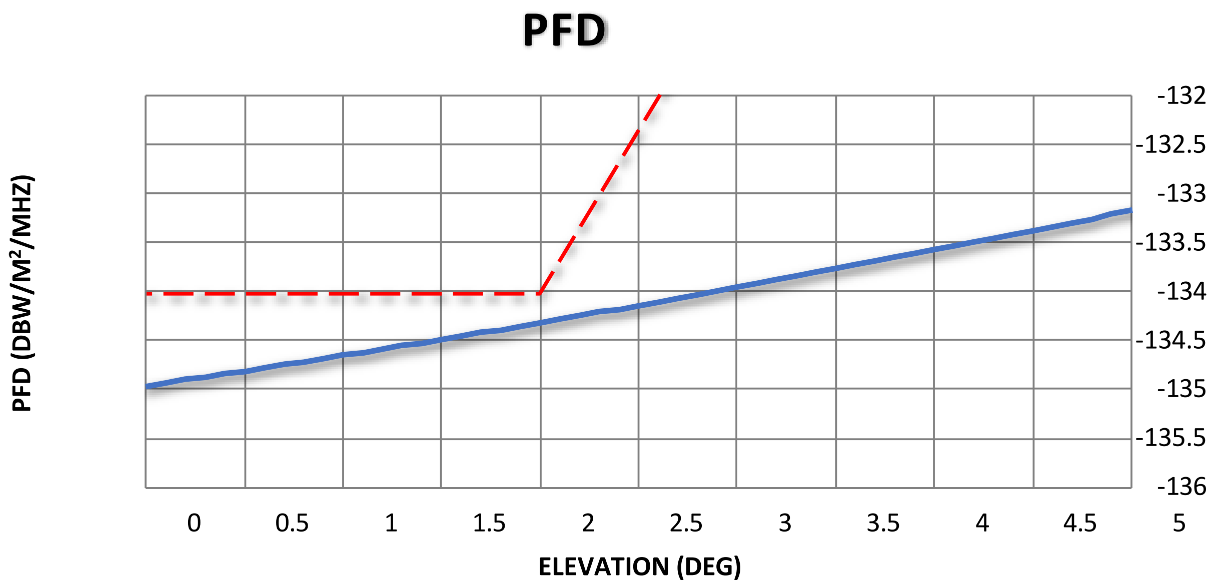

Figure 2. Theia Ku MVDDS (12.2-12.7 GHz) PFD vs. Elevation Angle

As illustrated by the analysis provided in this section, the Theia satellites comply with all the Ku-band FCC and ITU PFD limits.

Downlink PFD Limits in Ka-band

The FCC's Ka-band downlink PFD limits are defined in Section 25.146(a), which incorporates by reference the PFD limits specified in Table 21-4 of Article 21 of the ITU Radio Regulations. These limits apply in various parts of the Ka-band downlink bands used by Theia. Furthermore, certain sub-bands, such as 19.3-19.7 GHz, are subject to more relaxed ITU PFD limits defined by Article 21, Table 21-4, note 21.16.6B, of the Radio Regulations.

The Theia satellites use Ka-band downlink spectrum (17.8-18.6 GHz and 18.8-20.2 GHz) for communications with gateway earth stations with very high G/T. Therefore, the PFD limits will be easily met. To simplify the PFD analysis in these bands, only the most stringent Ka-band downlink PFD limits (reflected in Article 21, Table 21.4, note 21.16.6, of the ITU Radio Regulations) will be considered. By demonstrating compliance with the more stringent ITU/FCC PFD limits, the other FCC and ITU PFD limits are necessarily also met.

The most constraining Ka-band FSS downlink PFD limits are defined as follows:

- *-115-X dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5*

- *degrees above the horizontal plane;*
- *-115-X+((10+X)/20)(δ-5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and*
- *-105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.*

Where X is defined as a function of the number of satellites in the NGSO FSS constellation, n, as:

- *$X = 0$ dB for $n \leq 50$*
- *$X = (5/119)(n - 50)$ dB for $50 < n \leq 288$*
- *$X = (1/69)(n + 402)$ dB for $n > 288$*

These PFD limits apply to each Theia satellite. The value of "n" is 112 for the Theia constellation and therefore X is equal to 2.61 dB according to the above formulae. For Theia, the PFD limits can be expressed in the simplified version below:

- *-117.61 dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;*
- *-117.61+0.63(δ-5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and*
- *-105 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.*

Theia employs downlink power control to maintain a constant downlink EIRP density across the operational range of elevation angle between 12° and 90°. The PFD at edge of coverage ("EOC") of 12 degrees, along with the target EIRP Density levels at EOC and Nadir, are listed in Table 1.

Table 2 Ka-Band Downlink Constant EIRP Density – Maximum Levels

Ka Downlink Band	PFD (EOC) dBW/m^2/MHz	EIRP Density (Nadir) dBW/MHz	EIRP Density (EOC) dBW/MHz
17.8-18.6 GHz	-125.87	12.07	12.07
18.8-20.2 GHz	-125.87	12.07	12.07

Based upon maintaining constant EIRP density across the range of operational elevation angles from 12° to 90° and accounting for beam roll-off beyond the edge of coverage, the PFD curves for the Ka-band segments (17.8-18.6 and 18.8-20.2 GHz) are illustrated in Figure 3, Figure 4, and Figure 5, respectively.

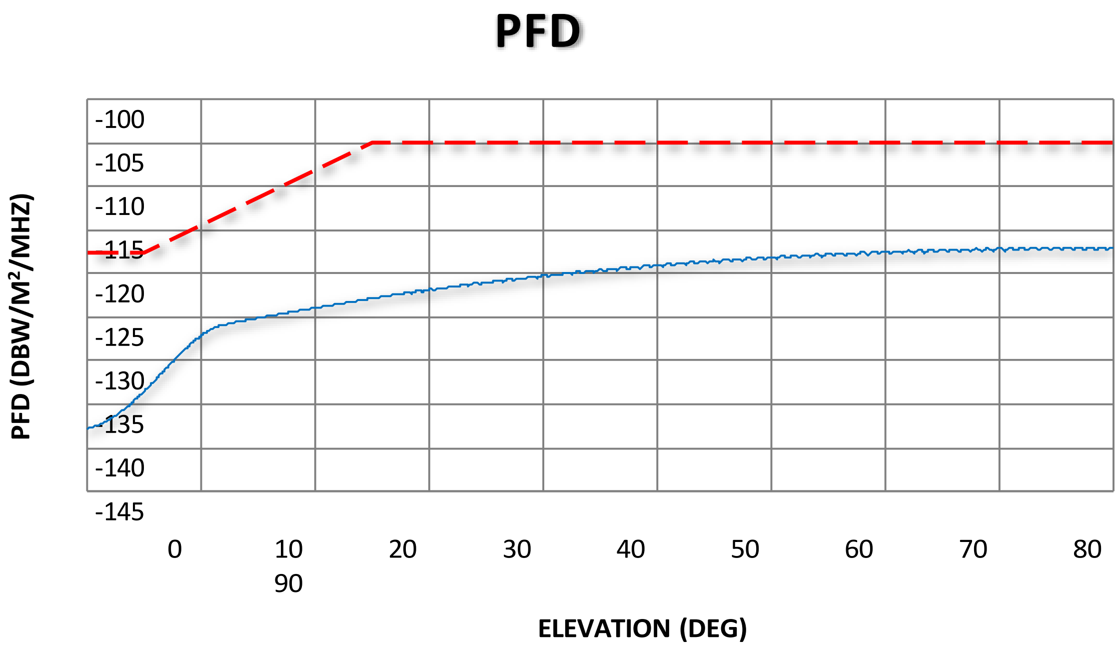

Figure 3. Theia Ka-Band Lower (17.8-18.6 GHz) PFD vs. Elevation Angle

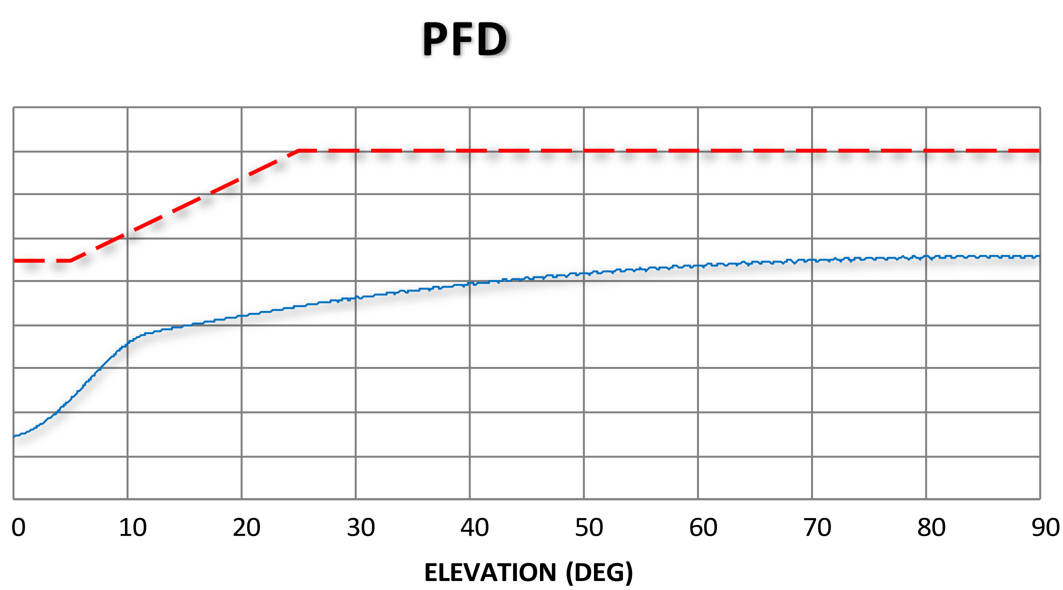

Figure 4. Theia Ka-Band Upper (18.8-20.2 GHz) PFD vs. Elevation Angle

z) PFD vs. Elevation Angle

As illustrated by the analysis provided in this section, the Theia satellites comply with all the Ka-band FCC and ITU PFD limits.

Downlink PFD Limits in V-band

The FCC's V-band downlink PFD limits are defined in Sections 25.208(r), 25.208(s) and Section 25.146(a)(1) incorporates by reference the PFD limits contained in

Article 21, Section V, Table 21-4 of the ITU Radio Regulations. Additionally, Section 25.208(r), (s), and (t) contain PFD limits that apply to various parts of V-band.

Theia will comply with the PFD limit specified in § 25.208 as shown in the table below. The PFD limits in the 37.5-40.0 GHz band are more stringent 12 dB than those in Article 21 of the RR, while the PFD limits in the 40.0-40.5 GHz and 40.5-42.0 GHz are the same and consistent with Article 21 of the RR.

Band	Applicable FCC Limit
37.5-40.0 GHz	25.208 (r)
40.0-40.5 GHz	25.208(s)
40.5-42.0 GHz	25.208(t)

In clear sky conditions, no rain fade, Theia will meet the most restrictive PFD limits specified in Section 25.208(r)(1) of the Commission's rules for NGSO FSS sy stems operating in the 37.5GHz to 40GHz band. During limited periods of operation during rain fades, Theia will exceed the PFD limits specified in Section 25.208(r)(1) of the Commission rules for NGSO FSS systems operating in the 37.5-40 GHz band but easily meet the worst-case PFD limits for this band as specified in Section 25.208(r)(2).

Theia satellites will use V-band downlink spectrum for communications with gateway and other high-capacity earth stations with very high G/T. Therefore, all of the remaining PFD limits will be easily met. To simplify the PFD, analysis only the most stringent V-Band downlink limits will be considered. By demonstrating compliance with the most stringent ITU limits, the other FCC and ITU PFD limits are also necessarily met.

The most constraining V-Band FSS downlink PFD limits under any condition defined by the ITU for the 37.5-40.0 GHz and 42.0-42.5 bands are:

- -120 dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -120 +0.75(δ-5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -105 dB(W/m2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

The most constraining V-Band FSS downlink PFD limits under clear sky conditions defined by the FCC for the 37.5-40.0 GHz bands are:

- -132 dB(W/m^2) in any 1 MHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
- -132 +0.75(δ-5) dB(W/m^2) in any 1 MHz band for angles of arrival δ (in degrees) between 5 and 25 degrees above the horizontal plane; and
- -117 dB(W/m^2) in any 1 MHz band for angles of arrival between 25 and 90 degrees above the horizontal plane.

Theia's V-band downlink will operate in the same manner across the entire V-band, even though the PFD restrictions vary by sub-band. Theia employs downlink power control to combat rain fades and maintains a constant downlink EIRP density across the operational range of the elevation angles between 12° and 90° during clear sky conditions when downlink power control is not required. The maximum PFD at edge of coverage (EOC) of 12 deg is -124.08 dB(W/m^2/MHz) which corresponds to a target EIRP density level over the entire operational footprint of 13.86 dBW/MHz. This PFD reflects Theia's satellites operating at maximum power levels but assumes only free space propagation (e.g., no rain or atmospheric losses).

Based upon maintaining constant EIRP density across the range of operational elevation angles from 12° to 90° and accounting for beam roll-off beyond the edge of coverage, the maximum PFD curves for the V-Band is illustrated in Figure 5.

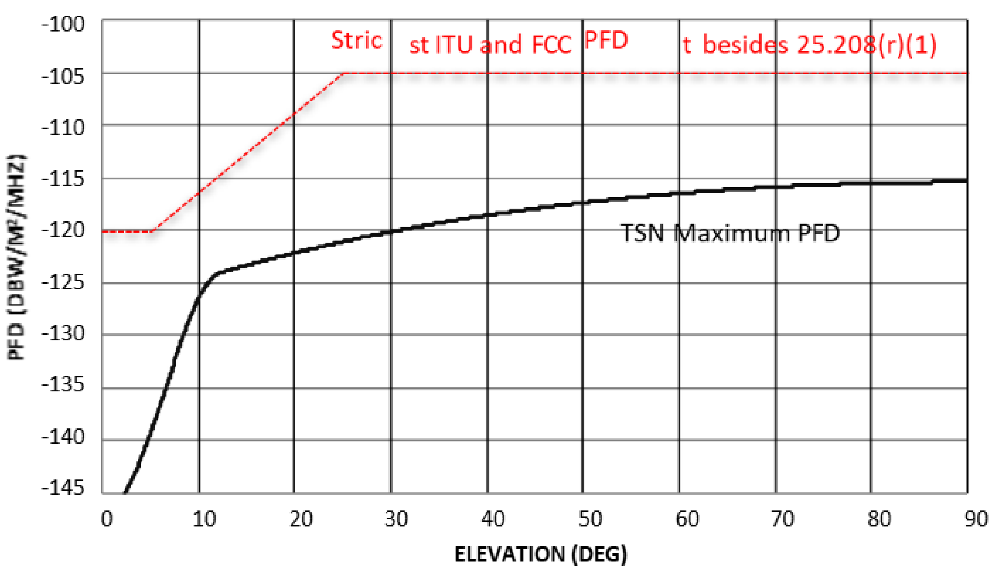

Figure 5: Theia's V-Band Maximum PFD vs. Elevation Angle

Appendix 3

Theia Link Budgets

User Link Uplink Link Budgets:

		40cm UT		80cm UT	
		EOC	NADIR	EOC	NADIR
Orbit Altitude	km	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	deg	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	deg	60.36	0.00	60.36	0.00
Slant Range	km	2224.06	800.00	2224.06	800.00
Link Frequency	GHz	14.50	14.50	14.50	14.50
Channel Symbol Rate	Msps	41.67	41.67	41.67	41.67
Bandwidth Efficiency	bps/Hz	0.92	0.92	1.84	1.84
Burst Information Data Rate	Mbps	38.19	38.19	76.66	76.66
ModCod		QPSK 9/20	QPSK 9/20	8APSK 26/45-L	8APSK 26/45-L
Effective EIRP	dBW	44.44	44.44	50.46	50.46
Free Space Loss	dB	182.62	173.74	182.62	173.74
Effective G/T	dBi/K	-5.2	-5.2	-5.2	-5.2
Receive Power	dBW	-116.71	-107.83	-110.69	-101.81
Received C/N	dB	9.06	17.94	15.08	23.96
C/I	dB	11.50	11.50	11.50	11.50
Required C/(N+I)	dB	2.48	2.48	7.12	7.12
Required C/N	dB	3.06	3.06	9.08	9.08
External Interference Loss	dB	1.00	1.00	1.00	1.00
Clear Sky Link Margin	dB	5.0	13.9	5.0	13.9

User Link Downlink Link Budgets:

		40cm UT		80cm UT	
		EOC	NADIR	EOC	NADIR
Orbit Altitude	km	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	deg	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	deg	60.36	0.00	60.36	0.00
Slant Range	km	2224.06	800.00	2224.06	800.00
Link Frequency	GHz	12.20	12.20	12.20	12.20
Channel Symbol Rate	Msps	415.83	415.83	415.83	415.83
Spreading	Chips/Sym	3.00	3.00	1.00	1.00
Bandwidth Efficiency	bps/Hz	0.15	0.15	0.56	0.56
Burst Information Data Rate	Mbps	62.16	62.16	234.71	234.71
Mod Cod		QPSK 2/9	QPSK 2/9	QPSK 2/9	QPSK 2/9
Effective EIRP	dBW	33.08	33.08	33.08	33.08
Free Space Loss	dB	181.12	172.24	181.12	172.24
Effective G/T	dBi/K	4.7	4.7	10.7	10.7
Receive Power	dBW	-116.93	-108.05	-110.91	-102.03
Received C/N	dB	-0.95	7.93	5.07	13.95
C/I	dB	12.00	12.00	12.00	12.00
Required C/(N+I)	dB	-1.38	-1.38	-0.20	-0.20
Required C/N	dB	-5.95	-5.95	0.07	0.07
External Interference Loss	dB	1.00	1.00	1.00	1.00
Clear Sky Link Margin	dB	4.0	12.9	4.0	12.9

Feeder Link Uplink Link Budgets:

		1.6m Gateway Terminal		4.8m Gateway Terminal	
		EOC	NADIR	EOC	NADIR
Orbit Altitude	**km**	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	**deg**	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	**deg**	60.36	0.00	60.36	0.00
Slant Range	**km**	2224.06	800.00	2224.06	800.00
Link Frequency	**GHz**	28.75	28.75	28.75	28.75
Channel Symbol Rate	**Msps**	2083.33	2083.33	2083.33	2083.33
Bandwidth Effciency	**bps/Hz**	2.17	2.17	4.16	4.16
Burst Information Data Rate	**Mbps**	**4522.65**	**4522.65**	**8668.02**	**8668.02**
ModCod		8PSK 13/18	8PSK 13/18	32APSK 7/9	32APSK 7/9
Effective EIRP	**dBW**	**74.59**	**74.59**	**84.23**	**84.23**
Free Space Loss	**dB**	188.57	179.68	188.57	179.68
Effective G/T	**dBi/K**	**8.5**	**8.5**	**8.5**	**8.5**
Receive Power	**dBW**	-78.33	-69.45	-68.70	-59.82
Received C/N	**dB**	29.95	38.84	39.59	48.47
C/I	**dB**	18.00	18.00	18.00	18.00
Required C/(N+I)	**dB**	8.44	8.44	15.27	15.27
Required C/N	**dB**	8.95	8.95	18.59	18.59
External Interference Loss	**dB**	1.00	1.00	1.00	1.00
Clear Sky Link Margin	**dB**	**20.0**	**28.9**	**20.0**	**28.9**

Feeder Link Downlink Link Budgets:

		17.8 GHz to 18.6 GHz			
		1.6m Gateway Terminal EOC	NADIR	4.8m Gateway Terminal EOC	NADIR
Orbit Altitude	**km**	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	**deg**	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	**deg**	60.36	0.00	60.36	0.00
Slant Range	**km**	2224.06	800.00	2224.06	800.00
Link Frequency	**GHz**	18.20	18.20	18.20	18.20
Channel Symbol Rate	**Msps**	666.67	666.67	666.67	666.67
Bandwidth Efficiency	**bps/Hz**	1.19	1.19	3.28	3.28
Burst Information Data Rate	**Mbps**	**791.40**	**791.40**	**2183.97**	**2183.97**
ModCod		QPSK 11/20	QPSK 11/20	16APSK 7/9	16APSK 7/9
Effective EIRP	**dBW**	**39.80**	**39.80**	**39.80**	**39.80**
Free Space Loss	**dB**	184.59	175.71	184.59	175.71
Effective G/T	**dBi/K**	**19.7**	**19.7**	**29.2**	**29.2**
Receive Power	**dBW**	-98.17	-89.29	-88.63	-79.74
Received C/N	**dB**	15.24	24.12	24.78	33.66
C/I	**dB**	18.00	18.00	18.00	18.00
Objective C/(N+I)	**dB**	4.06	4.06	12.39	12.39
Required C/N	**dB**	4.24	4.24	13.78	13.78
External Interference Loss	**dB**	1.00	1.00	1.00	1.00
Clear Sky Link Margin	**dB**	**10.0**	**18.9**	**10.0**	**18.9**

Feeder Link Downlink Link Budgets:

		18.8 GHz to 20.2 GHz			
		1.6m Gateway Terminal EOC	NADIR	4.8m Gateway Terminal EOC	NADIR
Orbit Altitude	km	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	deg	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	deg	60.36	0.00	60.36	0.00
Slant Range	km	2224.06	800.00	2224.06	800.00
Link Frequency	GHz	19.50	19.50	19.50	19.50
Channel Symbol Rate	Msps	1166.67	1166.67	1166.67	1166.67
Spreading		3.00	3.00	1.00	1.00
Bandwidth Efficiency	bps/Hz	0.19	0.19	1.29	1.29
Burst Information Data Rate	Mbps	225.50	225.50	1500.73	1500.73
ModCod		QPSK 13/45	QPSK 13/45	QPSK 11/20	QPSK 11/20
Effective EIRP	dBW	33.23	33.23	33.23	33.23
Free Space Loss	dB	185.19	176.31	185.19	176.31
Effective G/T	dBi/K	20.3	20.3	29.8	29.8
Receive Power	dBW	-104.74	-95.86	-95.20	-86.31
Received C/N	dB	6.24	15.12	15.78	24.66
C/I	dB	18.00	18.00	18.00	18.00
Objective C/(N+I)	dB	-0.06	-0.06	4.58	4.58
Required C/N	dB	-4.76	-4.76	4.78	4.78
External Interference Loss	dB	1.00	1.00	1.00	1.00
Clear Sky Link Margin	dB	10.0	18.9	10.0	18.9

Feeder Link Downlink Link Budgets:

		25.5 GHz to 27.0 GHz			
		1.6m Gateway Terminal EOC	NADIR	4.8m Gateway Terminal EOC	NADIR
Orbit Altitude	**km**	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	**deg**	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	**deg**	60.36	0.00	60.36	0.00
Slant Range	**km**	2224.06	800.00	2224.06	800.00
Link Frequency	**GHz**	26.25	26.25	26.25	26.25
Channel Symbol Rate	**Msps**	1250.00	1250.00	1250.00	1250.00
Bandwidth Efficiency	**bps/Hz**	2.09	2.09	4.10	4.10
Burst Information Data Rate	**Mbps**	**2615.29**	**2615.29**	**5118.87**	**5118.87**
ModCod		8PSK 25/36	8PSK 25/36	32APSK 7/9	32APSK 7/9
Effective EIRP	**dBW**	**46.90**	**46.91**	**46.90**	**46.91**
Free Space Loss	**dB**	187.78	178.89	187.78	178.89
Effective G/T	**dBi/K**	**22.9**	**22.9**	**32.4**	**32.4**
Receive Power	**dBW**	-91.07	-82.18	-81.53	-72.64
Received C/N	**dB**	19.61	28.50	29.15	38.04
C/I	**dB**	18.00	18.00	18.00	18.00
Objective C/(N+I)	**dB**	8.14	8.14	15.07	15.07
Required C/N	**dB**	8.61	8.61	18.15	18.15
External Interference Loss	**dB**	1.00	1.00	1.00	1.00
Clear Sky Link Margin	**dB**	**10.0**	**18.9**	**10.0**	**18.9**

Beacon Link Budgets:

		40cm UT		80cm UT	
		EOC	NADIR	EOC	NADIR
Orbit Altitude	km	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	deg	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	deg	60.36	0.00	60.36	0.00
Slant Range	km	2224.06	800.00	2224.06	800.00
Link Frequency	GHz	12.70	12.70	12.70	12.70
Channel Symbol Rate	ksps	833.33	833.33	833.33	833.33
Spreading		31.00	31.00	31.00	31.00
Bandwidth Efficiency	bps/Hz	0.01	0.01	0.01	0.01
Burst Information Data Rate	kbps	11.72	11.72	11.72	11.72
ModCod		QPSK 2/9	QPSK 2/9	QPSK 2/9	QPSK 2/9
Effective EIRP	dBW	6.64	-2.24	6.64	-2.24
Free Space Loss	dB	181.47	172.59	181.47	172.59
Effective G/T	dBi/K	5.0	5.0	11.0	11.0
Receive Power	dBW	-143.37	-143.37	-137.35	-137.35
Received C/N	dB	-0.41	-0.41	5.61	5.61
C/I	dB	20.00	20.00	20.00	20.00
Required C/(N+I)	dB	-1.53	-1.53	-1.53	-1.53
Required C/N	dB	-16.41	-16.41	-16.41	-16.41
External Interference Loss	dB	1.00	1.00	1.00	1.00
Clear Sky Link Margin	dB	15.0	15.0	21.0	21.0

TT&C Uplink Link Budgets:

		1.6m TT&C Terminal			4.8m TT&C Terminal		
		EOC	EOC	NADIR	EOC	EOC	NADIR
Orbit Altitude	**km**	800.00	800.00	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	**deg**	12.00	12.00	90.00	12.00	12.00	90.00
Nadir (Scan) Angle	**deg**	60.36	60.36	0.00	60.36	60.36	0.00
Slant Range	**km**	2224.06	2224.06	800.00	2224.06	2224.06	800.00
Link Frequency	**GHz**	30.00	30.00	30.00	30.00	30.00	30.00
Channel Symbol Rate	**ksps**	8.33	8.33	8.33	8.33	8.33	8.33
Bandwidth Effciency	**bps/Hz**	1.21	1.21	1.21	3.43	3.43	3.43
Burst Information Data Rate	**ksps**	**10.08**	**10.08**	**10.08**	**28.57**	**28.57**	**28.57**
ModCod		QPSK 11/20	QPSK 11/20	QPSK 11/20	16APSK 77/90	16APSK 77/90	16APSK 77/90
Effective EIRP	**dBW**	**46.96**	**46.96**	**46.96**	**56.51**	**56.51**	**56.51**
Free Space Loss	**dB**	188.94	188.94	180.05	188.94	188.94	180.05
Effective G/T	**dBi/K**	**-32.1**	**-22.1**	**-22.1**	**-32.12**	**-22.12**	**-22.12**
Receive Power	**dBW**	-146.97	-136.97	-128.09	-137.43	-127.43	-118.55
Received C/N	**dB**	15.30	25.30	34.18	24.84	34.84	43.72
C/I	**dB**	20.00	20.00	20.00	20.00	20.00	20.00
Required C/(N+I)	**dB**	4.18	4.18	4.18	12.90	12.90	12.90
Required C/N	**dB**	4.30	4.30	4.30	13.84	13.84	13.84
External Interference Loss	**dB**	1.00	1.00	1.00	1.00	1.00	1.00
Clear Sky Link Margin	**dB**	**10.0**	**20.0**	**28.9**	**10.0**	**20.0**	**28.9**

TT&C Downlink Link Budgets:

		1.6m TT&C Terminal			4.8m TT&C Terminal		
		EOC	EOC	NADIR	EOC	EOC	NADIR
Orbit Altitude	km	800.00	800.00	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	deg	12.00	12.00	90.00	12.00	12.00	90.00
Nadir (Scan) Angle	deg	60.36	60.36	0.00	60.36	60.36	0.00
Slant Range	km	2224.06	2224.06	800.00	2224.06	2224.06	800.00
Link Frequency	GHz	20.20	20.20	20.20	20.20	20.20	20.20
Channel Symbol Rate	ksps	8.33	8.33	8.33	8.33	8.33	8.33
Bandwidth Effciency	bps/Hz	1.23	1.23	1.23	3.45	3.45	3.45
Burst Information Data Rate	kbps	10.24	10.24	10.24	28.79	28.79	28.79
ModCod		QPSK 11/20	QPSK 11/20	QPSK 11/20	16APSK 77/90	16APSK 77/90	16APSK 77/90
EIRP	dBW	-7.06	2.94	2.94	-7.06	2.94	2.94
Free Space Loss	dB	185.50	185.50	176.62	185.50	185.50	176.62
Effective G/T	dBi/K	20.6	20.6	20.6	30.1	30.1	30.1
Receive Power	dBW	-145.04	-135.04	-126.16	-135.49	-125.49	-116.61
Received C/N	dB	17.40	27.40	36.28	26.94	36.94	45.83
C/I	dB	20.00	20.00	20.00	20.00	20.00	20.00
Required C/(N+I)	dB	4.28	4.28	4.28	12.98	12.98	12.98
Required C/N	dB	4.40	4.40	4.40	13.94	13.94	13.94
External Interference Loss	dB	1.00	1.00	1.00	1.00	1.00	1.00
Clear Sky Link Margin	dB	12.0	22.0	30.9	12.0	22.0	30.9

SAR Link Budgets:

Parameters	Spot mode
Frequency, Hz	1.286E+09
Power transmitted, dBW	33.8
Antenna Gain, dBi	38.33
Target Length, dihedral	2.00
σ, radar cross section, dBsm	38.7
Range, m	922737
Chirp Bandwidth, Hz	2.80E+07
Pulse length, sec	0.000016
PRF, kHz	3.99E+00
Pulse bandwidth, Hz	62500
Expected IF Bandwidth, Hz	1.94E+08
Noise Figure	2
Losses, dB	2.5
Boltzmanns constant, k	1.38E-23
Ant temp,T	290
System Temp	817.33
Thermal noise power in receiver, dBW	-116.60
SNR before coherent integration, dB	-18.48
Processing gain, dB	43.60
SNR after coherent processing gain, point tgt	**25.12**
SNR for Distributed Target, e.g. terrain	**-15.02**

Parameters	Strip mode
Frequency, Hz	1.286E+09
Power transmitted, dBW	33.8
Antenna Gain, dBi	38.33
Target Length, m	4.00
σ, radar cross section, dBsm	50.73
Range, m	1115863
Chirp Bandwidth, Hz	1.40E+07
Pulse length, sec	0.000016
PRF, kHz	3.71E+00
Pulse bandwidth, Hz	62500
Expected IF Bandwidth, Hz	1.98E+08
Noise Figure	2

Losses, dB	2.5
Boltzmanns constant, k	1.38E-23
Ant temp,T	290
System Temp	817.33
Thermal noise power in receiver, dBW	-116.51
SNR before Processing Gain, dB	8.25
Processing Gain, dB	7.65
SNR after processing gain, dB	**15.90**
SNR for Distributed Target, e.g. terrain	**-18.27**

V-band Link Budgets

Theia seeks to operate gateway links in V-band frequencies. Link budgets for V-band gateways, on a band-specific basis, are included below. Links budgets for similarly sized high-capacity earth stations would be identical to those included below.

Uplink Link Budgets:

		47.2GHz to 50.2GHz			
		1.6m Gateway Terminal		4.8m Gateway Terminal	
		EOC	NADIR	EOC	NADIR
Orbit Altitude	km	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	deg	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	deg	60.36	0.00	60.36	0.00
Slant Range	km	2224.06	800.00	2224.06	800.00
Link Frequency	GHz	48.70	48.70	48.70	48.70
Channel Symbol Rate	Msps	2500.00	2500.00	2500.00	2500.00
Bandwidth Effciency	bps/Hz	2.12	2.12	4.11	4.11
Burst Information Data Rate	Mbps	5304.52	5304.52	10287.11	10287.11
ModCod		16APSK 8/15-L	16APSK 8/15-L	32APSK 7/9	32APSK 7/9
Effective EIRP	dBW	75.17	75.17	84.71	84.71
Free Space Loss	dB	193.14	184.26	193.14	184.26
Effective G/T	dBi/K	12.1	12.1	12.1	12.1
Receive Power	dBW	-77.76	-68.88	-68.21	-59.33
Received C/N	dB	28.74	37.62	38.28	47.16
C/I	dB	18.00	18.00	18.00	18.00
Objective C/(N+I)	dB	8.25	8.25	15.13	15.13
Objective C/N	dB	8.74	8.74	18.28	18.28
External Interference Loss	dB	1.00	1.00	1.00	1.00
Clear Sky Link Margin	dB	19.0	27.9	19.0	27.9

		50.4GHz to 51.4GHz			
		1.6m Gateway Terminal		4.8m Gateway Terminal	
		EOC	NADIR	EOC	NADIR
Orbit Altitude	km	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	deg	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	deg	60.36	0.00	60.36	0.00
Slant Range	km	2224.06	800.00	2224.06	800.00
Link Frequency	GHz	50.90	50.90	50.90	50.90
Channel Symbol Rate	Msps	833.33	833.33	833.33	833.33
Bandwidth Effciency	bps/Hz	2.16	2.16	4.14	4.14
Burst Information Data Rate	Mbps	1797.77	1797.77	3448.42	3448.42
ModCod		8PSK 13/18	8PSK 13/18	32APSK 7/9	32APSK 7/9
Effective EIRP	dBW	70.56	70.56	80.10	80.10
Free Space Loss	dB	193.53	184.65	193.53	184.65
Effective G/T	dBi/K	12.5	12.5	12.5	12.5
Receive Power	dBW	-82.37	-73.49	-72.83	-63.95
Received C/N	dB	28.90	37.78	38.44	47.32
C/I	dB	18.00	18.00	18.00	18.00
Objective C/(N+I)	dB	8.39	8.39	15.20	15.20
Objective C/N	dB	8.90	8.90	18.44	18.44
External Interference Loss	dB	1.00	1.00	1.00	1.00
Clear Sky Link Margin	dB	19.0	27.9	19.0	27.9

Downlink Link Budgets:

		V-Band (37.5 to 42.5)			
		1.6m Gateway Terminal		4.8m Gateway Terminal	
		EOC	NADIR	EOC	NADIR
Orbit Altitude	km	800.00	800.00	800.00	800.00
Grazing (Elevation) Angle	deg	12.00	90.00	12.00	90.00
Nadir (Scan) Angle	deg	60.36	0.00	60.36	0.00
Slant Range	km	2224.06	800.00	2224.06	800.00
Link Frequency	GHz	40.00	40.00	40.00	40.00
Channel Bandwidth	MHz	5000.00	5000.00	5000.00	5000.00
Bandwidth Efficiency	bps/Hz	0.98	0.98	3.00	3.00
Burst Information Data Rate	Mbps	4070.66	4070.66	12500.02	12500.02
ModCod		QPSK 9/20	QPSK 9/20	16APSK 13/18	16APSK 13/18
Effective EIRP	dBW	49.55	49.56	49.55	49.56
Free Space Loss	dB	191.43	182.55	191.43	182.55
Effective G/T	dBi/K	25.5	25.5	35.0	35.0
Receive Power	dBW	-88.42	-79.53	-78.88	-69.99
Received C/N	dB	16.00	24.89	25.54	34.43
C/I	dB	18.00	18.00	18.00	18.00
Objective C/(N+I)	dB	2.86	2.86	11.45	11.45
Objective C/N	dB	3.00	3.00	12.54	12.54
External Interference Loss	dB	1.00	1.00	1.00	1.00
Clear Sky Link Margin	dB	12.0	20.9	12.0	20.9

Appendix 4

Theia Orbital Debris and Deorbit Analysis

This Appendix is intended to provide information regarding the orbital debris mitigation plans for the proposed non-geostationary satellite orbit ("NGSO") system of Theia Holdings A, Inc. ("Theia") and LTS Systems II, LLC, required by Sections 25.114(d)(14) and 25.283(c) of the rules of the Federal Communications Commission.

Spacecraft Hardware Design

Theia is familiar with the orbital debris mitigation requirements set forth in Section 25.114(d)(14) of the Commission's rules and is incorporating these requirements into the baseline Theia spacecraft design. Moreover, in developing Theia satellite requirements, Theia has worked closely with satellite manufacturers, engineering firms and other satellite industry participants that have designed, manufactured, launched and operated spacecraft pursuant to numerous FCC space station authorizations. Thus, Theia satellites benefit from the in-depth understanding of orbital debris mitigation of Theia and its system design partners.

Theia design features described herein will be imposed on the system satellite contractor as firm requirements and flowed down to all subcontractors. The satellite contractor and subcontractors will be required to incorporate into their designs explicit features for minimization of orbital debris.

Finally, the design features and operational procedures described herein reflect the current state-of-the-art in NGSO spacecraft manufacturing and operations. They are intended to serve as minimum thresholds for the design and operation of Theia satellites. Any potential updates to these design features or operational procedures will seek to enhance the orbital debris mitigation characteristics of Theia satellites and will be authorized by the Commission as appropriate.

Limiting Orbital Debris Mitigation During Planned Operations and the Risk of Collisions with Small Debris or Meteoroids—Section 25.114(d)(14)(i)

Theia has assessed the risk of debris release during normal operations and designed the satellite to ensure that no debris will be released during any mission phase. Although Theia has not selected a satellite manufacturing contractor for its proposed NGSO system, it has consulted with numerous design partners in developing its current baseline design. The Theia satellite design incorporates, for example, the use of non-debris generating appendage hold down and release mechanisms, selection of appropriate construction materials including external thermal control surfaces and coatings, and operational procedures.

In addition, the probability of the Theia space stations becoming a source of debris by collisions with small debris or meteoroids smaller than one centimeter in diameter that could cause loss of control and prevent post-mission disposal will also be assessed and limited.

Mitigating Accidental Explosions—Sections 25.114(d)(14)(iii) and 25.283(c)

Theia has assessed the probability of accidental explosions during and after completion of mission operations and has limited these risks in the Theia satellite design. Sources of stored energy on the Theia satellites include:

Chemical/pressure:

- Pressurized monopropellant hydrazine fuel tank (1 per satellite),
- Lithium-ion battery, and
- Constant conductance heat pipes. Kinetic:
- Reaction wheels (4 per satellite),
- Solar array drive motors (4 per satellite: 2 solar array panels, each with a 2-axis drive mechanism),
- Feeder link drive motors (4 per satellite: 2 gimbaled feeder link antennas, each with a 2-axis drive mechanism),
- Free space optical (FSO) heads (6 per satellite),
- Passive offset microwave radiometer spin table (8 satellites), and

- Hyper-spectral optical sensor telescope single-axis gimbal (52 satellites).

During the Theia satellite design and development program, the prime satellite contractor and satellite subcontractors will be required to perform failure modes and effects analyses (FMEA) to demonstrate acceptably low probability of failure from all possible sources. These analyses shall include the probability of failure of pressure vessels resulting in an accidental explosion. Suitable design safety margins shall be required and formally verified to demonstrate the achievement of acceptably low probabilities of occurrence of such failure modes.

At Theia satellite end-of-life, mission operational rules and procedures will call for the maneuvering of the satellite to a disposal orbit, followed by passivation of all stored energy sources. This includes de-spinning of the reaction wheels, venting of residual propellant and pressurant to the extent possible by opening all thruster valves, and connection of onboard electrical loads sufficient to cause the satellite's battery to fully discharge (which also results in the passivation of all other onboard kinetic energy sources).

The propulsion system design includes a fuel tank with a bladder. At the beginning of life (BOL), the tank is loaded with up to 800 kg of hydrazine propellant. After the fuel has been loaded, the fill/drain (F/D) valve is closed and manually secured with a screw-on safety cap. The bladder portion of the tank system is then pressurized with approximately 4.5 kg of inert gaseous nitrogen to a maximum expected operation pressure (MEOP) of 24.5 bar using the fill/vent valve (F/V).[63] When the spacecraft is mated to the launch vehicle and on the launch pad, the latch valve (LV) is commanded open to allow fuel into the propulsion system between

[63] It should be noted that all propulsion systems shall be proof tested to 1.5 x MEOP (36.75 bar in this case), and the design burst tested to 2 x MEOP (49 bar).

the LV and thrusters. During nominal operations throughout space vehicle life, the LV is never closed.

Throughout the life of the satellite, fuel is consumed for various maneuvers. At the end of operational life, the satellite is commanded into a deorbit maneuver with a depletion burn to exhaust all available fuel. At the completion of this maneuver, the 4.5 kg of inert nitrogen pressurant will remain on the "dry" side of the bladder in the tank, at a residual pressure of approximately 6 bar. Also, a small amount of fuel will remain in the propellant lines of the system in vapor form, which presents no hazard of escaping or causing later rupture, as it will reach the vapor pressure of hydrazine, about 0.28 bar at 25°C when all lines are opened at the thruster valves to passivate the system. This vapor will remain in the lines when the valves are closed upon removal of electrical power. In the unlikely event of a small particle (debris or meteor) puncturing the tank, the residual gaseous nitrogen would be released in a rapid manner, similar to a cold gas thruster, with a theoretical maximum delta-V of less than 5 m/s. In the extraordinarily unlikely event of a particle striking a passivated SV on precisely the line required to puncture both the fuel portion of the tank and the bladder, the maximum theoretical delta-V is about 7 m/s. Given that the orbital velocity during disposal is on the order of 7 km/s, this delta-V will have no noticeable effect on the orbit of the satellite, or alter the possibility of space vehicle breakup in any fashion.

The batteries used on the Theia satellites are based on Lithium-ion cells. Each cell is roughly the size and shape of a conventional "D" battery, and will incorporate a "leak before burst" safety disk to prevent explosion in the event of overcharge. The heat pipes used in the construction of the Theia space stations are sealed aluminum tubes filled with anhydrous ammonia. Per NASA-STD 8719.14, §4.4.4.1.2.f, sealed heat pipes do not need to be depressurized at end of mission.

Safe Flight Profiles - Section 25.114(d)(14)(iv to vi)

The probability of the Theia satellites becoming a source of debris by collisions with large debris or other operational space stations has been assessed and limited. The Theia orbit design took into account the probability of collision with large debris, including other operational Theia satellites and spacecraft of other satellite systems. In particular, the phasing offsets selected for Theia satellites in adjacent orbital planes were specifically analyzed and selected so as to minimize collision probabilities at the convergent polar crossings that occur each orbit.

The 112 individual Theia satellites in their approximately 800 km near-circular mission orbit will be monitored and tracked with the Theia satellite network maintained within specific orbital tolerances. Each Theia satellite's mission orbit will be monitored and tracked with the Theia satellite network. The satellites will be maintained via periodic propulsive station-keeping burns to a nominal orbital period of 6053 seconds and an eccentricity of 0.00126. The in-plane position along the velocity direction will be nominally maintained to ± 6 kilometers. Theia satellites will be maintained in frozen orbits[64] with perigee near the North pole and apogee near the South pole. The cross-track or the Right Ascension of the Ascending Node will be maintained to ± 0.08 degrees with respect to the satellites' in-plane neighbors. Occasionally, various mission operational considerations will result in different tolerances for individual satellites on a case-by-case basis. Using DAS3.27, the probability of Theia becoming a source of

[64] A frozen orbit limits the altitude range to be occupied by Theia satellites, reducing the number of objects with which conjunctions are possible. A frozen orbit, popularly used by other polar orbiting earth observation satellites and Iridium, also will allow Theia space stations to safely co-exist at smaller altitude separations with these other satellites.

debris by collision with large debris or other operational space stations computed is less than 0.001 (1 in 1,000) based on the above nominal operation parameters.

Theia will use specialized software in its mission control facility to regularly evaluate collision risks with other space stations, based on the most current available space station orbital element sets maintained and disseminated by USSTRATCOM. Collision avoidance maneuvers will be executed as required to reduce probabilities below NASA recommended thresholds. Experience with other NGSO satellites indicates the vast majority of potential collisions can be alleviated by changing the timing of an existing orbit maintenance maneuver (at zero impact to fuel budget). Nonetheless, a portion of Theia's mission orbit maintenance fuel budget is specifically reserved for collision avoidance maneuvers that cannot be accommodated by timing changes to planned maintenance maneuvers.

Whenever Theia satellites are required to undergo orbital maneuvers, pre-maneuver coordination with USSTRATCOM will be accomplished so that the appropriate authorities are aware of the maneuver plans and can advise Theia whether such maneuvers pose any risks. This includes screening planned launch trajectories and ascent from injection orbit to storage, transfer, or mission orbit. Theia intends to actively coordinate orbital activities with other owner-operators in their orbital regime, especially Iridium.

Orbit control and orbit knowledge will be specified to support Theia operations and support collision avoidance. Theia satellites will incorporate precision GPS navigation equipment to provide the best available orbit knowledge.

Post-Mission Disposal -- Section 25.114(d)(14)(vii) and 25.283(e)

Theia's orbital debris mitigation plans and procedures will comply with 25.114(d)(14)(vii)(B). Sufficient fuel (over 300 kg or 41 % of the overall fuel budget) will be reserved to accomplish the disposal maneuver sequence described below. The conservative reserve of a total of 300kg includes the propellant for deorbit delta-v usage, attitude control management during deorbit firings, residuals/trapped propellant and propellant loading and booking uncertainties. In addition, Theia intends to work with manufacture to derive independent gauging techniques to refine the knowledge of remaining propellant. Post-mission disposal will be carried out by propulsive maneuvering of the satellite into a lower orbit whose lifetime is consistent with NASA and international guidelines for LEO systems, *i.e.*, a predicted orbital lifetime of less than 5 years until atmospheric re-entry occurs as a result of natural orbital decay processes. At the end of a nominal mission, sufficient fuel margin should exist to further lower the orbit and achieve approximately 3.5 years until re-entry. This constitutes an uncontrolled re-entry. Theia will continue to coordinate with USSTRATCOM during the deorbit phase. The Theia tracking network together with GPS navigation will continue be utilized to provide enhanced satellite ephemeris for monitoring and mitigating close approaches with space debris as well as with other operators during the entire deorbit phase. Theia will continue best practices for coordinating, monitoring and mitigating close approaches. Theia intends to start the deorbit process of any satellite in the constellation which loses its mechanical redundancies impacting the control and maneuver capabilities to ensure successful deorbit.

Post-mission disposal will be performed in three phases. In Phase 1, the satellites' orbit altitude is lowered by approximately 50 km to 750 km to remove them from the operational altitude.[65] This orbit lowering process is estimated to consume approximately 40 kg of fuel (5% of total budget). The satellites will be designed with a 98% probability of success for this phase.

[65] This 750 km altitude is also below the operational altitude of the Iridium system.

In Phase 2, the perigee of the approximately 750 km circular Phase 1 orbit is successively lowered until a perigee altitude of no more than 425 km is achieved. This orbit lowering process is estimated to consume 130 kg of fuel (18% of total budget). The goal of phase 2 is to reduce the satellite perigee to 425 km and at this altitude the satellite perigee is predominantly subjected to atmospheric drag to initiate the natural orbit decay process. The satellites will be designed with a 98% probability of success for this phase.

In Phase 3, the satellite apogee will be reduced through a series of apogee-reducing maneuvers until fuel is expended and the satellite is passivated. The nominal fuel reserve is estimated to be near 130 kg (18% of total budget) and should support a final disposal orbit of 425 km apogee and 425 km perigee, with an estimated orbital lifetime less than 4 years meeting the compliance with the maximum 5 year predicted orbital lifetime requirement. The satellites will be designed with a 98% probability of success for this phase

Once the satellite is circularized to 425km altitude, any remaining fuel margin will be expended through a series of perigee/apogee-reducing depletion maneuvers until fuel is expended and the satellite is passivated. This step will further accelerate the satellite orbit decay rate and thus quicken its Earth re-entry lifetime, improving the disposal characteristics of Theia satellites. As performance for this phase relies on the fuel margins of individual Theia satellites at end-of-life, no specific probability of success has been assigned.

Following the Phase 3 apogee-lowering and the depletion maneuvers, the satellite will be fully passivated by opening all thruster valves, turning off all electro-mechanical actuators, discharging the batteries, and isolating satellite power systems from the solar arrays to prevent inadvertent recharge of the satellite. The satellites will be designed with a 98% probability of success for full passivation at end-of-life and disposal. An assessment of the probability of collision with large objects when the satellites complete passivation at altitude below 425 km was computed to be 9.8072E-6 using DAS3.2.7, far less than the 1 in 1000 standard set forth in Section 25.114(d)(14)(a)(1).

A casualty risk assessment for uncontrolled atmospheric re-entry of Theia satellites has been conducted using the NASA-supplied DAS (Debris Assessment Software) code (as suggested by Section 25.114(d)(14)(d)(vii)(d)(2)(ii)). As inputs to the DAS software, each Theia satellite was modeled as one of the three remote sensors (hyperspectral imager, active radar and passive radiometer), in addition to a common collection of 188 primitive objects (boxes, cylinders, and flat plates) representing the satellite bus and the common optical remote sensing apparatus installed on every Theia satellite. Appropriate material properties were established for each object.

These items were assumed (by the DAS software) to break-up and start reentry at a default altitude of 122 km (not editable in DAS). Reentry inclination was set to 98.6 degrees and reentry year set to 2050 (latest year supported by DAS demographics). Applying these assumptions in DAS, it was determined that up to 549.6 kg of the satellite might survive reentry, with a total casualty area of 15.8m^2. Using this information, DAS calculated a raw casualty risk figure of 1:5200, which assumes the entire world's population is in the open and unsheltered. Because the kinetic energy of the fragments *vis-à-vis* how the population is sheltered affects the casualty risk, additional analysis was performed to account for population sheltering.

Heavy sheltering is assumed to protect persons from impact energies up to 100 kJ (kilojoules); light sheltering is expected to provide protection from about 50 J to 5 kJ. 19% of the population is assumed to be unsheltered, 59% light sheltered, and 22% heavy sheltered ("Safety Design for Space Operations", T. Sgobba editor in chief, 2013. ISBN 978-0-08-096921-

3). Consistent with these assumptions, and applying the population demographics embedded in DAS for the year 2050, the estimated casualty risk for each of the remote sensing configurations is as follows:

Object	Risk	
Satellite + Hyperspectral Imager	8.96E-05	1:11,200
Satellite + Active Radar	8.19E-05	1:12,200
Satellite + Passive Radiometer	8.73E-05	1:11,500

These values are consistent with the 1:10,000 objective applied in this circumstance.

Theia intends to develop and submit an application amendment at the appropriate time to effect minor changes to its satellite design as a result of developments within the processing rounds.

Technical Certification

I, Philippe Dupuis, certify that I am a technically qualified person responsible for the preparation of the updates to the technical analyses for the 1215-1300 MHz, 19.4-19.6 GHz, 29.1-29.5 GHz, 37.5-42.5 GHz, 47.2-50.2 GHz, and 50.4-51.4 GHz frequencies in Theia Holdings A, Inc.'s application to Modify the Theia System and LTS Systems II, LLC's Application to Construct, Launch, and Operate the Theia NGSO System. I am familiar with Part 25 of the Commission's Rules (47 C.F.R. Part 25).

In preparing these analyses, I relied on data, information, and analyses previously submitted by Old Theia in the original Theia application and amendment, File Nos. SAT-LOA-20161115-00121 and SAT-AMD-20170301-00029. I do not have underlying knowledge of the accuracy of that information and these data, but note that most of these analyses have been previously approved by the FCC.

/s/ Philippe Dupuis
Philippe Dupuis
President & Spectrum Strategy Consultant
Telecomm Strategies, Inc.

July 6, 2026