TECHNICAL APPENDIX

I. INTRODUCTION

This Technical Appendix to the Starfish Space, Inc. ("Starfish") application for authority to launch and operate the Otter 24B spacecraft provides information in response to Section 25.114(d) of the Commission's rules and to support the application.

II. CONTACT INFORMATION

Benjamin Ponto
Mission Manager
Starfish Space, Inc.
665 Andover Park W
Tukwila, Washington 98188

III. GENERAL DESCRIPTION OF OTTER 24B SYSTEM

Otter 24B is an in-space satellite servicing spacecraft designed for life extension and end-of-life services for Geostationary Orbit ("GSO") and Low Earth Orbit ("LEO") satellites. The Otter 24B spacecraft has been developed to execute long term missions to inspect, dock with, and service multiple satellites, including the capability to station-keep on orbit as needed. This allows Otter 24B to undertake multiple on-orbit service missions with a single spacecraft, lowering costs to customers and minimizing the physical presence in the LEO and GEO environment.

For this mission, Otter 24B will service two satellites: the U.S. Space Force's "Asset #1" and "Asset #2."[1] Asset #1 will be positioned in a non-geostationary orbit between GSO and the end-of-life disposal altitude[2] at 3° inclination. Asset #2 will be located at or near GEO altitude at a 10° inclination. Otter 24B will dock with and deliver each Asset to an orbital altitude consistent with the disposal orbit

[1] Starfish is not able to publicly disclose the identity of Asset #1 or Asset #2 at this time though Starfish and the Space Force have determined the location of the rendezvous, proximity ops, and docking demonstration that will occur. Both Asset #1 and Asset #2 are licensed and operated by the United States government.

[2] This altitude begins at 36,050 km.

for both GSO satellites and those operating in Geosynchronous Orbit ("GEO"), herein referred to as the "graveyard orbit." During this mission, Otter 24B will undertake the following operations and services:

- Performing visual inspection of the client spacecraft and the local space environment around both Otter 24B and the client spacecraft;
- Conducting safe docking operations with the client spacecraft;
- Conducting station-keeping and attitude control of customer satellites;
- Performing on-orbit station-keeping while in a dormant operational mode;
- Transit client spacecraft to new orbital slots and locations (e.g., graveyard); and
- Transit to and from the geostationary graveyard.

The Otter 24B spacecraft utilizes the Corvus V, a bus design by Astro Digital, a bus manufacturer with three decades of on-orbit heritage. The Corvus XL, V's predecessor, has successfully flown five missions since 2021. By leveraging this proven platform, Otter 24B can offer hardware reliability while ensuring safe and cost-efficient satellite servicing missions. This strategy also enables Starfish to rapidly construct and deploy additional Otter spacecraft as demand for on-orbit satellite servicing grows.

The Corvus V bus is customized with proprietary technologies developed by Starfish specifically to enable satellite servicing missions. These bespoke elements of Otter 24B have been designed with a focus on safety and redundancy. Starfish provides a brief description of these novel bus technologies.

Two Manta Booms

Manta is a lightweight, articulating boom that enables efficiently maneuvering and communications during rendezvous, proximity ops, and docking ("RPOD"). Otter 24B will be equipped with two Manta booms, which are each affixed to the bus through a resilient "shoulder" joint. Each boom houses a thruster, a transmitter and a receiver. Once Otter 24B is docked, Manta enables greater efficiency by directing the thrust vector through the combined center of mass of Otter and its client, while also providing flexibility to direct the thruster plume away from sensitive components on the client spacecraft. Please Refer to Figure 1 below.

Manta also contains an antenna which allows Otter 24B to maintain line of sight communications without compromising ideal docking geometry. Use of the Manta boom enables Otter to efficiently leverage its massive ΔV payload, even when docked with much larger clients. The below figure demonstrates how Manta will be used to facilitate line-of-sight with the Earth during station-keeping operations, with the yellow cone representing the transmissions from Otter 24B.

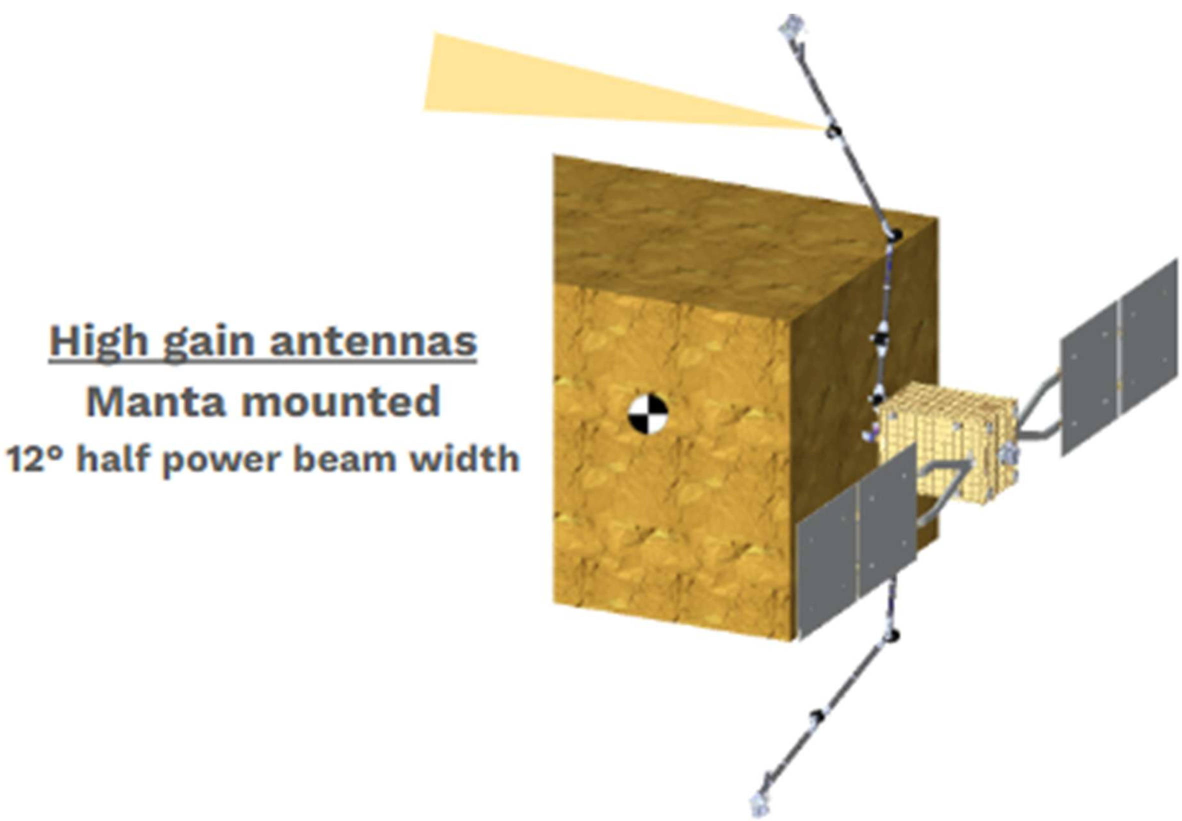

Figure 1: Depiction of deployed Manta Booms

Docking

On this mission, Otter 24B will carry a mechanical gripper docking system. In all cases, Otter 24B is able to perform its mission without requiring a proprietary docking plate or fiducial to be installed on its client, nor does the client spacecraft need a specific hardpoint feature, such as an apogee kick motor or separation ring.

Starfish has collaborated with the Space Force to identify ideal docking locations on the Asset #1 and Asset #2 satellite buses. Based on these conversations, Otter 24B's docking mechanism will enable secure docking with both satellites, allowing for both short- and long-term station-keeping maneuvers.

Nautilus Sub System

Starfish designed the Nautilus Docking Mechanism to enable an Otter to dock with satellites that were not originally designed for docking. The Nautilus docking mechanism is a universally compatible, non-destructive capture system for docking with objects in orbit. Designed with modularity in mind, Nautilus offers two docking options: an electrostatic adhesion and a mechanical grip. These dual docking capabilities ensure that an Otter can effectively "grab" its client spacecraft and maintain a stable connection, enabling station-keeping and orbital relocation operations. These advantages all jointly enable rapid response capabilities, a larger envelope of compatible docking partners, and lower cost points.

For this mission, Otter 24B will use a mechanical gripper shown in Figure 2 below.

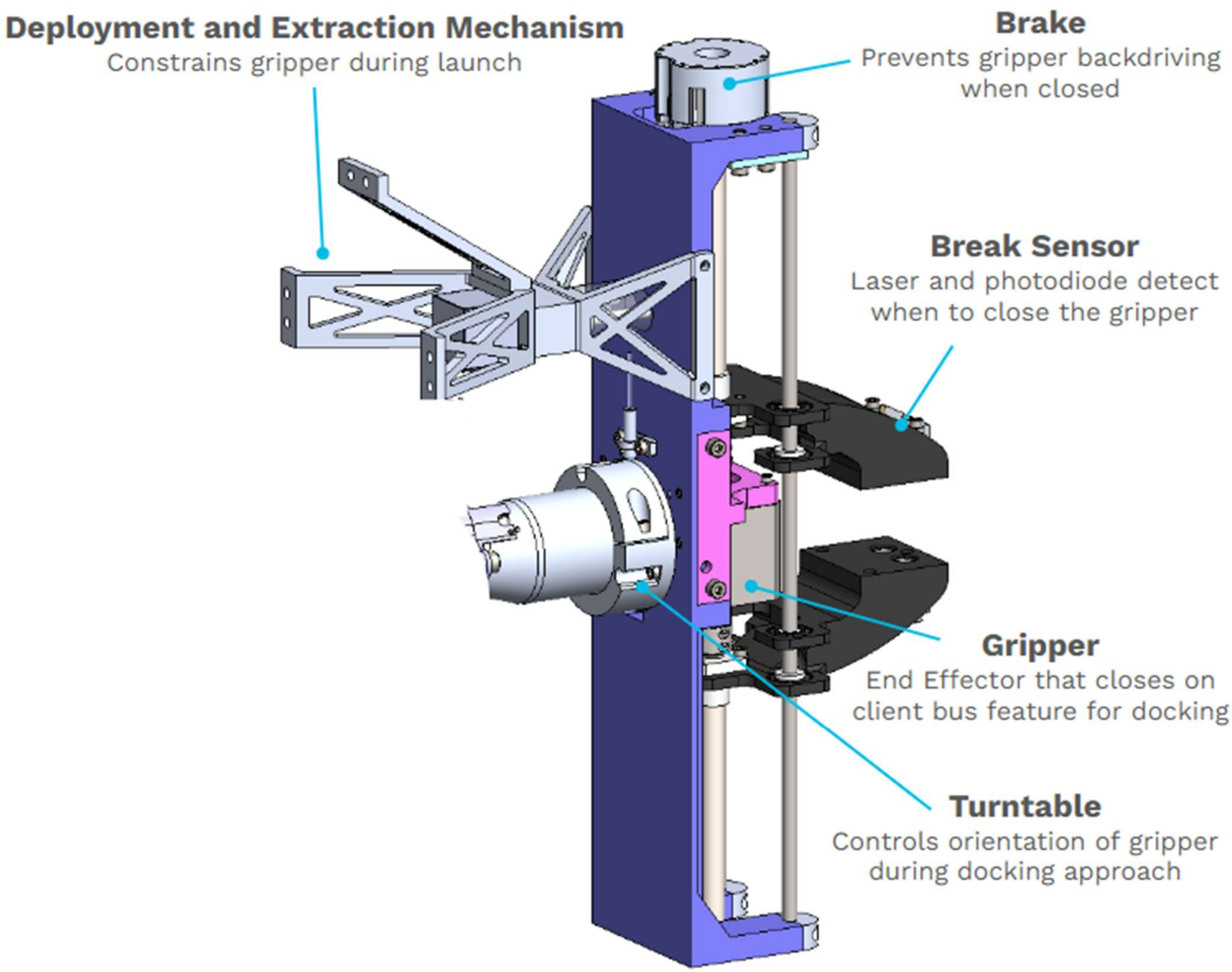

Figure 2: Mechanical Gripper

CEPHALOPOD Autonomous Guidance System and CETACEAN Relative Navigation System

Otter 24B is equipped with the CEPHALOPOD Autonomous Guidance and Control System and the CETACEAN Relative Navigation System, ensuring safe and reliable operations even if communications with the ground are interrupted. These bespoke design features enable Otter 24B to provide innovative docking and station-keeping services to multiple Space Force satellites throughout the mission.

A. Space Segment

The Otter 24B will use an Innoflight transmitter to conduct both TT&C and payload communications. All transmissions from Otter 24B will be in the 8025-8400 MHz ("EESS band") and 8450-8500 MHz ("SRS band") band segments, with the EESS band to be used only in the event that Otter 24B is unable to utilize the SRS band due to coordination constraints. All Otter 24B transmission characteristics will also be coordinated with in-band and adjacent band Federal spectrum users.

Starfish's research indicates that there are no GEO or GSO space stations operating in the SRS band. There is only slightly more deployment in the EESS band as Starfish has identified only three in-band GSO notifications.[3] The absence of GEO space stations in SRS band and limited presence in the EESS band will ensure that Otter 24B can protect GEO systems with its downlink transmissions. Out of an abundance of caution, Starfish will ensure that it does not use the EESS band in close proximity to existing GEO notifications in the band.

i. Tracking, Telemetry and Commanding (TT&C)

Otter 24B will only transmit telemetry and tracking data in the SRS and EESS bands using channels that will range between 10 kHz and 2 MHz depending on the needed data rate. The corresponding duty cycles will vary depending on the phase of the Mission.

[3] Starfish's research shows GSO Notifications at 137° W.L., 75° W.L., and 128.2° E.L that include the EESS band.

Downlink Telemetry Mode	Center Frequency	Data Rate & Avg. Duty Cycle
Launch and Early Operations Phase ("LEOP")	8490 MHz	100 kbps 0.5hr/day
In-Transit	8490 MHz	100 kbps 1hr/day
RPOD	8490 MHz	100 kbps 2hr/day
Servicing	8490 MHz	100 kbps 1hr/day
Backup/emergency	8200 MHz	100 kbps 1-2 hr/day[4]

Table 1. Downlink data rates and transmission times for each phase of Otter 24B telemetry mode.

ii. Payload Data

Otter 24B will only transmit telemetry and tracking data in the SRS and EESS bands using channels that will range between 10 kHz and 2 MHz depending on the needed data rate, with duty cycles varying depending on the Phase of the Mission. The payload data will include data from Otter 24B's sensors and cameras regarding the residential space environment and, during RPOD. Payload data will include images captured by the vision system, the health and status of Manta and Nautilus, as well as CEPHALOPOD and CETACEAN guidance navigation and control (GNC) estimates. Please note that Otter 24B will rarely need to send payload communications during LEOP.

[4] The duration of transmission and bandwidth needs will depend on which Phase of the mission requires support from the backup channel.

Downlink Payload Mode	Bandwidth (Center Frequency)	Data Rate & Avg. Duty Cycle
LEOP	8490 MHz	100 kbps 1hr/month
In-Transit	8490 MHz	100 kbps 1hr/month
RPOD	8490 MHz	1000 kbps 2hr/day
Servicing	8490 MHz	100 kbps 1hr/day
Backup/emergency	8200 MHz	100 kbps 1-2hr/day[5]

Table 2. Downlink data rates and transmission times for each phase of Otter 24B payload data.

iii. Spectrum Use Duty Cycles

Otter 24B will only transmit intermittently through all Phases of its mission, with the transmission rate varying depending on the operations undertaken. Below, Starfish outlines the expected duty cycles for each of the four Phases.

	Downlink			
Phase	Duty Cycles (% of transmission per day)		Hours ON per orbit	
-	MAX	AVG	MAX	AVG
LEOP	13.9%	2.1%	3.33	0.5
Transit (GEO)	27.8%	4.2%	6.66	1.0
RPOD	55.6%	8.3%	13.33	2.0
Servicing	27.8%	4.2%	6.66	1.0

Table 3. Downlink duty Cycles for each phase of Otter 24B Mission.

Starfish notes that the duty cycles outlined above are extremely conservative, reserving significant portions of time for unlikely worst-case scenarios. Starfish will coordinate its spectrum use with the respective federal agencies and in-band operators.

[5] The duration of transmission and bandwidth needs will depend on which Phase of the mission requires support from the backup channel and Payload backup will not be necessary for LEOP.

iv. Guidance, Navigation, and Control (“GNC”)

The GNC will be accomplished with Starfish’s proprietary technology guidance and control software package, CEPHALOPOD. CEPHALAPOD is optimized for low thrust Electric Propulsion (“EP”), enabling autonomous RPOD with a single EP thruster, with calculations and trajectories generated and optimized fully onboard. CEPHALAPOD provides path-planning guidance for RPOD, processes state estimates and evaluates abort and approach decisions.

Otter 24B will use onboard functions for maintaining attitude/pointing control, momentum control, and orbit/position control throughout all phases of the mission. These functions utilize a number of sensors including star trackers, sun sensors, attitude rate sensors, LEO & GEO-capable GPS, and optical ranging data provided from ground command. The on-board GNC flight software processes these sensor data and ground commanded inputs to establish the desired attitude, orbit, and relative position/attitude to the customer satellite. Translational and rotational capabilities are facilitated by four reaction wheels and three hall-effect thrusters.

v. Electric Power Subsystem (“EPS”)

The Otter 24B EPS, designed and built by Astro Digital US Inc., is an enhanced version of the Corvus platform EPS, which has extensive heritage in space. The enhancements include part selection for radiation, sparing, and improved design to support higher power generation and loads that are required by the mission. The system comprises three primary subsystems: solar array, batteries, and power distribution elements.

The solar array, designed and built by MMA Design LLC, features a new design with two wings, each consisting of two panels. Each wing is connected to a solar array drive assembly, allowing independent steering controlled by the flight computer. The nominal tracking vector will be towards the sun regardless of spacecraft orientation.

The battery subsystem is composed of five Astro Digital Direct Energy Packs (“DEPs”) connected in parallel. Each DEP contains 16 lithium ion 21700 cells arranged in an 8s2p configuration. The system is designed to isolate or disconnect individual DEPs from the battery bank as needed, allowing continued operation with reduced energy storage capacity in the event a single DEP fails. The nominal bus voltage ranges from 24 to 32V. Each DEP is connected to three converters that dynamically adjust voltage to track the peak power point of the Photovoltaic ("PV") strings on the MMA solar array. At End-of-Life ("EOL"), the system can be passivated by disconnecting all DEPs.

vi. Command and Data Handling ("CDH")

Starfish will manage CDH for Otter 24B via third party ground stations and with support of a third-party Satellite Mission Management provider to help store data and manage mission operations. Starfish will issue commands and receive telemetry data necessary to safely operate Otter 24B. NSA-approved encryption will be used to protect all command and telemetry data and transmissions to and from Otter 24B. Starfish Space will operate its Mission Operations Center ("MOC") in Tukwila, WA.

vii. Propulsion

Otter 24B is designed to use three thrusters to accomplish its mission, providing significant redundancy to enhance mission success. The first thruster, mounted on the body, will be expended during long-range traverses and docking. The second and third thrusters, mounted on Manta, will share thruster duties for the remainder of mission phases.

The propulsion system chosen for the mission is the Safran Thruster PPS®X00 with a lifetime thrust of 500 kNs with Xenon Propellant (EPS X00). The System includes:

- One (1) Flight Model PPS®X00 thruster, qualified with xenon gas
- One (1) Power Processing Unit (PPU)
- One (1) Fluidic Management System (FMS)

The PPS®X00 offers significant advantages, including high lifetime capability within this power range and an excellent thrust-to-electrical power ratio, which enables reduced operating time or the number of thrusters needed. Several innovations have been incorporated in the discharge chamber and magnetic circuit designs to propose competitive and reliable solutions while maintaining high performance. It can be delivered as part of an electric propulsion subsystem, including Power Processing Unit and Propellant Management System.

viii. Thermal Control Subsystems (“TCS”)

The Otter 24B TCS is comprised of both passive and active elements. Primary analysis is done by Astro Digital, with additional payload-specific supplemental analysis provided by Starfish. A system thermal model has been developed with component level thermal limits taken into account. This model informs passive design decisions, including coatings, tapes, finishes, and Multi-Layer Insulation (MLI) locations. For cold exceedances that cannot be mitigated passively, heaters are used with an active controller tied to one or more RTDs that monitor temperature.

B. Ground Segment

The Otter 24B ground segment will support the operations of Otter 24B throughout all phases of the mission. The ground segment consists of the MOC, ground stations, and networks that connect the ground stations remotely to the MOC.

The Starfish MOC will be located in Tukwila, WA.

Ground segment operations will vary depending on the phase of Otter 24B’s mission. However, earth stations will transmit in S-band and receive in the SRS band and potentially the EESS band.

i. Tracking, Telemetry and Commanding (TT&C)

Otter 24B will receive its TT&C data via S-band, using channel sizes and duty cycles varying depending on the Phase of the Mission. The channels will vary between 10 kHz and 200 kHz.

Starfish will rely on frequency deconfliction to mitigate the potential for harmful interference to Federal and non-Federal space stations operating in GSO and NGSO from its TT&C uplink signals. Starfish has identified three center frequencies that will allow it to transit its planned orbital path while avoiding potential center-frequency overlap with other S-band systems.

Table 4 delineates Otter 24B's spectrum usage during each stage of its operations.

Uplink Telecommand Mode	Center Frequency	Data Rate & Avg. Duty Cycle
LEOP	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 0.5hr/day
In-Transit	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 0.5hr/day
RPOD	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 5hr/day
Servicing	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 1hr/day
Backup/emergency	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 1-2hr/day

Table 4. Uplink bandwidths for telemetry mode.

ii. Payload Data

Otter 24B will also receive its payload data via S-band using channel sizes and duty cycles varying depending on the Phase of the Mission. The channels will vary between 10 kHz and 200 kHz. The payload data will include directional inputs for Otter 24B's sensors and cameras regarding the residential space environment and, during RPOD, the client spacecraft. Payload data will also include software updates and directions to the vision system, the health and status of Manta and Nautilus, as well as CEPHALOPOD and CETACEAN GNC estimates.

When operating in NGSO, Starfish will rely on frequency deconfliction to mitigate the potential for harmful interference to federal and non-federal space stations operating in GEO and NGSO from its payload uplink signals, which are identical to its TT&C upload transmissions. Starfish has identified three center frequencies that will allow it to transit its planned orbital path while avoiding potential center-frequency overlap with other S-band systems.

Table 5 delineates Otter 24B's spectrum usage during each stage of its operations.

Uplink Payload Mode	**Center Frequency**	**Data Rate & Avg. Duty Cycle**
LEOP	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 1hr/month
In-Transit	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 1hr/day
RPOD	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 5hr/day
Servicing	2048.5 MHz 2027 MHz 2103 MHz	100 kbps 1hr/day
Backup	2048.5 MHz 2027 MHz 2103 MHz	5-100 kbps 1-2hr/day

Table 5. Uplink bandwidths for each phase of Otter 24B payload data

iii. Spectrum Use Duty Cycles

The Otter 24B will only transmit intermittently through all Phases of its mission, with the transmission rate varying depending on the operations undertaken. Below, Starfish outlined expected duty cycles for each of the four mission Phases.

	Uplink			
Phase	**Duty Cycles (% of transmission per day)**		**Hours ON per orbit**	
-	**MAX**	**AVG**	**MAX**	**AVG**
LEOP	13.9%	2.1%	3.33	0.5
Transit (GEO)	27.8%	4.2%	6.66	1.0
RPOD	69.4%	20.8%	16.66	5.0
Station-keeping	27.8%	4.2%	6.66	1.0

Table 6. Uplink duty Cycles for each phase of Otter 24B Mission.

Starfish notes that the duty cycles outlined above are extremely conservative, reserving significant portions of time for unlikely worst-case scenarios. Starfish will coordinate all of its spectrum use with the respective Federal agencies.

iv. Ground Station Locations

Starfish will coordinate the use of each band at each of the following locations with Federal spectrum users.

Earth Station Provider	Location Name
Atlas	Mingenew, Australia
Atlas	Accra, Ghana
Atlas	Mwulire, Rwanda
Atlas	Cordoba, Argentina
AWS	Portland, OR USA (back up)
Atlas	Paumalu, HI, USA
AWS	Dubbo, Australia (back up)

Table 7. Earth station operator and location for Otter 24B Ground Station Network.

C. Concept of Operations

The Otter 24B system is composed of two main segments: the space segment, which includes all aspects of the spacecraft and associated design, and the ground segment, which encompasses all ground-based services and hardware – including mission operations centers ("MOCs"), transportation and the launch site.

Starfish notes that Otter 24B will operate in NGSO throughout all phases of its mission.[6] A detailed description of Otter 24B's mission Phases are described below.

i. Phase 1 – LEOP, Transit to Asset #1, and RPOD with Asset #1

The Otter 24B spacecraft will launch as a rideshare payload on a National Security Space Launch and be injected into orbit at approximately 36101 km altitude +/- 100 km. Starfish will conduct

[6] *See e.g.,* 47 CFR § 25.103.

in-orbit testing ("IOT") for Otter 24B at this altitude after completing separation from the launch vehicle. During this period, Otter 24B will intermittently transmit and receive signals to confirm nominal operations and trajectory while testing its onboard sensors and equipment. The limited duty cycle and use of spectrum will enable Starfish to coordinate Otter 24B's spectrum.

Otter 24B will then perform a long-range rendezvous with Asset #1 to demonstrate its RPOD capabilities by performing inspection and docking operations, demonstrate station-keeping capabilities, and eventual disposal. The long-range rendezvous will take 100 days as Otter 24B transits to Asset #1's location between 35,800 and 36,600 km altitude,[7] with an inclination of 3 degrees. During this time, Asset #1 will drift west at approximately 4.2 degrees per day.

Once the operational maneuvers are confirmed to be safe, Otter 24B will initiate its RPOD maneuvers. It will follow an iterative course, charting a conservative flight path designed to ensure a safe rendezvous and avoid any risk of collision. This conservative approach, supported by Otter 24B's onboard sensors and thrusters, will enable a reliable and safe approach to Asset #1. At any point during this approach, Starfish will have the ability to issue an abort command and instruct Otter 24B to conduct emergency maneuvers away from Asset #1 if necessary. Please see the below diagram of Starfish's Concept of Operations ("ConOps") for RPOD.

[7] Asset #1 is in an elliptical orbit with a 36500 +/- 100 km apogee and 35900 km +/- 100 km perigee.

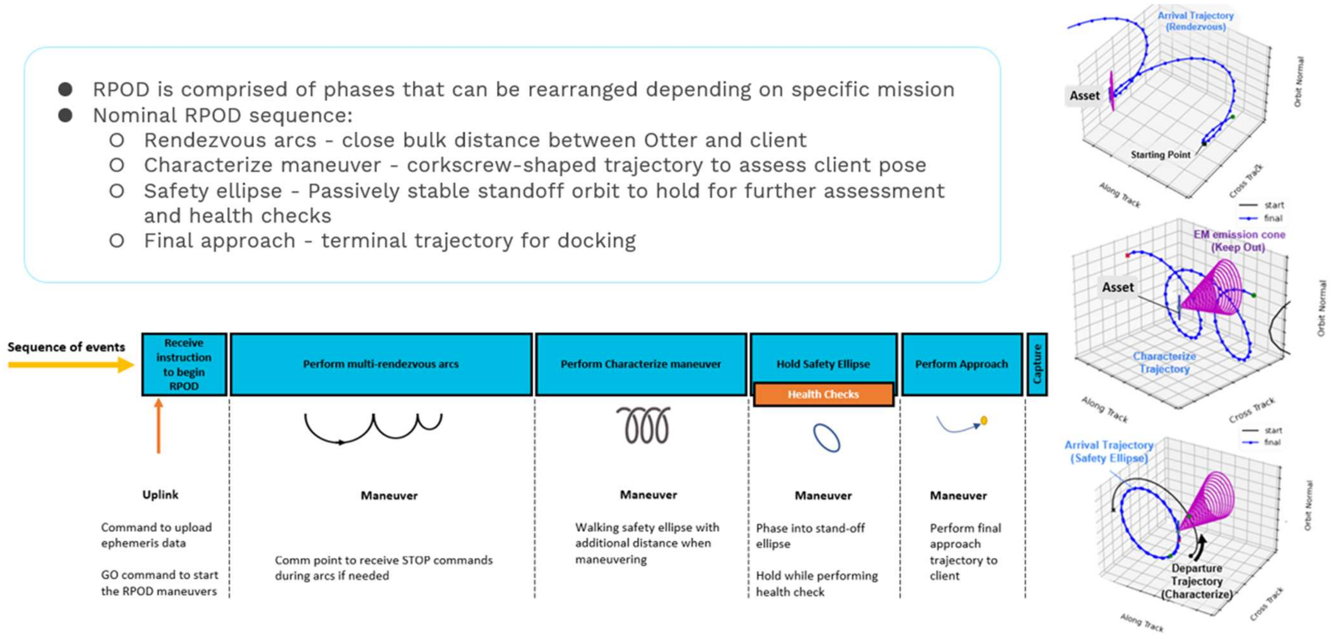

Figure 3: Otter 24B RPOD ConOps

The onboard sensors, including cameras and an illuminating light, will be processed by the onboard CETACEAN navigation system. As Otter approaches its client spacecraft it will activate its mechanical gripper. Please see Figure 4 below for a description of the Otter 24B docking procedure.

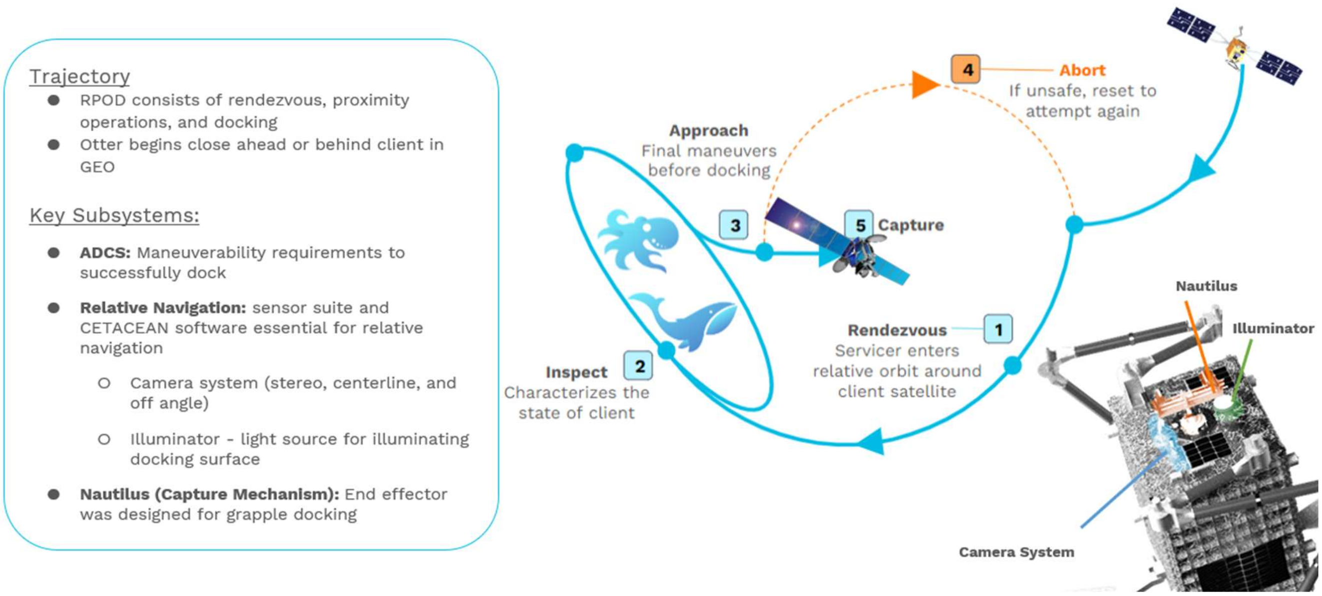

Figure 4: Otter 24B RPOD Overview

Before Otter 24B's final approach, Starfish will halt its progression toward Asset #1 to perform final positioning and internal system state of health checks. Once these final checks are completed, Otter 24B will be given the go ahead to approach Asset #1 for docking. Otter 24B will then dock with Asset #1 and demonstrate its station-keeping abilities. Otter 24B may conduct multiple docking and separation tests during this period. The entire docking ConOps and station-keeping demonstration is expected to take approximately 14 days to execute and complete. After the demonstration station-keeping mission with Asset #1 is complete, Otter 24B will perform an augmented maneuver to transfer the satellite to a stable orbit at approximately 36,050 km altitude.

Throughout the approach, docking, detachment and separation operation, Otter 24B's use of spectrum will increase, requiring short term periods of higher duty cycles and larger bandwidths. Given the short duration of these operations, approximately two weeks, Starfish will be able to successfully coordinate this more intensive use. As outlined in this technical appendix, Otter 24B will be equipped with autonomous systems to ensure safe RPOD maneuvers in the event that spectrum access is limited or interrupted.

During station-keeping, Otter 24B's spectrum and bandwidth requirements will again be reduced and should facilitate the protection of other in-band operators through its sporadic use of spectrum. Once the operation is complete and Asset #1 is disposed, Otter 24B will detach from Asset #1 and safely maneuver away from the spacecraft before proceeding to Asset #2.

ii. Phase 2 – Transiting to, RPOD and disposal of Asset #2

After servicing Asset #1, Otter 24B will conduct a long-range transfer to the Asset #2 satellite. This transfer will take approximately 3 months as Asset #2 will be located in NGSO, at 10 degrees inclination, and altitude of approximately 35,786 km and drifts approximately 1.2 deg/day (east).

Otter 24B will then use its RPOD system to reliably and safely rendezvous and dock with the Asset #2 satellite. The docking procedure will take approximately fourteen days to complete. Otter 24B's approach to Asset #2 will follow an identical process as its approach to Asset #1, with the caveat that Starfish aims to glean valuable operational data from the Asset #1 demonstration and may adjust its mission operations based on the results of Phase 1. Once in close proximity to Asset #2, Starfish will halt the approach to perform final system health and positioning checks. Once these final checks are complete, Otter 24B will be given clearance to dock with Asset #2. Otter 24B will then dock with Asset #2.

Once docked, Otter 24B will remain attached to Asset #2 and perform an augmented maneuver to dispose of Asset #2 in GEO graveyard at 36,050 km altitude and 10° inclination. This disposal will take approximately 2 months.

During the approach, docking, detachment and separation phases, Otter 24B's use of spectrum will increase, requiring short term periods of higher duty cycles and larger bandwidths. Given the short-term nature of these operations, approximately two weeks, Starfish expects it will be able to successfully coordinate this more intensive use. As outlined in this technical appendix, Otter 24B will be equipped with autonomous systems to ensure safe RPOD maneuvers in the event that spectrum access is limited or interrupted.

During Asset #2's disposal, Otter 24B's spectrum and bandwidth requirements will again be reduced and should facilitate the protection of other in-band operators through its sporadic use of spectrum over the course of its mission.

iii. Phase 3 – Standby for Additional Missions

After the disposing of Asset #2, Otter 24B will detach from Asset #2 to begin Phase Three. Otter 24B will maneuver away from Asset #2 relying on its on-orbit sensors to provide the relative position of each spacecraft to ensure a safe detachment and separation.

Otter 24B will then transit towards a safe standby orbit at an altitude of approximately 36,050 km, and an inclination of 10°. During this transit and standby operation, Starfish will coordinate directly with any with spacecraft near Otter 24B's standby orbit and utilize ground-based orbital parameters and space environment data from its on-orbit sensors to safely station-keep this region. Otter 24B expects to service additional assets with its excess capacity until reaching its end of life.[8]

iv. Phase 4 – Standby and End of Life

When Otter 24B approaches its end-of-life stage within six years after launch, it will conduct orbit raising operations until it reaches the graveyard orbit and prepares for its own end-of-life.

[8] As discussed with Space Bureau staff, Starfish will apply for authority to conduct additional missions when sufficient operational information is available.

IV. RADIO FREQUENCIES, POLARIZATION, AND LINK BUDGETS

A. Radio Frequencies and Polarization Plan

Table 8 provides the tunable frequency range for the TT&C system.

	Command - Uplink		Telemetry - Downlink	
	Tunable Frequency Range (MHz)	Polarization	Tunable Frequency Range[9] (MHz)	Polarization
S-band	2025-2110	RHCP	N/A	N/A
SRS and EESS bands	N/A	N/A	8025-8500	RHCP

Table 8. Otter 24B TT&C Tunable Frequency Ranges and Polarization

B. Emission Compliance

The carrier frequency of each transmitter for Otter 24B shall be maintained within 0.002% of the reference frequency.[10] All emissions from Otter 24B shall meet the out-of-band emission limits specified in the Commission's rules.[11]

C. Coverage Areas

The coverage area of the Otter 24B TT&C beam is the entire area of visible Earth from Otter 24B's operating location.

V. LINK BUDGETS

A. S-Band Link Budgets

The S-band link budgets for the commanding and ranging uplink are provided in Annex A.

B. X-Band Link Budgets

Otter 24B will transmit in either the SRS band or the EESS band referred to collectively here

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[9] Starfish is only seeking authority to transmit in the 8200-8400 MHz and 8450-8500 MHz bands.
[10] *See* 47 CFR § 25.202(e).
[11] *See* 47 CFR § 25.202(f).

as the "X-band." The X-band link budgets for the telemetry and ranging downlink are provided in Annex B.

VI. ANTENNA CHARACTERISTICS

Otter 24B will only receive command beams from the ground stations. Therefore, pursuant to Section 25.114(c)(4)(v) of the FCC's rules Starfish has specified the command beam peak flux density at the command threshold in Annex C.

VII. ANTENNA GAIN CONTOURS

The high gain X-band space-Earth beam (XTXH) offers a 3dB beamwidth of +/-15° from the GSO orbit. The Earth's diameter occupies roughly +/-8.7° degrees within that beam width. This antenna has peak gain at Nadir. The gain contours of the high gain X-band downlink antenna varies by ~1 dB across the surface of the Earth. Accordingly, the gain at 2 dB below the peak falls beyond the edge of the Earth. The following diagram, Figure 1, shows the contours of the high gain X-band space-Earth beam (XTXH). Note that no contours fall onto the Earth's surface because the gain at the Earth's limb is ~1 dB below peak.

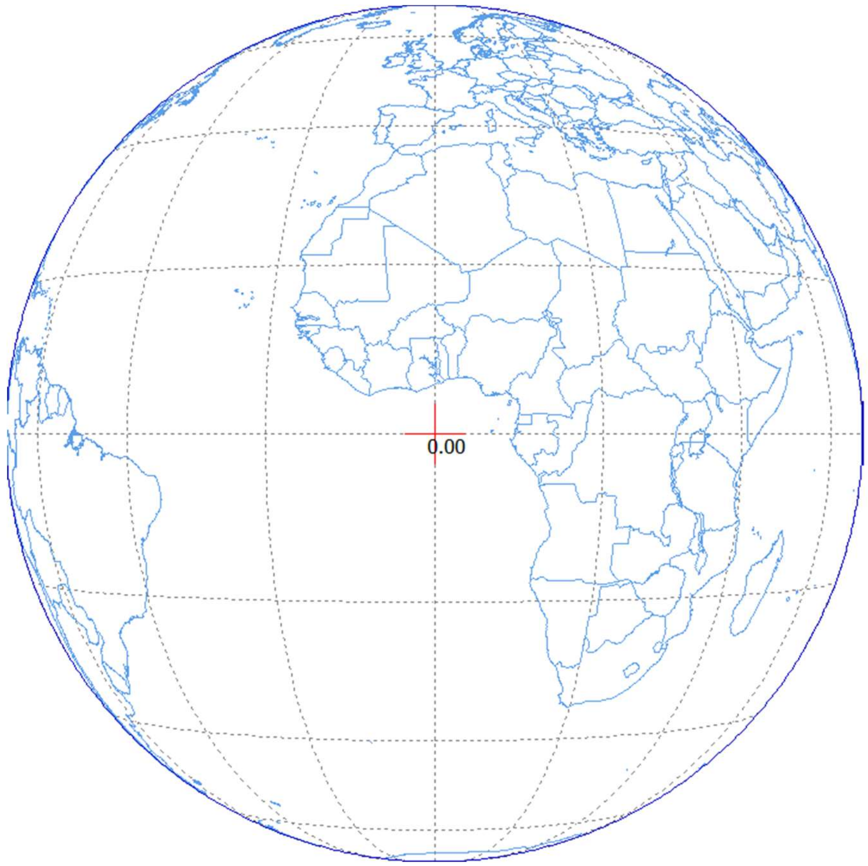

Figure 1 XTXH Antenna Beam Projection from 0 E.L.

The following diagram, Figure 2, shows the contours of the low gain X-band space-Earth beam (XTXL). The antenna pattern is isoflux-like in nature with a peak gain of 7.8 dBi at an angle of ~26 degrees off of boresight (well off of the Earth's surface). The -2 dB contour is ~11.5 degrees off of Nadir and also falls off of the Earth's surface. The projection below shows the projection of the -4 dB contour, from a GSO longitude of 0E as an example from GEO and also shows that the gain towards Nadir is 4.2 dB below the peak at an absolute value of 3.6 dBi.

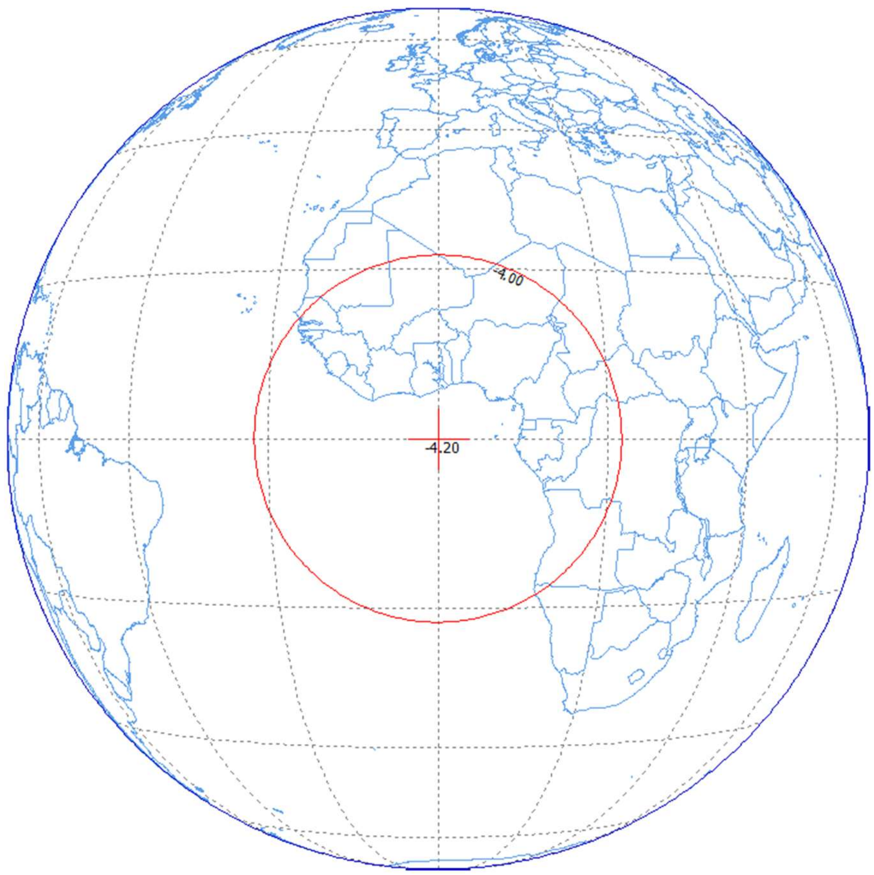

Figure 2 XTXL Antenna Beam Projection from 0 E.L.

The high gain S-band Earth-space beam (SRXH) offers a 3dB beamwidth of +/-25° from the GSO orbit. The Earth's diameter occupies roughly +/-8.7° degrees within that beam width. This antenna has peak gain at Nadir. The gain contours of the high gain S-band uplink antenna varies by <1 dB across the surface of the Earth. Accordingly, the gain at 2 dB below the peak falls beyond the edge of the Earth. The following diagram, Figure 3, shows the contours of the high gain S-band Earth-space beam (SRXH). Note that no contours fall onto the Earth's surface because the gain at the Earth's limb is <1 dB below peak.

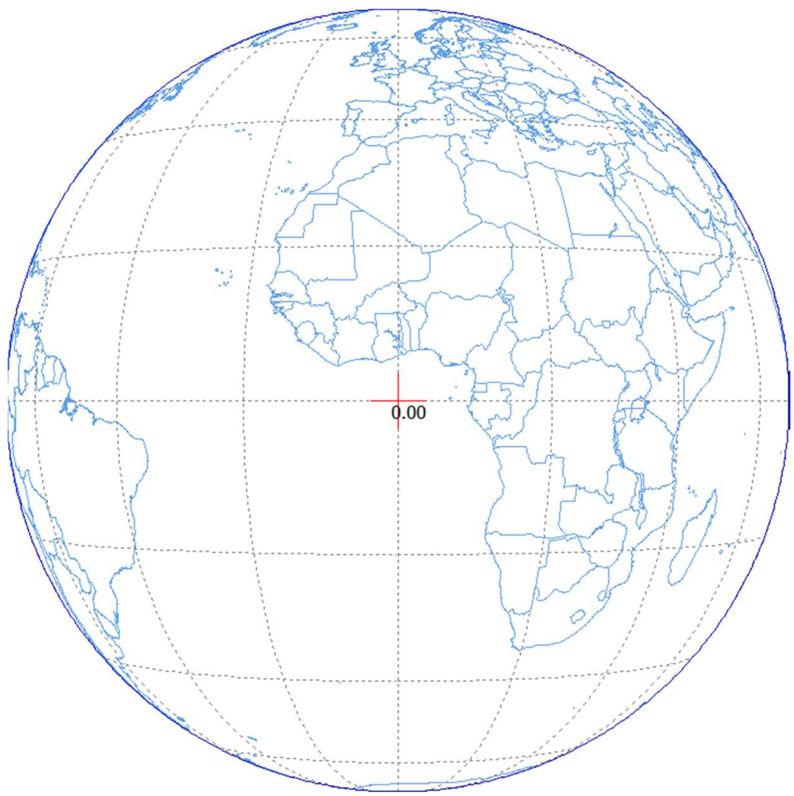

Figure 3 SRXH Antenna Beam Projection from 0 E.L.

The low gain S-band Earth-space beam (SRXL) offers a 3dB beamwidth of +/-30° from the GSO orbit. The Earth's diameter occupies roughly +/-8.7° degrees within that beam width. This antenna has peak gain at Nadir. The gain contours of the high gain S-band uplink antenna varies by <1 dB across the surface of the Earth. Accordingly, the gain at 2 dB below the peak falls beyond the edge of the Earth. The following diagram, Figure 4, shows the contours of the low gain S-band Earth-space beam (SRXL). Note that no contours fall onto the Earth's surface because the gain at the Earth's limb is <1 dB below peak.

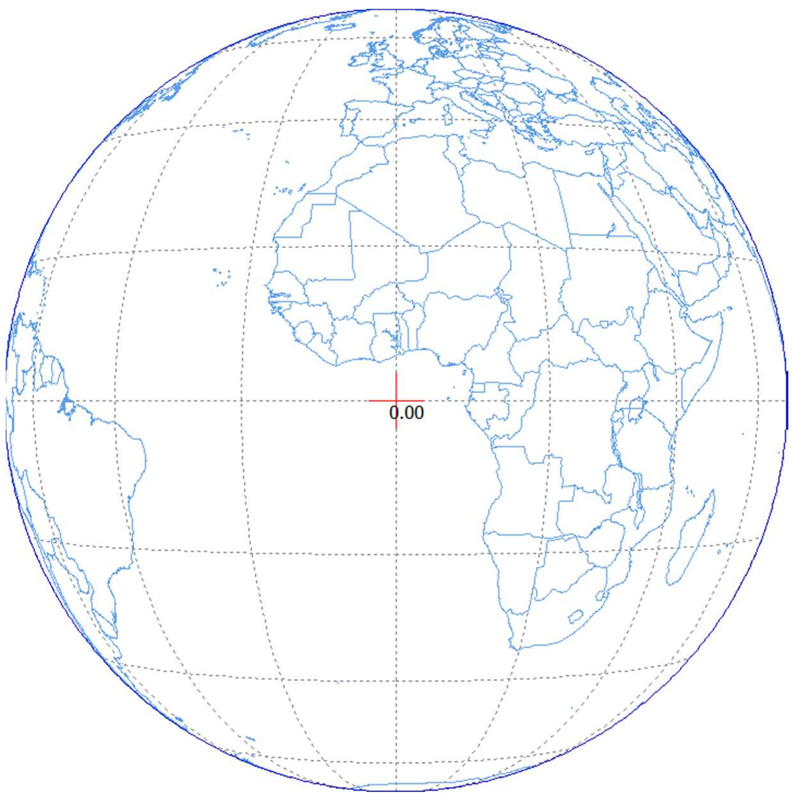

Figure 4 SRXL Antenna Beam Projection from 0 E.L.

VIII. COORDINATING UPLINK TRANSMISSIONS

All transmissions from the ground to the Otter 24B spacecraft as it is operating in NGSO will be coordinated with in-band users to ensure that Starfish does not cause harmful interference to other commercial or Federal government users in the band.

There are no Commission rules or ITU recommendations related to protecting GSO space stations in the S-band.[12] Starfish has identified the limited number of S-band space stations along the GSO and is planning to use channel deconfliction to protect these in-band systems. To facilitate deconfliction, Starfish will seek to coordinate multiple center frequencies for its S-band uplink transmissions. Its limited use of these channels, both in terms of duty cycles and channel size, will facilitate coordination of multiple center frequencies.

IX. SPECTRUM SHARING AND INTERFERENCE MITIGATION

Starfish acknowledges that its operations must protect primary Federal users in the band as well as other existing in-band operations. Below is a demonstration of how Starfish and the Otter 24B spacecraft will protect these existing operations.

Starfish will initiate coordination of its proposed use with Federal operators in the band shortly after filing this application.

A. Power Flux Density

Otter 24B's transmissions in the X-band will comply with Article 21 of the ITU Radio Regulations. As demonstrated below, the power flux density ("PFD") will not exceed the prescribed limits in Article 21.

B. Protecting Co-Frequency Space Stations

The Otter 24B will operate in NGSO throughout its mission, including when it services Asset #1 and Asset #2 in GEO.

To protect in-band operators Starfish is currently coordinating a center frequency of 2048.5 MHz in S-band, along with backup center frequencies at 2027 MHz and 2103 MHz through the NTIA process. These center frequencies have been selected based on an analysis indicating that Starfish can successfully coordinate their use of these center frequencies with in-band Federal operators, including Federal GSO space stations.

[12] *See e.g.,* ITU Radio Regulations, Article 22.

As noted above, Starfish has determined that there are no GEO or GSO space stations operating in the SRS band and only three GSO notifications in the EESS band.[13] The absence of GSO and GEO operators in the SRS band and limited presence in the EESS band will ensure that Otter 24B can protect GEO systems with its downlink transmissions. Out of an abundance of caution, Starfish will ensure that it does not use the EESS band in close proximity to existing GSO notifications in the band.

C. Compliance with Deep Space Protection Requirements

Otter 24B's transmissions in the SRS band will comply with ITU-R Recommendation SA. 1157-1. Starfish will deploy a radio frequency filter on its downlink transmitter to ensure its emissions will protect the adjacent band Deep Space Network. Specifically, the maximum allowable interference to deep-space earth station receivers in the 8.40-8.45 GHz band are characterized as:

Receiver noise spectral density (dB(W/Hz))	**Maximum CW interference power (dBW)**	**Maximum noise-like interference power spectral density (dB(W/Hz))**	**Maximum allowable interference power spectral flux-density (dB(W/m2 · Hz))**
-215	-220	-220.9	-255.1

Transmissions will also comply with ITU-R recommendation SA. 1810-1 which provides design guidelines for operations in the EESS band to protect sensitive deep-space receivers in the SRS band.

D. Band Edge Interference

As identified above, Starfish is seeking to operate in center frequencies that are not in close proximity to the band's edge. Starfish has purposefully sought these center frequencies to limit the possibility of any harmful interference to adjacent band services and operations.

X. ORBITAL LOCATION REQUESTED

As discussed in the Narrative, Otter 24B will seek to operate in NGSO near the Geostationary Arc to service two or more assets. Services will occur between altitudes of 35,586 and 36,800 km

[13] Starfish's research shows GEO Notifications at 137° W.L., 75° W.L. and 128.2° E.L that include the EESS band.

altitude.

Otter 24B will be injected into orbit at approximately 36101 km altitude +/- 100 km after launch. It will be commissioned and then transit to Asset #1 location between 35,800 and 36,600 km altitude,[14] with an inclination of 3 degrees. Otter 24B will conduct a satellite servicing check-out and station-keeping demonstration with Asset #1 before disposing it in the GEO graveyard at 36,050 km, altitude.

Following its detachment from Asset #1, Otter 24B will transit to Asset #2 at 10 degrees inclination, and an altitude of approximately 35,786 km. After inspection and disposal of Asset #2, Otter 24B will transit to a safe standby orbit at 10-degree inclination and 36,050 km altitude awaiting future tasking. Otter 24B will services additional assets as its capacity permits.

No more than six years after launch Otter will safely dispose of itself in the geostationary graveyard orbit and an altitude of approximately 36,050.

XI. ORBITAL DEBRIS MITIGATION PLAN

A. Otter 24B Flight Safety

Starfish has developed the CEPHALOPOD Autonomous Guidance System and CETACEAN Relative Navigation System to ensure that Otter 24B can safely transit its residential space environment and operate in close proximity to client spacecraft during RPOD.

Under nominal operations, CEPHALOPOD and CETACEAN will collaborate, utilizing sensor information from Otter 24B and command inputs from the ground to maintain a safe trajectory and manage thrust relative to the residential space environment.

In the event that Otter 24B experiences a communication interruption, CEPHALOPOD and CETACEAN will leverage available information, including real-time sensor data from Otter 24B's onboard sensors, to ensure Otter 24B maintains a safe flight profile until ground communications are restored.

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[14] Asset #1 is in an elliptical orbit with a 36500 +/- 100 km apogee and 35900 km +/- 100 km perigee.

The Otter 24B spacecraft will have three different thrusters onboard: one on the Astro Digital bus and one on each Manta boom. This design ensures propulsive redundancy to conduct collision avoidance maneuvers to effectively complete Otter 24B's post-mission disposal.

B. Mitigation Against Accidental Explosion Events

Starfish has performed extensive analysis to identify potential risks associated with the Mission and technologies. Starfish is tracking potential risks at the subsystem and system level and has developed and implemented mitigation strategies for each one.

Starfish has assessed the potential for accidental explosions caused by both internal and external sources during and after the completion of its mission and identified the highest risk would be collision with the client satellite. Otter 24B has mitigated this risk by developing RPOD trajectories that limit relative speeds between the client and Otter to single digit centimeter per second velocities. Contact between the two objects would cause slight disturbances to either spacecraft and would not be debris-causing collisions.

Starfish has assessed and limited the probability of accidental explosions during and after completion of mission operations, including prior to and after Rendezvous and Proximity Operations (RPO). As noted in our application, the highest identified risk for accidental explosions is a potential collision with the client satellite. To mitigate this risk, we have implemented comprehensive safety measures during Rendezvous, Proximity Operations, and Docking (RPOD).

Starfish has assessed and limited the probability of an accidental explosion from the pressure system by implementing the following safeguards:

- In the event of an overpressure we have a valve rated to our maximum expected operating pressure (MEOP). If pressure increases in the system the safety relief valve opens and vents until below MEOP
- The burst pressure threshold of the tank is 2.2 times higher than MEOP, ensuring structural integrity.
- A software actuated "vent mode" to open valves from the fuel tank to the thruster.

The probability of a battery explosion is extremely low (< 0.01%) as multiple independent faults would need to occur for such a failure. In the unlikely event that a battery cell does explosively rupture, the small size, mass, and potential energy of these small batteries is such that while the spacecraft could be expected to vent gases, most debris from the battery rupture should be contained within the spacecraft due to the lack of penetration energy to the multiple enclosures surrounding the batteries.

At the end of the mission, all remaining propellant will be vented to the environment using the software "vent mode." The solar array charging circuit will be disabled and the battery cells will be discharged completely.

By implementing these proactive safety measures, Starfish ensures compliance with all regulatory requirements and minimizes the risk of accidental explosions or debris generation throughout the mission.

Starfish has also developed an abort framework to enact safe path planning in the event of anomalous behavior to the client or Otter. This divert trajectory moves Otter to a passively safe standoff orbit until ground operators deem nominal maneuvering can be reinstated. Otter 24B has mitigated this risk by developing ConOps to limit high relative velocities as well as constructing maneuvers that step closer to the client with checks and additional object characterization. With the mitigation in place Starfish calculates the off-nominal contact and explosion risk to be less than 0.2%.

C. Mitigation Against Collisions with Other GEO Satellites and non-RPOD Tracked Residential Space Objects ("RSO")

Starfish will undertake the standard efforts to prevent any collisions between Otter 24B and other GEO satellites and Tracked RSO. This will include registering with and coordinating any maneuvers with the 18th and 19th Space Defense squadrons as well as coordinating with commercial operators as needed. Coordination will include sharing information regarding initial deployment, ephemeris, and/or planned maneuvers with the 18th and 19th Space Defense squadrons and other operators.

Using NASA's Debris Assessment Software (DAS) analysis, Starfish has determined that the probability of accidental collision with orbital debris during the mission's five-year duration in GEO is 2.72E-5, which is less than 0.01 required by the Commission's rules. Note, this mission is direct inject to GEO. Starfish has also assessed and limited the probability that Otter 24B will become a source of debris due to collisions with small debris. This assessment was conducted in accordance with orbital debris mitigation guidelines, and the probability of such collisions has been calculated to be 0.01 (1 in 100) or less. This ensures compliance with 47 CFR § 25.114(d)(14)(ii), reflecting a careful approach to minimizing the risk of debris generation from such collisions.

D. Mitigating Debris from Potential Collisions with Large Objects

Starfish has assessed and limited the risk of Otter 24B colliding with large debris and becoming a source of debris, in accordance with 47 CFR § 25.114(d)(14)(iv)(A)(1). Through detailed analysis and monitoring of orbital debris, we have implemented measures to minimize the probability of such collisions. Starfish employs advanced tracking and collision avoidance protocols to ensure that Otter 24B remains clear of large debris during its mission. These efforts align with the regulatory requirements and ensure that Otter 24B does not contribute to additional debris in orbit. The probability of collision with large objects for the Otter 24B mission will be 4.66E-5, which is less than 0.001 required by the Commission's rules.

To further minimize this risk, Starfish will be working with the 18th and 19th Space Defense Squadrons as follows:

<u>Pre-launch Measures</u>:

- Starfish will register Otter 24B with the 18th Space Defense Squadron.
- Starfish will test and rehearse LEOP activities.
- Starfish will receive separation state data from ULA to prepare for the expected state.
- Starfish will submit an orbital data request (ODR) to request early orbit collision avoidance (CA) support.

<u>Post-launch Measures</u>:

1. Starfish will upload maneuver ephemerides whenever maneuvers occur.

- During orbit transfers, Special files will be uplinked ahead of maneuvers, while Operational files will be updated for the next 8 hour period.
- During servicing, both Starfish and the customer will upload maneuver ephemerides to allow for both parties to receive collision data messages (CDMs) directly.

2. Starfish will receive CDMs, and track collision probability over time to assess collision risk.
3. Any objects that are consistently on track for a collision over time will be flagged for further assessment.

Prior to the expected time for collision, Starfish will maneuver Otter 24B to avoid the object. If the object is an operational asset, Starfish will attempt to contact and coordinate with its owner to perform maneuvers and avoid collision.

E. Mitigating Debris - Rendezvous, Proximity Operations and Docking

Starfish recognizes that its proposed mission creates potential debris-generating risks. While the Commission has previously authorized satellite servicing missions, the Otter 24B mission presents a distinct set of operational parameters. Starfish has diligently developed mitigation strategies for potential orbit generating debris introduced by its novel mission architecture.

Starfish assessed the amount of debris released during normal operations and determined that because Otter 24B deployables are all self-contained, no debris will be created. This assessment includes a thorough evaluation of potential sources of orbital debris, concluding that by virtue of the Otter design and planned operation, debris generation is effectively minimized and controlled. Our approach involves routine assessments and the application of preventive measures to maintain a safe and responsible operational environment, in compliance with 47 CFR § 25.114(d)(14)(i).

Starfish has developed a robust and proprietary Guidance, Navigation and Control ("GNC") software, which includes Monte Carlo testing to simulate docking performance. Starfish's GNC software relies on the use of a physics-based simulation framework and incorporates an abort framework for autonomous abort maneuvers in the event of a projected conjunction event. These simulations have enabled Starfish to design and develop flight paths that are both safe and efficient, while providing Otter 24B with an effective collision mitigation mechanism once in orbit.

Starfish has used these simulations to design flight patterns that ensure the Otter 24B spacecraft will have multiple “off-ramps” during its approach to the client spacecraft. As shown in Figure 6 below, the elliptical nature of Starfish’s approach maneuvers provides regular opportunities to divert Otter 24B away from the client spacecraft without abrupt maneuvers. In the event of an anomaly, Starfish will have regular opportunities to abort the approach and safely maneuver Otter 24B away from the client spacecraft.

i. Notifications to Space Force During RPOD and an Overview of Starfish Autonomous and Operator-Initiated Aborts and Notifications

Starfish Space and Space Force will develop a full set of processes and procedures for mutual ConOps which we will jointly rehearse before Mission launch. The ConOps development and rehearsal period includes a Technical Interchange Meeting (TIM) with documentation defining off-nominal behavior prior to the Mission where Starfish software will autonomously detect such behavior. Starfish will provide notification to Space Force in a mutually agreed amount of time before the commencement of any RPOD activities’ sequence.

Downlinked data will be received by the Starfish Satellite Operations Control (SOC). Starfish personnel will be available around-the-clock to monitor mission status, resolve any issues that arise, and make critical decisions as needed.

If any aborts or trajectory changes that deviate from planned trajectories are conducted, Starfish will notify Space Force with details regarding those changes, including details of the new safe orbit that Otter 24B has entered into. During proximity operations and docking, Starfish Space and Space Force will have an open line of communication. More specifically, the Starfish SOC and Space Force’s SOC will be in direct and constant communication.

The following describes Otter 24B autonomous and operator-initiated aborts and notification of aborts and abort-driven trajectory changes to Space Force:

ii. Autonomous Aborts and Notifications

Starfish Space’s CEPHALOPOD guidance software can autonomously detect when built-in safety criteria is being violated in the Otter 24B spacecraft itself or when its propagated trajectory threatens the docking partner, Space Force. In the scenario when such off-nominal detection occurs, CEPHALOPOD will autonomously abort a given trajectory to a passively safe orbit. Because the capability to respond to sudden unexpected circumstances is critical not just for this Otter 24B mission, but for any mission conducting RPOD, the CEPHALOPOD guidance software has been architected to continuously plan potential abort trajectories for its current maneuver. This provides Otter 24B with the flexibility to move away from client space stations immediately without waiting for a ground command.

Because the intention is for abort maneuvers to purposefully and instantaneously deviate Otter 24B from nominal planned trajectories, Starfish cannot give advance notification to Space Force that aborts will occur. However, Starfish Space will provide immediate notification to Space Force as soon as it becomes aware that an abort maneuver has occurred.

Starfish will downlink to ground stations that have been selected to allow Otter 24B to maximize contact time and minimize contact gap time during critical RPOD operations. With this robust network of ground stations in place, Starfish Space will be able to utilize several ground station passes per orbit to speedily downlink trajectory changes autonomously made by Otter 24B. In addition, Starfish plans to initiate each RPOD mission phase at the time that will give Otter 24B the optimal ground station contact coverage. Otter 24B will remain in a passively safe orbit until this time, and only then will be given the go-ahead to enter the next RPOD activities' phase.

iii. Operator-Initiated Aborts and Notifications

In addition to autonomous abort decision-making onboard Otter 24B via our CEPHALOPOD software, there will be human operators-on-the-loop on the ground. Starfish operators, via the Starfish SOC, will: 1) be constantly monitoring key telemetry during RPOD testing, 2) decide if the mission can continue as planned if off-nominal behavior is observed, and 3) manually command an abort if needed. Operators' primary focus is to prevent any unsafe contact between Otter 24B and customer spacecraft and will abort for any off-nominal scenario not captured by autonomous software monitoring. As previously mentioned, during proximity operations and docking, Starfish Space and the Space Force will have an open line of communication. As soon as a manual abort has been initiated via the Starfish SOC, the Space Force SOC will be immediately notified of the abort and new trajectory information.

iv. Starfish Space's Collision Avoidance Procedure

Regardless of mission phase, our collision avoidance procedure can be executed in accordance with the recommendations outlined below from the Spaceflight Safety Handbook for Operators. If the expected conjunction is with an object that is not our intended docking partner, we will assess collision risk with all other affected parties with the usual guidelines. If the conjunction warning is for our intended docking partner, Starfish Space and the Space Force Operations team will be in regular contact and actively coordinating to safely conduct what amounts to a "planned conjunction" (RPOD). Under any circumstances, Starfish certifies that it will be able to take appropriate action if the 18th and 19th Space Defense Squadron notifies Starfish Space Otter 24B of a potential conjunction during any of the mission phases.

Based on the Spaceflight Safety Handbook for Operators, Starfish will use the following threshold for initiating collision avoidance planning given a conjunction warning:

- Probability of Collision >= 1 e^-4;
- Overall miss distance <= 1 km;

And the target for risk reduction will be:

- Maneuver to achieve Probability of Collision <= 1 e^-7 and,
- Overall miss distance >= 1 km

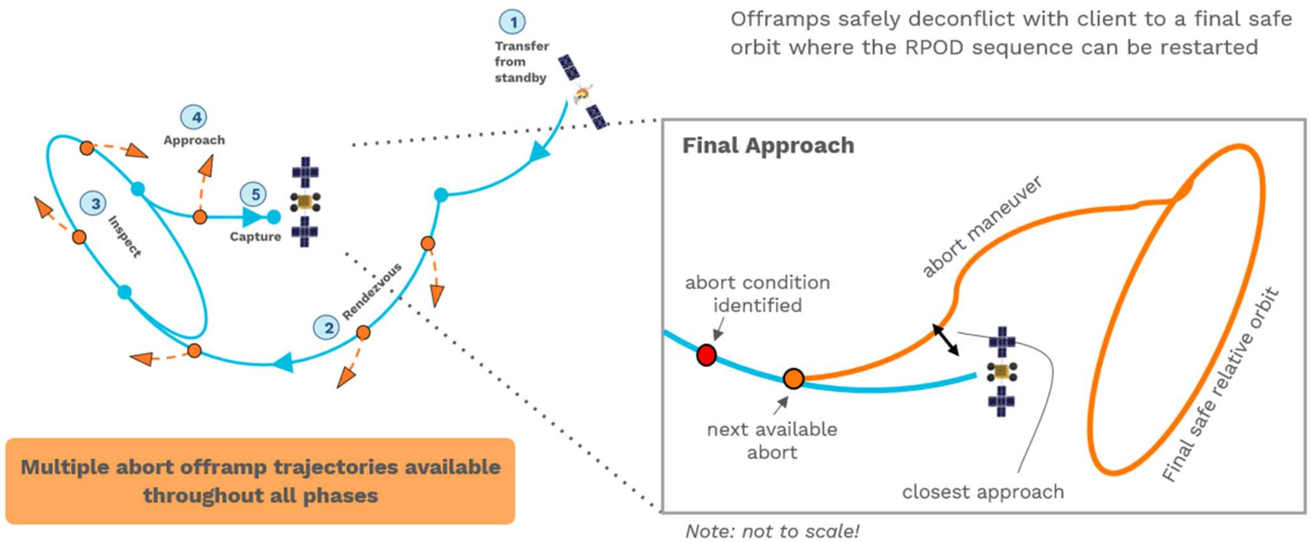

Figure 6: RPOD Abort Trajectories

F. Post-Mission Disposal

Once Otter 24B has safely completed its on-orbit mission, it will conduct orbit-raising maneuvers to the graveyard orbit used by GSO satellites. As noted above, Otter 24B will have three thrusters onboard ensuring that there is sufficient propulsive redundancy to complete its post-mission disposal maneuvers. Starfish will reserve an appropriate level of fuel for its end-of-life maneuvers to ensure that these maneuvers can be completed as described in this application.

Starfish expects that the Otter spacecraft will have some residual xenon fuel remaining in its tanks during the mission.[15] Some of its fuel may inadvertently escape during operations as well. Although the plume concentration near the thruster is much greater than natural abundance levels, the increase in atmospheric concentration due to its release from an ion thruster is shown to be small at all altitudes, even for volumes of modest size. In the worst case such as a rapid release of the entire contents of the propellant tank, the fuel will be fully diffused after a short period measured in hours. Neutral atoms released from the thrusters can be ionized via several mechanisms.[16] This means that

[15] Starfish will provide a supplement with further details regarding its end-of-life disposal plans in conjunction with this application. Starfish will file this supplement separately in order to requests confidential treatment for this information.

[16] Mark W. Crofton & Toby D. Hain, *Environmental Considerations for Xenon Electric Propulsion*, IEPC-2007-257, at 28 (2007), presented at the 30th Int'l Electric Propulsion Conf., Florence, Italy,

any fuel that escapes during operation or is vented at the end-of-life stage will pose little threat to nearby spacecraft, including Starfish's client spacecraft.

Starfish has provided a separate attachment further detailing its fuel reserve for end-of-life disposal. Due to the commercial sensitivity of this matter, Starfish has requested that this information remain confidential. However, it intends to provide the Commission with sufficient information to assess Otter 24B's end-of-life disposal plan.

Sept. 17-20, 2007, https://electricrocket.org/IEPC/IEPC-2007-257.pdf.

Technical Certification

I, Ryan Henderson hereby certify, under penalty of perjury, that I am the person responsible for supervising the preparation of the engineering information contained in the technical portions of the foregoing application and the related attachments, that I am familiar with Part 25 of the Commission's rules, and that the technical information is complete and accurate to the best of my knowledge and belief.

/s/ Ryan Henderson
Ryan Henderson
Principal Systems Architect
Starfish Space, Inc.

Dated: May 23, 2025

Annex A – S-Band Link Budgets

Uplink	Low Gain	High Gain
Transmitter Assumptions (Ground)		
Station EIRP [dBW]	50	50
Pointing Loss [dB]	-1.0	-1.0
Polarization Loss [dB]	-0.23	-0.23
Elevation Angle [deg]	20	20
Link Availability [-]	99.5%	99.5
Receiver Assumptions (Otter)		
Pointing Loss [dB]	-0.10	-0.10
Antenna Gain [dBiC]	5.0	10.1
Line Loss [dB]	-0.8	-0.0
Otter G/T [dB/K]	-24.1	-16.1
Link Performance		
Data Rate Desired [kbps]	10	100
Link Margin	11.1	9.0

Annex B – X-band Link Budgets

Downlink	Low Gain	High Gain
Transmitter Assumptions (Otter)		
Otter EIRP* [dBW]	12.97	24.67
Pointing Loss* [dB]	-0.10	-0.30
Polarization Loss [dB]	-0.23	-0.08
Elevation Angle [deg]	20	20
Link Availability [-]	99.5%	99.5%
Receiver Assumptions (Ground)		
Pointing Loss [dB]	-1	-1
Antenna Gain [dBiC]	52.7	55.5
Line Loss [dB]	-0.9	-0.9
Station G/T [dB/K]	29.4	30.3
Link Performance		
Data Rate Desired [kbps]	100	950
Link Margin	5.9	6.1

Annex C – PFD Analysis

The high gain X-band antenna has a peak gain of 15.8 dB and a maximum of 9 dBW of RF power into the antenna port. This downlink will operate at a maximum symbol rate of 1 Msps and a minimum symbol rate of 100 ksps. Based upon these inputs the following curves illustrate the PFD from the high gain X-band downlink from the orbit altitude of the GSO arc, 35786 km. Any operations from the GSO graveyard orbit will result in slightly less PFD.

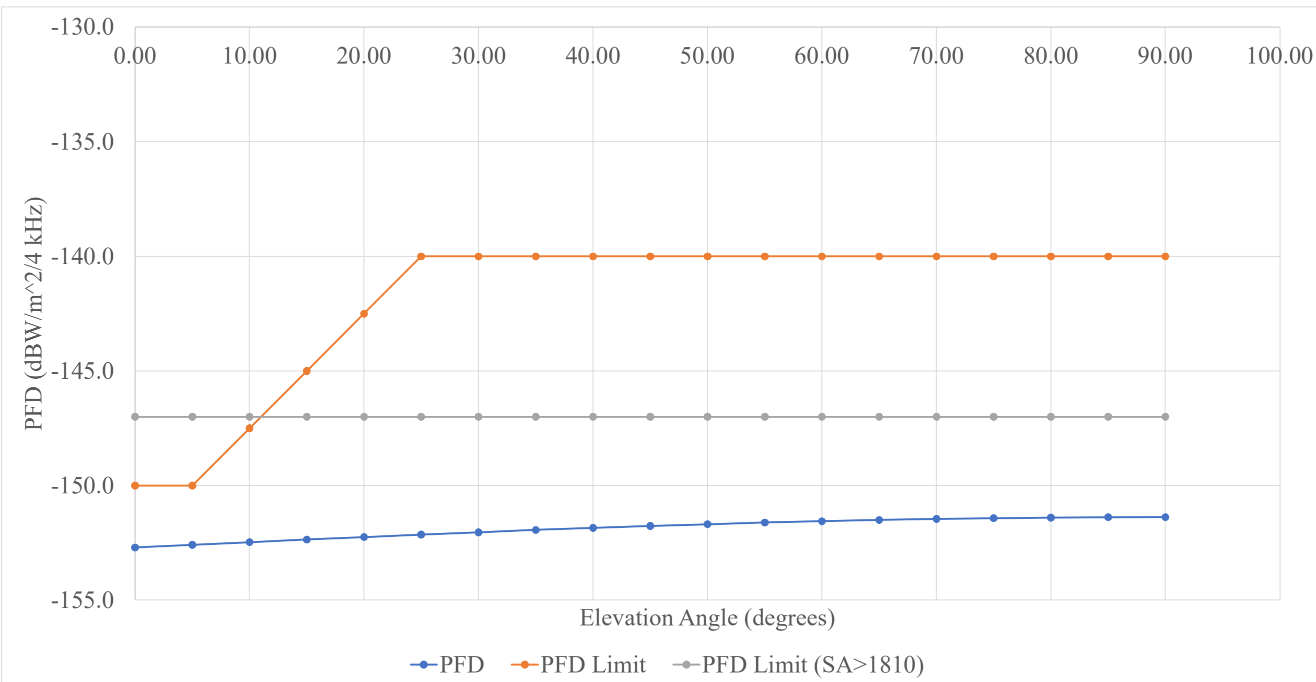

Figure 7: X-band PFD, High Gain Antenna, 24.67 dBW EIRP, 100 ksps, GSO Orbit

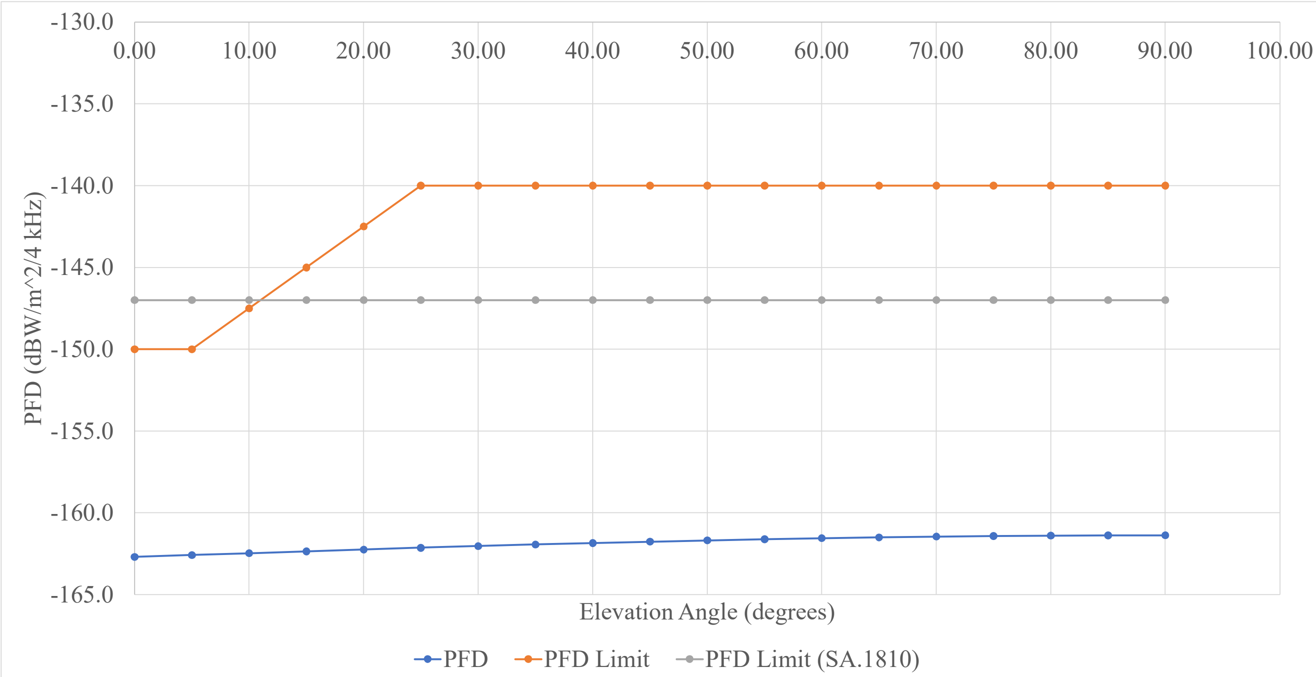

Figure 8: X-band PFD, High Gain Antenna, 24.67 dBW EIRP, 1 Msps, GSO Orbit

The low gain X-band antenna has a peak gain of 7.8 dB and a maximum of 8.5 dBW of RF power into the antenna port. This downlink will operate at a maximum symbol rate of 100 ksps and a minimum symbol rate of 15 ksps. The high gain X-band antenna has a peak gain of 15.8 dB and a maximum of 9 dBW of RF power into the antenna port. This downlink will operate at a maximum symbol rate of 1 Msps and a minimum symbol rate of 100 ksps. Based upon these inputs the following curves illustrate the PFD from the low gain X-band downlink from the orbit altitude of the GSO arc, 35786 km. Any operations from the GSO graveyard orbit will result in slightly less PFD.

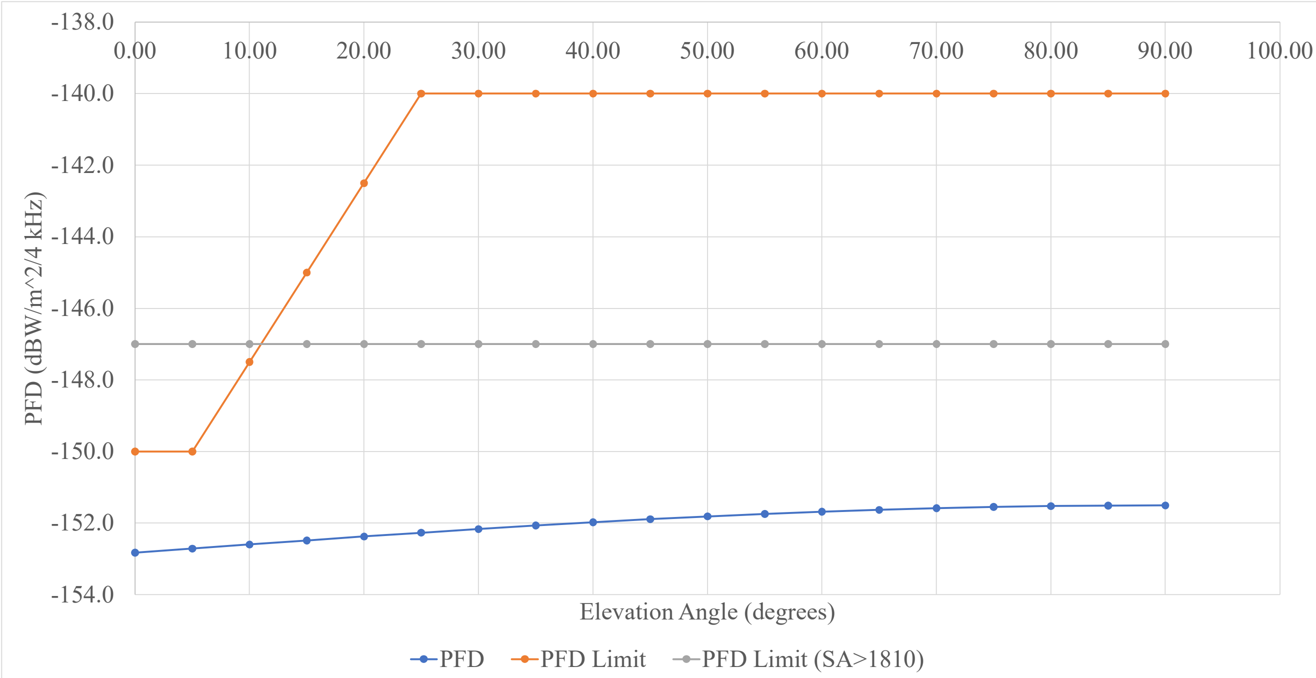

Figure 9: X-band PFD, Low Gain Antenna, 16.3 dBW EIRP, 15 ksps, GSO Orbit

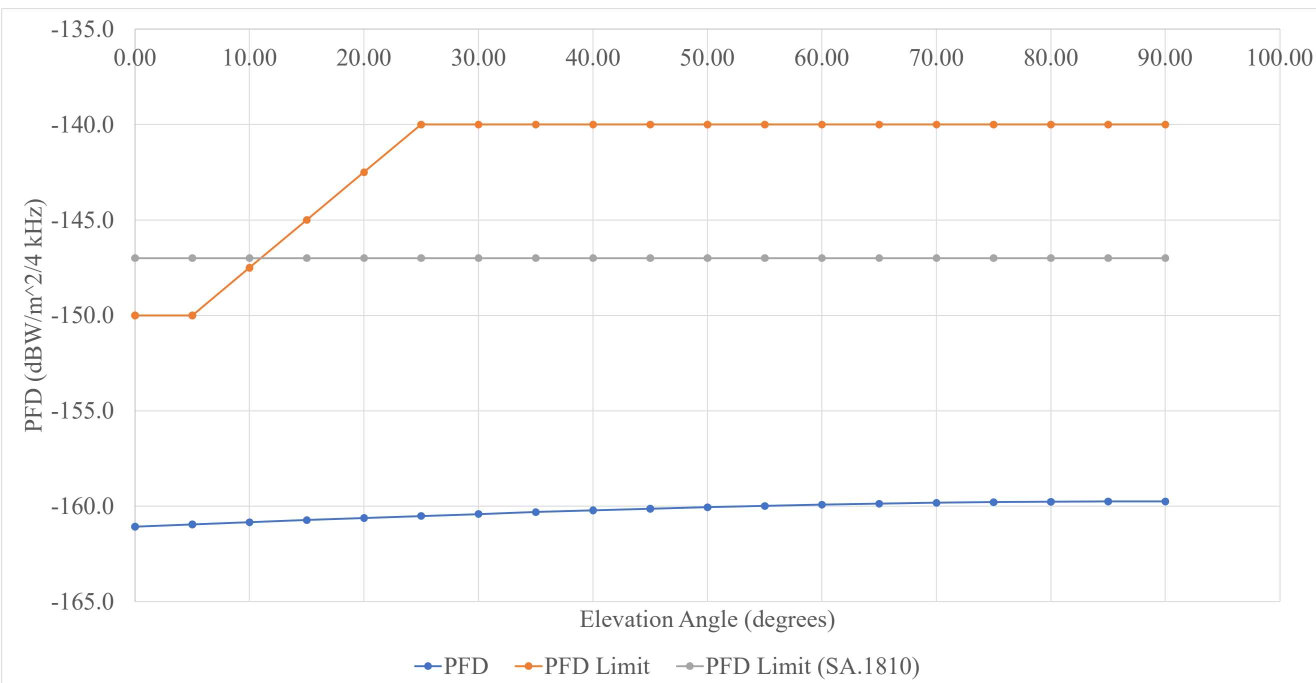

Figure 10: X-band PFD, Low Gain Antenna, 16.3 dBW EIRP, 100 ksps, GSO Orbit