Gravitational Reference Advanced Technology Test in Space

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1 Background

The Gravitational Reference Advanced Technology Test (GRATTIS) is a NASA-funded technology demonstration led by the University of Florida (UF). GRATTIS was selected in 2024 as part of NASA's In-Space Validation of Earth Science Technologies (InVEST) program, the demonstration is designed to revolutionize how we measure Earth's gravity to track water and ice movement.

GRATTIS features two key technologies:

1. Primary Technology: Two identical Simplified Gravitational Reference Sensors (S-GRS) for high-precision gravity mapping
2. Secondary Technology: An Optomechanical-Distributed instrument for Inertial sensing and Navigation (ODIN) for advanced satellite motion tracking.

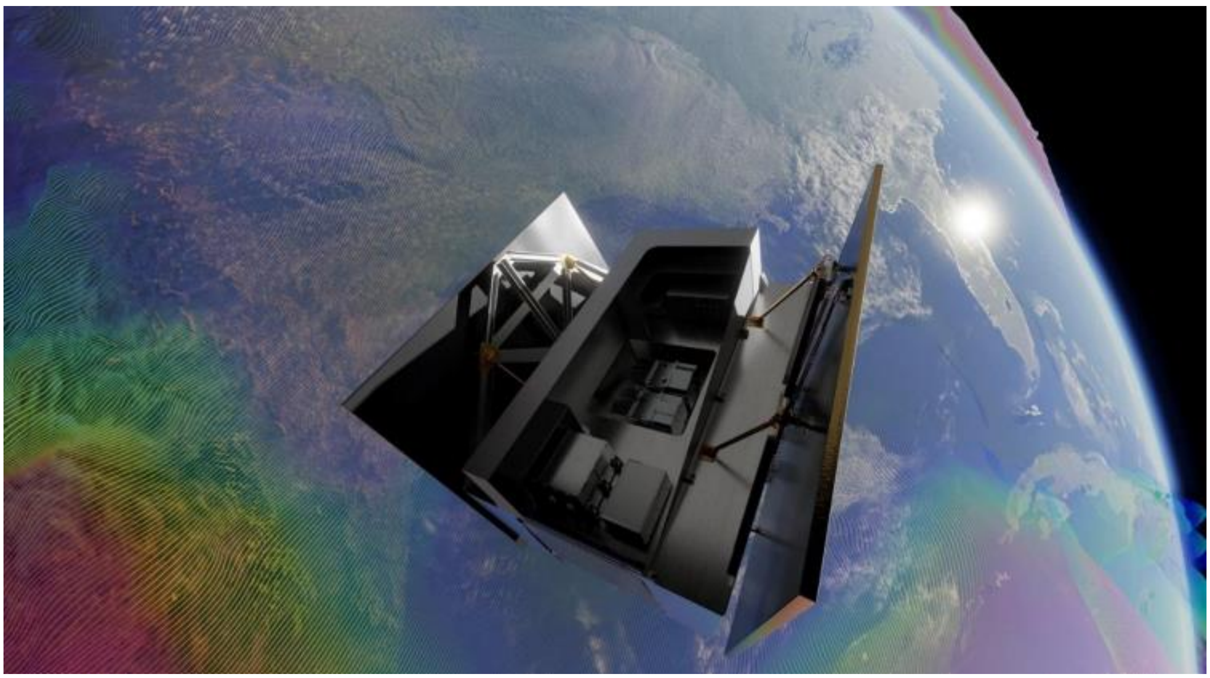

Figure 1-1: Rendering of the GRATTIS spacecraft in Earth orbit showing the Earth's geoid, the ultimate science goal for this technology demonstration mission (Credit: University of Florida)

2 Project Organization

The project is organized as follows:

Organization	Contribution
University of Florida	Principal Investigator Mission Lead S-GRS payload development lead
CrossTrac Engineering	Project Management Software Management
Apex Space	Commercial satellite bus provider, payload I&T
BAE Systems	S-GRS sensor head
Fibertek	S-GRS electronics
University of Arizona	ODIN payload development lead
University of Texas at Austin	Austin's Oden Institute and Center for Space Research (CSR)
Maverick Space	Launch Services Provider
SpaceX	Launch Provider
Ruda Optical	ODIN sensor package
IST Precision	ODIN electronics

3 Spacecraft Owner & Operator

GRATTIS is a PI-led Technology Demonstration by the University of Florida supported by the NASA under Grant No. 80NSSC24K1408.

The GRATTIS Spacecraft owner and operator is the University of Florida.

4 Objectives

The primary objective of GRATTIS is to test the Simplified Gravitational Reference Sensor (S-GRS). This next generation inertial sensor is significantly more sensitive than those used on missions like GRACE-FO (Gravity Recovery and Climate Experiment Follow-On). By measuring nanometer-scale changes in gravity, this demonstration aims to provide unprecedented data on:

- Hydrology: Monitoring groundwater reserves and droughts.
- Cryosphere: Tracking the melting of ice sheets and glaciers.
- Oceanography: Observing changes in sea levels and ocean currents.

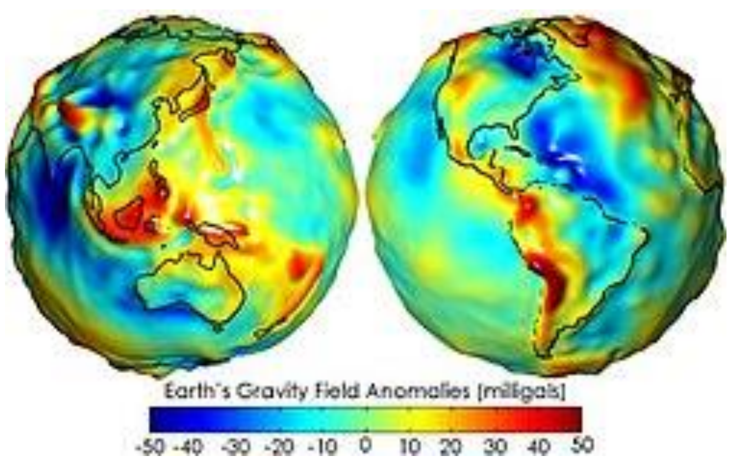

Figure 4-1: Earth Gravity Field Anomalies (credit: NASA Earth Observatory)

The secondary objective is to test the Optomechanical-Distributed instrument for Inertial sensing and Navigation (ODIN) instrument for advanced satellite motion tracking. ODIN is a gyro-free inertial navigation unit based on an array of linear optomechanical resonators.

Refer to Section 8 for a detailed description of these key technologies.

5 Launch & Orbit

GRATTIS is currently slated for Q1 2027 (Notionally, Feb 1, 2027) on a SpaceX Falcon 9 Transporter-19 rideshare mission from Vandenburg Air Force Base, CA to a 510 km – 590 km Sun-Synchronous Orbit (SSO). The nominal operating altitude is 590 km, where the inclination is 97.7 deg for a SSO. GRATTIS has communicated to SpaceX that the preferred drop off is 590 km, however, the spacecraft carries propulsion to perform an orbit raise maneuver if the spacecraft is deployed <590 km. Pre-launch coordination will be performed with the 18th Space Defense Squadron (18 SDS), and Space-Track.org will be utilized for spacecraft tracking, identification, and maneuver planning.

6 Mission Duration

The total nominal operating lifetime of the spacecraft is 12 months if the spacecraft is dropped-off at the nominal operational altitude of 590 km, and up to 13 months if the spacecraft is dropped off <590 km.

The GRATTIS spacecraft (235 kg wet) is designed to remain in orbit for the entirety of the technology demonstration.

Table 6.1: GRATTIS Mission Duration by Phase

Phase	Duration
Spacecraft Bus Commissioning	1 mo.
Orbit Raise (if required, 530 km to 570 km)	Up to 1 mo.
Payload Operations	5 mo.
Orbit Lowering (570 km to 215 km)	Up to 6 mo.
Total	12 mo. (nominal) Up to 13 mo.

After the orbit lowering maneuver when spacecraft reaches 590 km x 234 km, it will take approximately 2 months for the spacecraft to re-enter atmospherically. Hence, the total Mission Lifetime to spacecraft demise is nominally 14 months, and up to 15 months if an orbit raise is required at the beginning of the mission. This projected mission lifetime was verified through NASA's Debris Assessment Software (DAS) Ver. 3.2.7, and is detailed further in the *GRATTIS-RP-101 GRATTIS Orbital Debris Assessment Report* Attachment.

7 Concept of Operations (ConOps)

7.1 Launch

GRATTIS is slated to launch from Vandenberg Space Force Base, California, as a rideshare payload aboard a SpaceX Transporter-19 mission in Q1 2027. The spacecraft will be deployed into a 510 km – 590 km SSO.

7.2 Spacecraft Commissioning (1mo.)

Following deployment from the launch vehicle (LV), GRATTIS will automatically enter a protective *Safe Mode*, remaining in this state for 30-40 minutes (per LV requirements) to ensure sufficient physical separation from the launch vehicle before initiating Spacecraft Commissioning.

During Spacecraft Commissioning, critical spacecraft components are powered and enabled. Detumble will then begin, utilizing magnetic torque rods to reduce the spacecraft's rotational momentum below a 0.2 Nms threshold. Once stabilized, the reaction wheels are powered on and enabled to provide 3-axis attitude control, with the torque rods utilized for momentum desaturation. The satellite then transitions into *Idle Mode* awaiting initial ground acquisition to begin communications checkout.

During communications checkout when the spacecraft is over the ground station, the spacecraft will be commanded, by the ground, to begin S-band and X-Band communications to verify data rate/throughput and frequency allocation compliance. Note that the communications checkout may require multiple passes before completion.

After communications checkout is complete, the remainder of the spacecraft subsystem health checks will be performed to confirm readiness for nominal operations. These checkouts also include a propulsion system checkout, which includes turning on the propulsion system controller and initiating checkout burns. All propulsive burns, including those for checkout, will be coordinated with the 18th Space Defense Squadron (18 SDS) and reported on Space-Track.org.

7.3 Communications

The GRATTIS communication architecture is shown below:

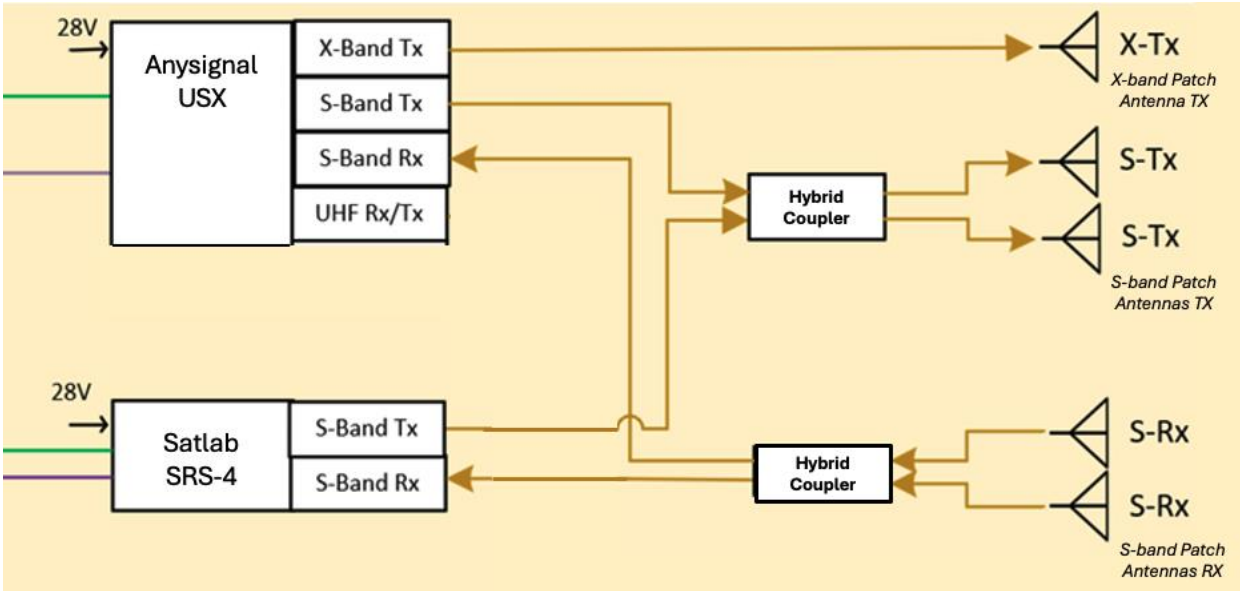

Figure 7.3-1: GRATTIS Communications Architecture

S- and X-Band: S- and X-Band communications are required to bifurcate critical command functions from high-volume science data transfer. The S-Band link is essential for robust Telemetry, Tracking, and Command (TT&C), providing a reliable, low-rate interface for continuous spacecraft health monitoring and emergency recovery. Simultaneously, the X-Band downlink is essential for the high-resolution gravitational sensing suite, which generates a significant daily data volume of 9,500 Mbit/day. Utilizing the X-Band spectrum allows for the efficient offloading of this large science payload within the constraints of two daily ground passes, ensuring that the S-Band remains clear for vital flight-safety operations. The spacecraft is only capable of storing up to two days of science data to accommodate one missed ground contact.

Two ground station passes per day are planned, leveraging the Leaf Space commercial ground station network (licensed separately from the spacecraft). Mission operations will be conducted by University of Florida (UF) through their Mission Operations Center (MOC).

The S-Band receiver stays on at all times throughout the demonstration. The S- and X-Band transmitters only transmit in response to ground command. All uplink commands are secured utilizing AES-256 encryption standards to prevent unauthorized access and ensures the integrity of the command link between the UF MOC and the spacecraft. Both S-band and X-band transmitters are all capable of ceasing transmissions when commanded, as-needed.

Refer to Section 9.3 for additional detail on the Communications subsystem.

7.4 **Orbit Raise** (Up to 1 month, if required)

If GRATTIS is deployed below its nominal operating altitude of 590 km, an orbit raise maneuver will be performed utilizing its Hall Effect Thruster (HET) propulsion system (Xenon as the propellant). Although the orbit raise is expected to take approximately 1-2 weeks, 1 month is allocated for the orbit raise to include margin. The orbit raise maneuver will be coordinated with the 18th Space Defense Squadron (18 SDS) and reported on Space-Track.org.

7.5 **Payload Operations** (5 mo.)

The payload checkout and operations follow a phased approach, detailed in this section.

Instrument Checkout (~2 wks): This is the payload checkout for the S-GRS and ODIN instruments. The S-GRS and ODIN payload telemetry, UV light systems, laser stability, noise levels, electronics, temperature sensors, and data collection capabilities for the entire sensing suite are verified during this phase (as-applicable).

S-GRS Checkout (3~ wks): After instrument checkout is complete, the demonstration transitions to individual sensor operations, starting with a 15-day period for S-GRS 1 and a 6-day period for S-GRS 2. Each S-GRS undergoes launch lock disengagement, test mass release, and acceleration measurement demonstrations. At the end of S-GRS Checkout, both test masses will be in a free-floating/released configuration. ODIN remains idle mode during this time.

S-GRS Science (~3 wks): After S-GRS checkout, the demonstration transitions to the S-GRS science phase, where differential acceleration is measured utilizing both S-GRS. After the S-GRS science phase is complete, both S-GRS 1 and 2 launch locks are reengaged ("regrabbed"). ODIN remains in idle mode during this science phase.

ODIN Science (~1 mo.): Then the focus shifts to ODIN operations, including a 6-day initialization where the launch locks are released, and a 24-day dedicated science phase. ODIN measures the motion of 12 resonators by means of laser interferometry. Combinations of these signals allow to calculate linear acceleration, angular acceleration, and centripetal terms of the spacecraft. Other combinations provide the inherent noise of ODIN by cancelling out the spacecraft motion. ODIN remains in science mode as the payload operations transition to the next phase.

S-GRS & ODIN Science (~2 mo.): After individual S-GRS and ODIN science phases are complete, a comprehensive joint operation phase begins. ODIN remains in science mode while performing complex coordinated measurements alongside individual and dual S-GRS test mass releases to validate the integrated performance of the entire gravitational sensing suite. After this 60-day period, the technology demonstration is considered complete.

7.6 **Decommissioning**

At the end of the technology demonstration, the S-GRS and ODIN payloads will be turned off. In coordination with 18 SDS, the spacecraft will be commanded to perform a propulsive retrograde orbit lowering maneuver to reduce the satellite's altitude and increase atmospheric drag with the remaining propellant level taken into account. Refer to Section 9.5 for additional information on the propulsion system.

The orbit lowering process is planned to take approximately 6 months (assuming 59 km to 234 km), and the remainder of passive atmospheric re-entry is expected to take an additional 2 months before spacecraft demise. Before atmospheric re-entry, the electrical power system (EPS) will be ramped down by draining the battery and disconnecting the solar panels, and any remaining propellant will be expelled to ensure safe decommissioning. The spacecraft is designed to burn up during atmospheric re-entry, minimizing the risk of debris and ensuring safe disposal.

A formal ODAR analysis has been performed to verify that the spacecraft adheres to all FCC requirements regarding orbital lifetime and post-mission atmospheric demise. There are no frangible materials or planned debris release from GRATTIS. Refer to the *GRATTIS-RP-101 GRATTIS Orbital Debris Assessment Report* Attachment for additional detail.

8 Key Technologies

The GRATTIS technology demonstration is driven by two key technologies further detailed in this section:

- **Simplified Gravitational Reference Sensor (S-GRS)** for high-precision gravity mapping.
- **Optomechanical-Distributed instrument for Inertial sensing and Navigation (ODIN)** for advanced satellite motion tracking.

There are two primary science modes, inertial pointing and nadir pointing. In both cases the solar arrays are oriented to be coplanar with the orbit plane to minimize drag, while oriented to be pointed in the direction relative to the Sun that supports power generation.

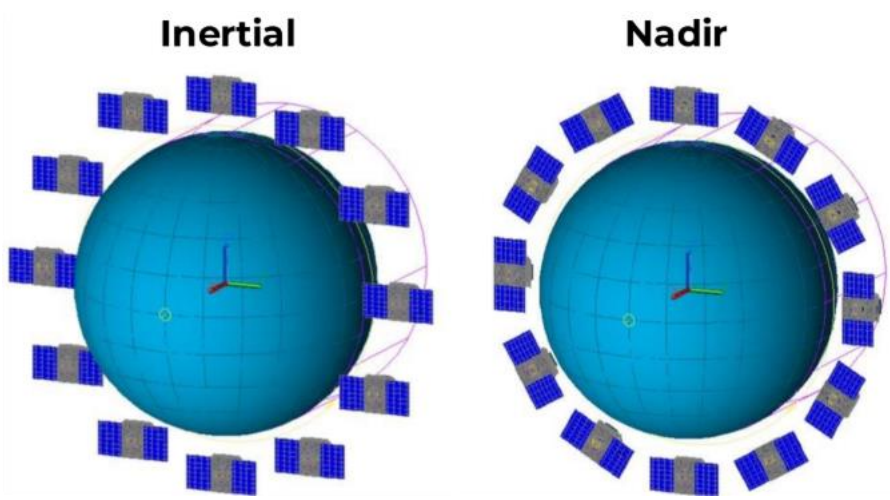

Figure 8-1: GRATTIS Inertial and Nadir Pointing diagram

The following sub-sections outline each of the technologies in further detail.

8.1 Simplified Gravitational Reference Sensor

The Simplified Gravitational Reference Sensor (S-GRS) is an ultra-precise inertial sensor designed to isolate a spacecraft's motion caused purely by Earth’s gravity from "noise" like atmospheric drag or solar radiation pressure. The S-GRS is a streamlined version of the technology used in the joint NASA ESA Laser Interferometer Space Antenna (LISA) Pathfinder mission slated to launch in 2035.

GRATTIS will fly two identical S-GRS (two separate test masses) each housed within its own sensor head. By mounting two identical sensors next to each other near the satellite's center of mass, the integrated system will compare their outputs to cancel out "common-mode" noise, such as the vibration of the satellite itself, to determine the acceleration noise floor of the sensor.

The main elements of the S-GRS include:

- *Test Mass (TM):* A high-density, gold-plated tungsten cube (0.5 kg ea) that serves as the inertial reference point.
- *Electrode Housing (EH):* A precision-machined structure that surrounds the test mass; it contains electrodes for both capacitive sensing (detecting where the mass is) and electrostatic actuation (applying tiny forces to keep the mass centered).
- *UV LED Charge Management System:* uses ultraviolet light to "photo-electrically" discharge the test mass, preventing static buildup that would otherwise cause "stray" forces.
- *Caging and Release Mechanism:* A mechanical "launch lock" that firmly holds the test mass during the high-vibration environment of a rocket launch and then gently releases it into free-fall during mission operations. This system allows both release and re-capture the test masses on-orbit.
- *Enclosure:* A titanium mounting frame and enclosure that maintains a clean environment around the sensor that is vented to space once in orbit to eliminate "gas damping" (air molecules bumping into the test mass).
- *Sensing and Actuation Unit (SACU):* High-stability electronics unit that processes the capacitance signals from the electrodes and applies electrostatic actuation voltages to the electrodes. This unit also provides the UV light for test mass discharge.
- *Power and Caging Unit (PACU):* Unit that converts the 28 V spacecraft power to the various voltage rails needed by the SACU. This unit also contains the drivers for the launch lock and test mass release mechanism.

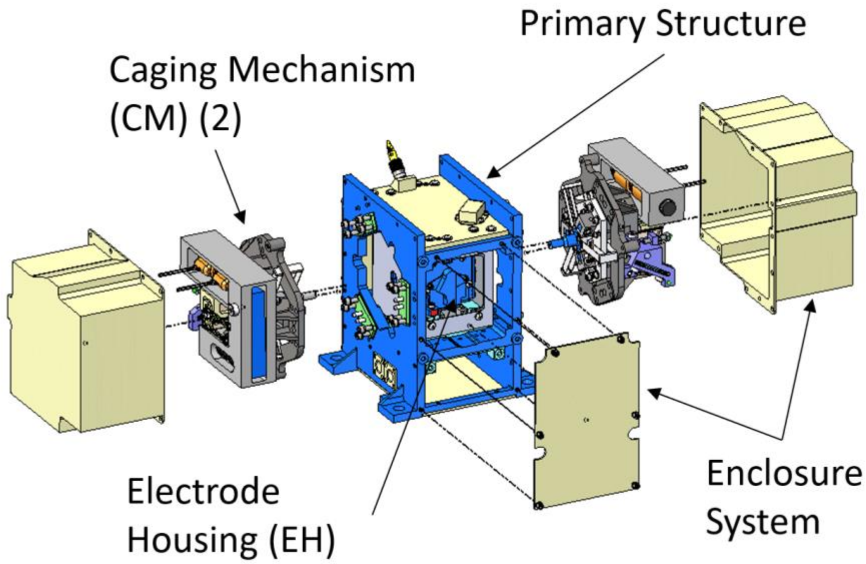

Figure 8.1-1: S-GRS Sensor Head containing the test mass, electrode housing, Caging and Release Mechanism, and Enclosure

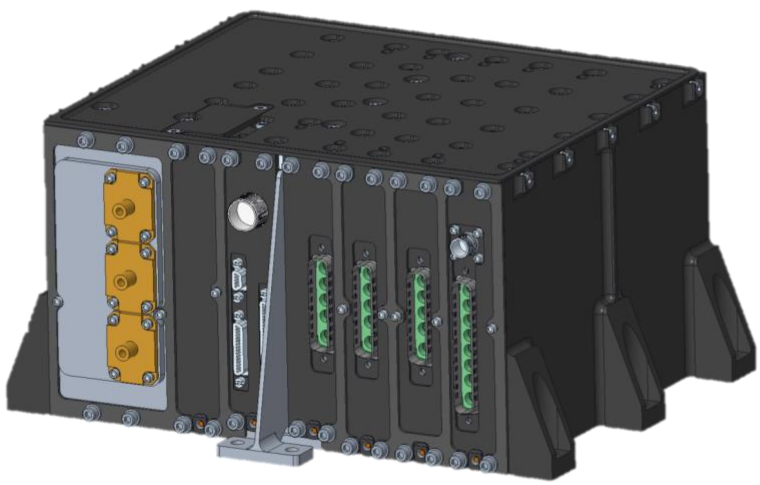

Figure 8.1-2: SGR-S Sensing and Actuation Unit

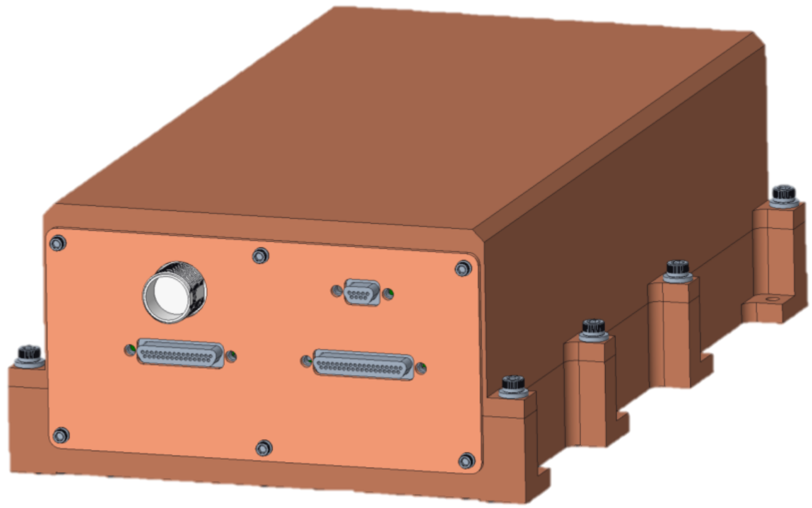

Figure 8.1-3: Power and Caging Unit

The S-GRS Size, Weight, and Power (SWaP) are detailed as follows:

- Size (ea):
  - S-GRS Head: 255.88 mm x 169.506 mm 154.940 mm
  - SACU: 220.131 mm x 251 mm x 124.910 mm
  - PCU: 234.010 mm x 144.780 mm x 80.315 mm
- Total Weight (ea): 22.5 kg
  - S-GRS Head: 8.2 kg
  - SACU: 8.0 kg
  - PACU: 2.5 kg
  - S-GRS Harnesses: 3.8 kg
- Power: 35 W nominal (each)
- Sensitivity: $<10^{-10}$ $m/s^2 / \sqrt{Hz}$

8.2 Optomechanical-Distributed instrument for Inertial sensing and Navigation (ODIN)

The Optomechanical-Distributed instrument for Inertial sensing and Navigation (ODIN) is a high-precision, low-cost secondary payload designed to complement the S-GRS by providing redundant, high-bandwidth measurements of a satellite's linear and angular motion. Unlike traditional heavy accelerometers, ODIN utilizes an array of six compact sensor subassemblies distributed across the spacecraft to capture motion in all three dimensions simultaneously.

The main elements of the ODIN include:

- *Optomechanical Sensor Array:* A distributed set of twelve sensors that use laser interferometry light to measure the motion of a mechanical mass, providing linear acceleration and angular rotation data.
- *Fused Silica Resonators:* Precision-engineered mechanical elements made of high-purity fused silica that serve as the vibrating reference for the sensors.
- *Laser Interferometer System:* A miniaturized optical system that uses laser light to track the position of the resonators with picometer-level accuracy. At the core of the interferometers, there are two 1550 nm diode lasers.
- *Electronics:* High-speed circuitry phasemeters that converts raw optical signals into digital motion data while maintaining a very low noise floor. This unit also includes a frequency offset phase-lock loop to generate a beat-note between two 1550 nm lasers. The electronics box also manages the payload data processing, timing synchronization, and streams payload data to the spacecraft bus for downlink. This unit also manages the launch locks for the 12 resonators.
- *Launch locks:* picomotors that lock the resonators during launch and prevent them from moving. The launch locks ensure the resonators and their thin flexures survive launch conditions.

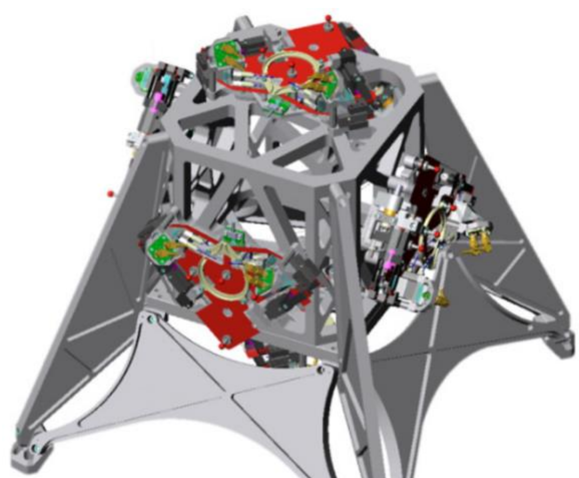

Figure 8.2-1: ODIN Optomechanical Sensor Package

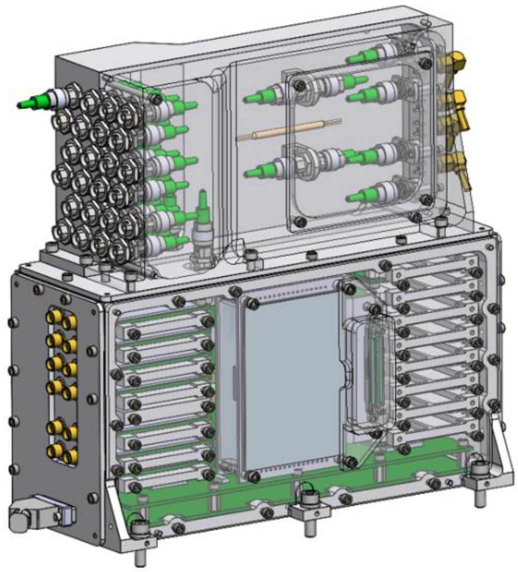

Figure 8.2-2: ODIN Electronics box

The ODIN SWaP is as follows:

- Size:
    - Optomechanical Sensor Package: 415 mm × 415 mm × 445 mm
    - Electronics box: 97 mm × 225 mm × 213 mm
- Weight: 17.29 kg
    - Optomechanical Sensor Package: 12.5 kg
    - Electronics box: 3.4 kg
    - Harness: 1.35 kg
- Power: 53.5 W
- Sensitivity:
    - Linear acceleration: 10^{-9} m/s^2/√Hz at 1 mHz
    - Angular acceleration: 2×10^{-9} rad/s^2/√Hz at 1 mHz

9 Spacecraft Description

GRATTIS utilizes the Aries commercial spacecraft bus from Apex. Aries is a standardized, ESPA-class microsatellite bus (210 kg dry mass) that is configured to host the S-GRS and ODIN payloads to meet the GRATTIS demonstration objectives. A system block diagram of the spacecraft is shown in Figure 9-1, a system block diagram of the payload suite is shown in Figure 9-2, and a graphic of the GRATTIS Spacecraft is shown in Figure 9-3.

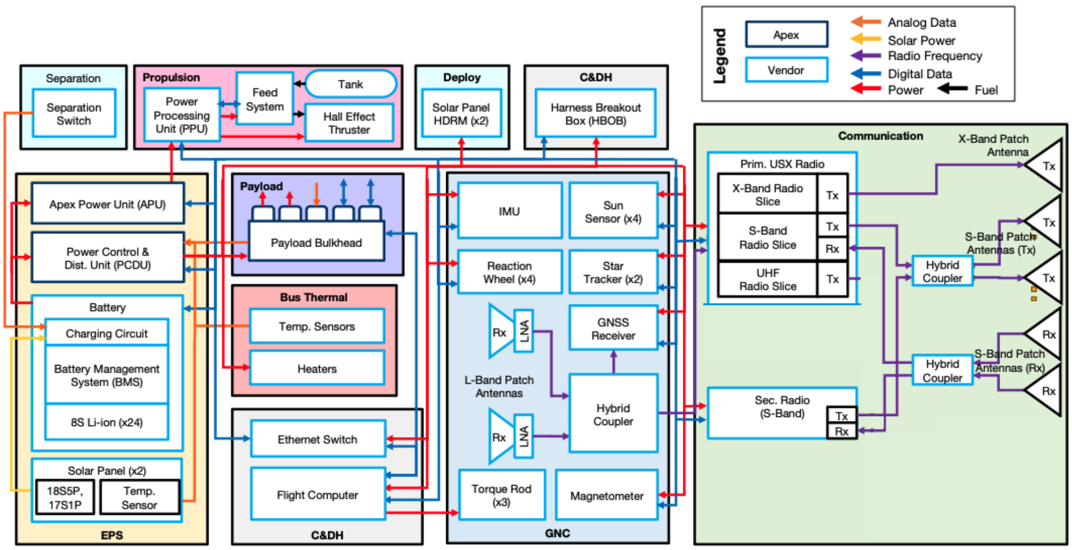

Figure 9-1 GRATTIS spacecraft bus block diagram

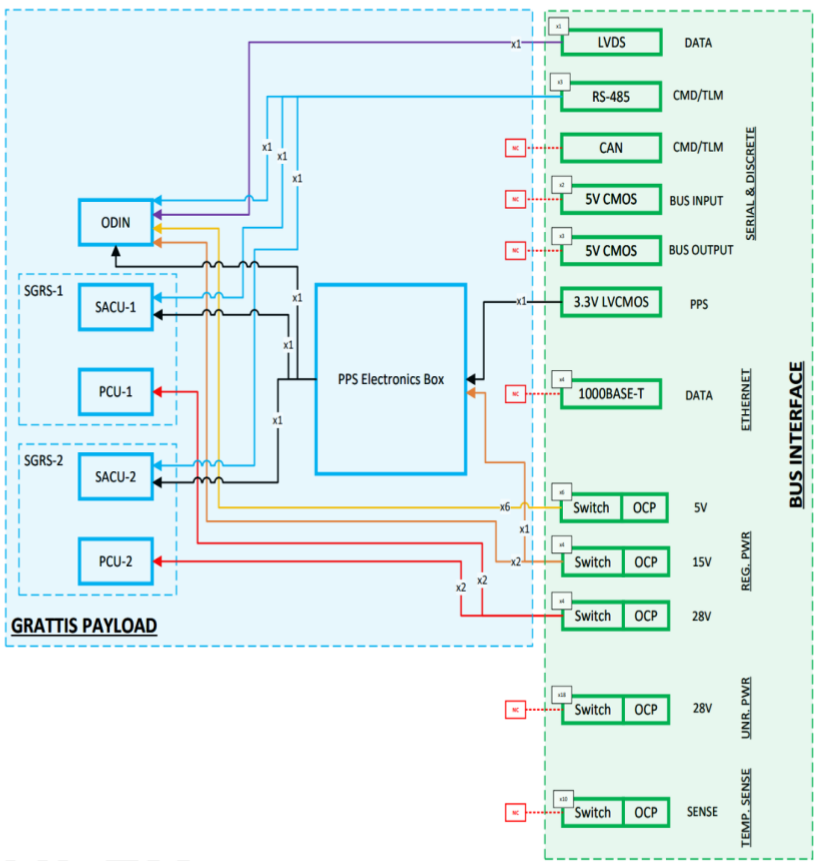

Figure 9-2: GRATTIS payload block diagram

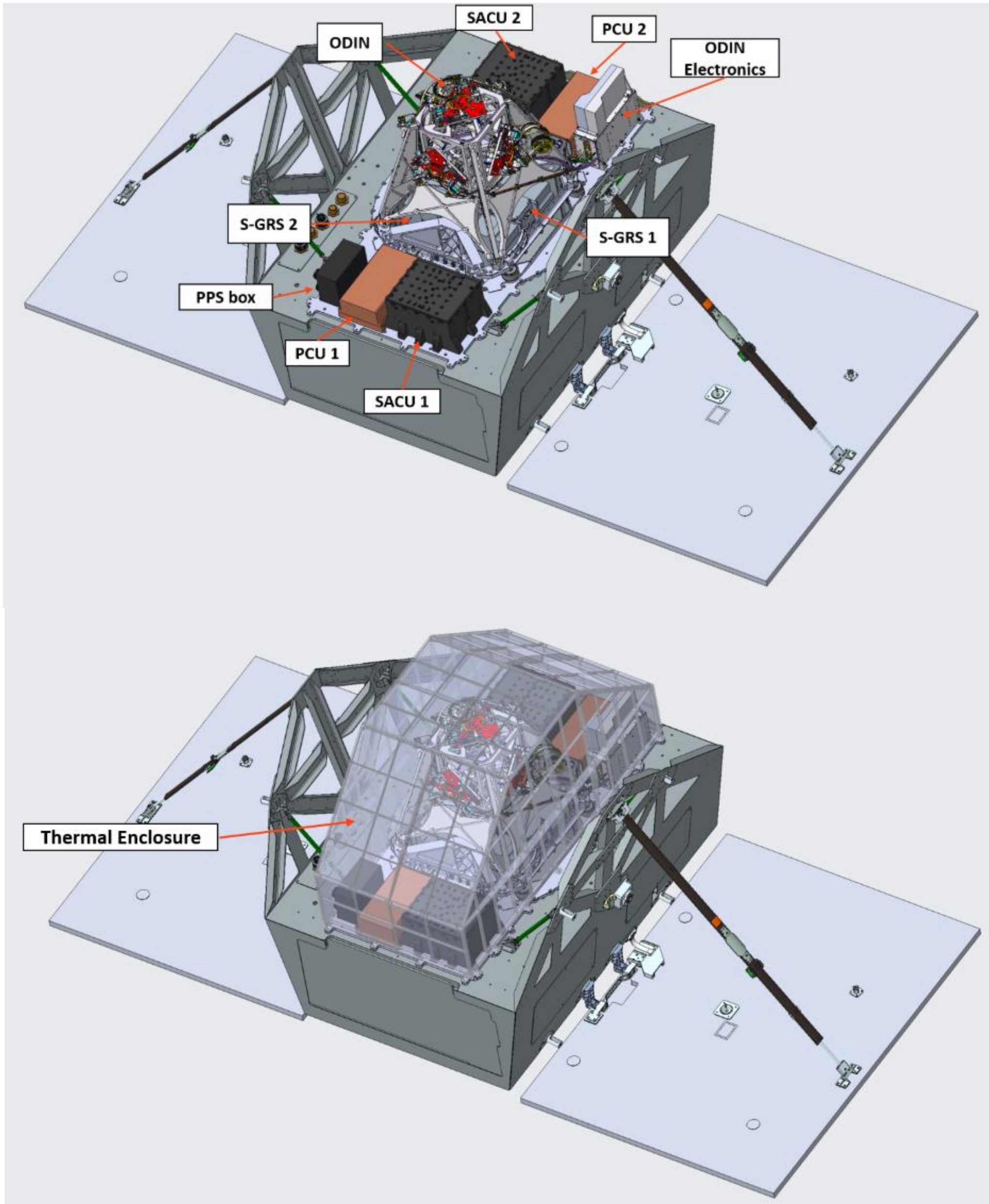

Figure 9-3: GRATTIS spacecraft in a deployed configuration. (Top) Payloads shown on the top deck of the spacecraft. (Bottom) Payloads shown with thermal enclosure.

9.1 Command & Data Handling

The spacecraft (SC) bus avionics system is a distributed architecture where multiple SC functions are handled on three main components: 1) Flight Computer, 2) Battery Assembly, and 3) Power Control and Distribution Unit (PCDU).

The Flight Computer provides command and data handling, SC timing, and payload data capture, storage and downlink. It also provides SC attitude knowledge and pointing control. The Battery Assembly is the SC power storage component and works in conjunction with the PCDU and solar arrays to power the SC. The PCDU distributes power to all SC bus and payloads, along with monitoring and controlling the spacecraft thermal control system.

The Flight Computer is based off a multi-processor System on a Chip (SoC) that is constantly monitored via triplicated logic residing on a radiation qualified Field Programmable Gate array (FPGA). Both the SoC and FPGA are housed on a single board computer which contains 4GB of volatile program memory, 128GB of non-volatile mass data storage NAND Flash, and multiple 256KB of NOR boot memory. The SC Flight Software (FSW) is a configurable and modular system that runs on an embedded Linux platform. The FSW is based largely on MAX FSW, an existing framework with heritage across multiple Buses and mission types.

Commanding and controlling the GRATTIS payloads is achieved through file uploads from the SC Flight Computer to each of the Payloads. For file uploads, each file will contain a complete set of commands in the exact order to execute a specific operation. This approach ensures precise and reliable command execution.

9.2 Guidance and Navigation Control System

The SC GNC subsystem utilizes a suite of sensors and actuators that allow for 3-axis pointing and and momentum management. Sensors include two (2) star trackers, four (4) sun sensors, one (1) triaxial magnetometer, and (1) gyroscope. Actuators include four (4) reaction wheels, and three (3) magnetic torque rods. The magnetic torque rods are used to desaturate the reaction wheels. The SC consists of a Global Positioning System (GPS) system to provide time, position, velocity, and acceleration.

9.3 Communications System

As stated prior, the communication subsystem contains a primary Anysignal USX radio that covers 2 frequencies (S-Band, and X-Band) and a block-redundant Satlab SRS S-Band radio. A block diagram of the GRATTIS communication system is shown in Figure 9.3-1.

S-band is used for TT&C to maintain satellite health and status as well as provide sequences for on-orbit activities. S-band is the primary uplink path to the satellite. X-band is used for payload data and is only for high data rate downlink to the ground. S-band is fully redundant with two TX/RX antennas and hybrid couplers that cross-strap these to two sets of S-band TX and RX radio slices.

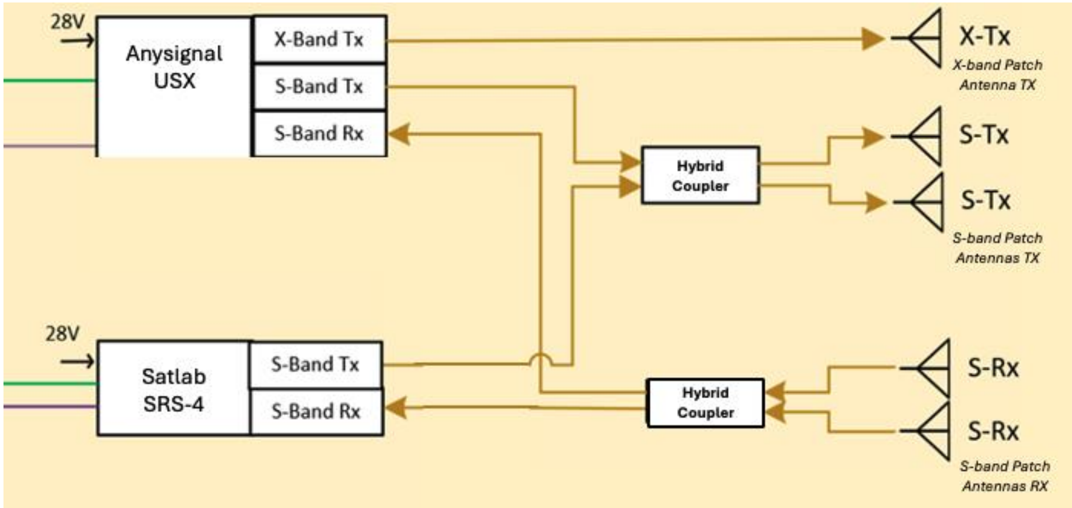

Figure 9.3-1: Communication Subsystem Block Diagram

A summary of the Anysignal USX and Satlab SRS-4 Radios is shown in the tables below.

Table 9.3-1: Anysignal USX Radio Specifications

	S-band	X-band
Transmitter		
Frequency	2200-2290 MHz	8025-8500 MHz
RF Output Power	32 dBm	32 dBm
Bit Rates	10 kbps –2 Mbps	1-125 Mbps
FEC	RS, conv code	LDPC/BCH
Modulations	BPSK, QPSK	DVB-S2 (BPSK, QPSK, 8PSK, 16APSK, 32 APSK)
Receiver		
Frequency	2025-2110 MHz	-
Bit Rates	Up to 2 Mbps	-
Modulations	BPSK, QPSK, OQPSK	-
Noise Figure	2.5 dB	-

Table 9.3-1: Satlab SRS-4 Radio Specifications

	S-band
Transmit	
Frequency	2200 – 2290 MHz
Modulation	BPSK, QPSK, 8PSK
Transmit Power	2W
Receive	
Frequency	2025-2110 MHz
Modulation	BPSK/QPSK
Sensitivity	-122 dBm

Figure 9.3-1, 9.3-2, and 9.3-3, detail the SC antennae and locations on the spacecraft bus, listed below:

- S-Band antenna (TX/RX) on the -Y face
- S-Band antenna (TX/RX) on the +Y face
- X-Band antennas (TX) on the +Y face
- UHF antenna (TX/RX) on the +Z face
- UHF antenna (TX/RX) on the -Z face

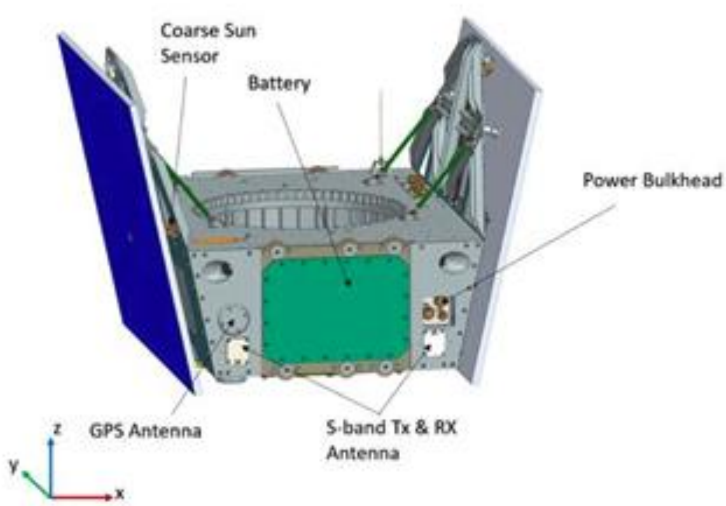

Figure 9.3-2: Antennae on SC -Y Face

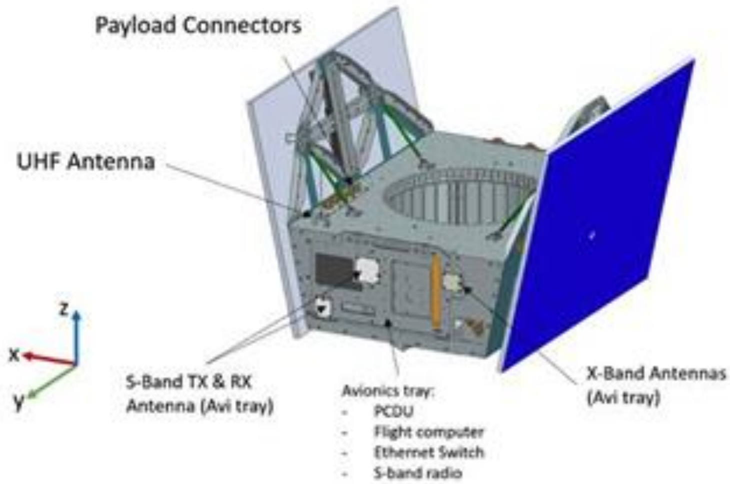

Figure 9.3-3: Antennae on SC +Y Face

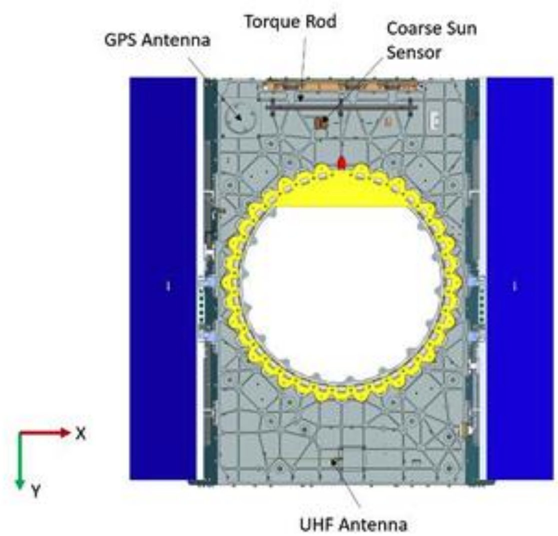

Figure 9.3-4: Antennae on SC -Z Face

The University of Florida Mission Operations team will leverage Leaf Space's global network of commercial ground stations. Utilizing Leaf Space's automated scheduling and multi-band antenna infrastructure will allow the team to maximize data downlinks and maintain reliable, low-latency communication with the spacecraft throughout the life of the mission.

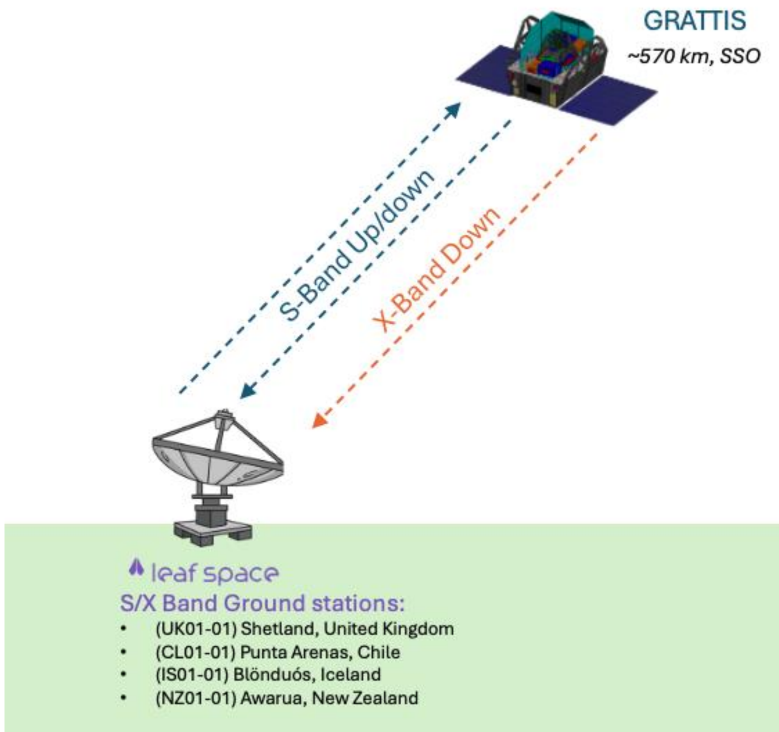

Figure 9.3-5: GRATTIS Space-Ground Link Diagram

9.4 EPS

The SC power system bus consists of two (2) solar arrays, a battery and a Power Control and Distribution Unit (PCDU). The battery module consists of 160 Li-ion LG INR18650 MJ1 lithium salt batteries in a 20 parallel – 8 series configuration. The battery capacity is 1680 Whrs, and designed not to exceed a 20% depth of discharge (DOD) during nominal operations to maximize lifetime performance. Each 8 cell module is charged and sensed independently with a dedicated charger and Battery Management System (BMS). The battery has a 24 hr watchdog timer capable of power cycling the bus triggered by loss of communication between the Flight Computer and the battery controller. The also battery has integrated charging and MPPT. The battery has inhibits, and a FDIR (Fault Detection, Isolation, and Recovery), UVLO (Undervoltage Lockout), OVLO (Overvoltage Lockout), and Thermal Runaway Protections.

The solar array utilizes a flight-proven design from Space Tech GmbH (STI) featuring triple-junction Gallium Arsenide solar cells (CTJLC half-pipe), with layout 18s5p+17s1p. Each solar array wing (2 total) consists of 113 triple-junction Gallium Arsenide solar cells, in a CTJ30 large form factor. The efficiency of each cell is 29.5% at AMO at 25 degrees C. The solar panels are a composite honeycomb structure.

Deployment of each solar array is mechanically and electrically independent but are actuated automatically in a sequential manner during the separation sequence upon boot up. Three components enable the deployment motion of each solar array: hold down release mechanism (HDRM), hinge, strut. The HDRM has burn-wire that when sufficiently powered, will release the solar array to move freely about the hinge-line. As the solar array deploys, the strut will extend until it reaches the end of motion. The hinge does not have a locking mechanism; instead, the strut will passively lock in place as shown when it reaches the end of motion. The stowed and deployed solar array wing configurations are shown below.

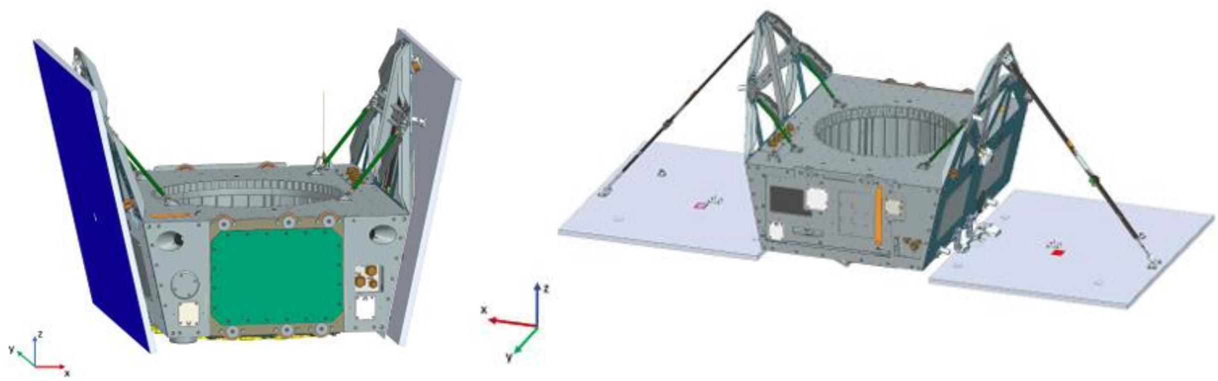

Figure 9.4-1: SC solar array stowed (left) and deployed (right) configurations

9.5 Propulsion

GRATTIS will utilize a propulsion system sized to reduce the SC altitude and re-enter per FCC guidelines (<5 years). The SC electric propulsion system consists of a Exoterra Iris 250 Hall-Effect Thruster (HET), Power Processing Unit (PPU), Valve Control Unit (VCU), Propellant Distribution System (PDS), propellant tank, and Xenon as Fuel. A block Diagram of the Prop system is shown below.

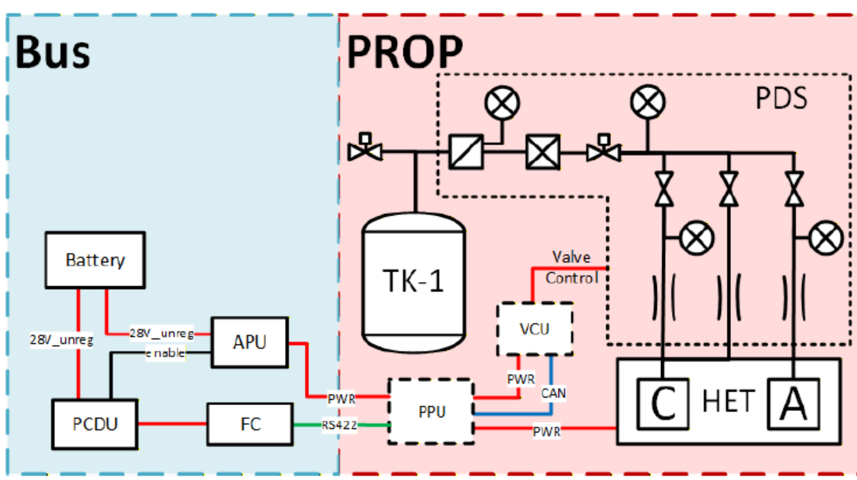

Figure 9.5-1: Propulsion Block Diagram

The thruster is designed to operate in a power range of 350-400W at the thruster input but is limited to 380W due to PPU setpoints. The thruster magnetic circuit has been specifically optimized for extended lifetime operating on Xenon, and the truster is not throttle-able. The system uses instant start, center mounted cathode. The Thruster has been qualified to 400 kN-s (~5000 hours). The propulsion is located in the center-body -Z face of the SC, shown below.

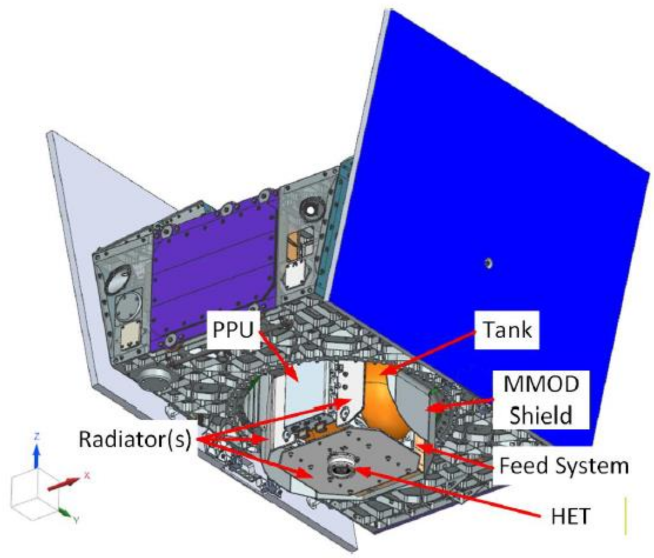

Figure 9.5-2: SC view detailing propulsion system

9.6 Structures

The SC bus primary structure is engineered for efficient load distribution through three core components shown in Figure 9.6-1:

- *Base Deck:* Houses the majority of the Apex bus components and subsystems.
- *Center Cylinder:* Acts as the primary structural bridge between the base and top decks; its 24-inch bolt pattern aligns directly with the separation mechanism to provide a streamlined load path to the launch vehicle.
- *Top Deck:* This surface is primarily reserved for mounting the GRATTIS mission instruments, shown in Figure 17.

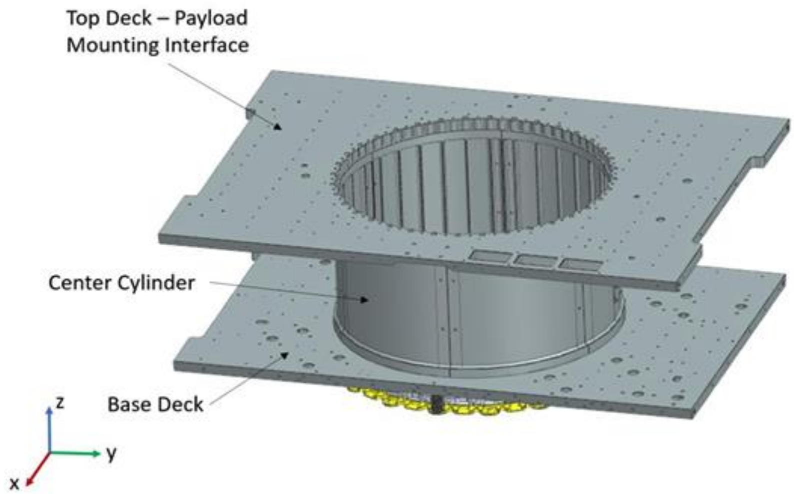

Figure 9.6-1: SC Primary Structure

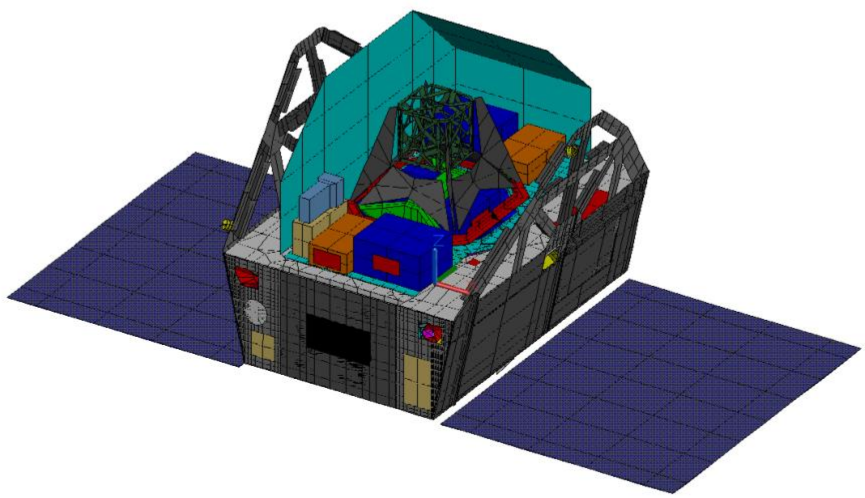

Figure 9.6-2: S-GRS & ODIN Payload Suite on SC Top Deck

The SC utilizes a standard Full XL Plate launch vehicle interface integrated with a 24-inch Rocket Lab Lightband separation system, ensuring a reliable and low-shock release into its target operational orbit.

9.7 Thermal

The SC bus features a thermal control subsystem designed to keep all bus and payload components within the allowable flight temperatures. Components are temperature controlled passively using Multi-Layer Insulation (MLI) and radiators. The SC PCDU also controls up to 12 active heater circuits for the Payload. These can be used for survival heating (when most avionics are turned off) and operational heating (to keep Payload within allowable temperature range during operation).

10 Summary

This document has provided a comprehensive narrative for the GRATTIS technology demonstration, detailing the background, organization, spacecraft owner/operator, test objectives, launch & orbital parameters, spacecraft architecture, key technologies, and concept of operations.