NASA CSLI Application

In Response to Solicitation NNH23ZCF001

OSPREY
Ocean Satellite for Plastic Research & Environmental Yield

Lehigh University's First CubeSat

Table of Contents

Mission Parameters, Details, Points of Contact

OSPREY Mission Parameters								
Mission Name	Mass (Kg)	Size	Desired Orbit		Acceptable Orbit Range	400 km @ 51.6 deg Acceptable?	Readiness Date	Desired Mission Life
OSPREY	3.013	3U	Altitude	450 km	390 - 500 km	Yes	Mar. 2026	2 Years
			Inclination	45 deg	45 - 75 deg			

OSPREY Project Details						
Focus Area	Student Involvement	NASA Funding		Sponsoring Organization (s)	Collaborating Organization (s)	
		Yes or No	Organization		List	International
Science	Yes	No	N/A	Yes	None	No

Abstract

OSPREY is a 3U CubeSat proposal developed by the Lehigh University Space Initiative, a student-run club with projects in astronautical engineering and robotics. The Lehigh University Space Initiative has developed a proposal for a 3U CubeSat to study the toxicity, density, type, and variance across garbage patches to inform scientific, environmental, and wildlife preservation decisions.

OSPREY will capture spectral data to classify the presence of plastics floating in the ocean. The mission's primary objective is to provide spectral data for estimating the concentration and distribution of plastic waste, as well as its potential impact on marine ecosystems and wildlife. OSPREY's data will be instrumental for environmental agencies and conservation, facilitating informed decisions to mitigate the adverse effects of oceanic plastic pollution.

Ocean plastics have been aggregating in waters around the globe at a rapidly accelerating rate and as such pose an increasing threat to wildlife, human health, and the economy. Due to their ubiquity in the environment, such plastics are consumed at high rates by marine life (making up as much as 74% of their diet in some cases (cite the Ocean Cleanup here)). The presence of toxic chemicals associated with ocean plastics, such as PBT's and plasticizers, are also likely to pose a threat to marine and human life.

The current methods for monitoring marine plastic pollution rely on a combination of shipborne surveys, aerial reconnaissance, and manual sampling, which are labor-intensive and limited in scope. Additionally, current attempts to monitor marine plastics from space are limited by spatial resolution, which typically only reaches 10m.

OSPREY's mission embarks in a context where tracking ocean plastics remains a significant challenge. The proposal describes a 3U CubeSat Satellite that will record the presence of ocean plastics by using the Normalized Difference Vegetation Index. The data collected will also serve as a basis for advanced machine learning models to further classify marine debris and pollution.

OPREY will be equipped with a capable imager to accomplish its scientific goals: the HyperScape100. The 1.5U camera is optimized for CubeSats and has a GSD of 4.75m and coverage in the VNIR spectral range, meeting the scientific requirements for detecting ocean plastics from space.

Proposal Details

Primary Mission

Primary Mission Statement

OSPREY has the primary goal of studying the density, type, and variance of garbage and plastic patches to inform scientific, environmental, and wildlife preservation decisions**.** OSPREY will capture spectral data to classify the presence of plastics floating in the ocean. OSPREY will target the sources of ocean plastics, including the mouths of large rivers and coastal cities.

The Current State of Tracking Ocean Plastics

The current state of ocean plastic tracking predominantly relies on methodologies like trawler expeditions and aircraft flyovers. These methods, although crucial in enhancing our knowledge, have introduced significant uncertainties and limitations due to their reliance on statistical approximations and the vast scale of ocean garbage patches. The potential for using affordable CubeSat platforms could provide the ability to provide extensive, continuous, and more accurate data coverage. This approach is particularly promising for observing and detecting plastics by capturing specific wavelengths within the Visible Near-Infrared (VNIR) spectral regions.

The Science of Detecting Ocean Plastics from Space

The primary method of detecting ocean plastics from space involves utilizing spectral data to generate indices that can classify different materials based on their unique reflectance properties. The Normalized Difference Vegetation Index (NDVI) is one of the most widely used indices with applications for analyzing a multitude of materials from space. The NDVI is a measure of vegetation health in a region based on the reflectivity of NIR and red light, and is calculated using these two wavelengths with the following formula: NDVI=(NIR−Red)/(NIR+Red)

This formula results in values ranging from -1 to +1. NDVI values closer to +1 indicate healthier and denser vegetation, while values closer to -1 typically indicate non-vegetated surfaces like water, rocks, or barren land. Ocean plastics can be classified by NDVI due to their unique spectral reflectance signatures.

$$NDVI = \frac{(R_{rs,NIR} - R_{rs,RED})}{(R_{rs,NIR} + R_{rs,RED})}$$

Equation 1

Many studies on ocean plastics from space have used spectral data from satellites to generate NDVI measurements. Much of the spectral data used for studying ocean plastics comes from the Multispectral Instrument (MSI) onboard Sentinel-2 (1) and the Landsat mission. The NDVI is an important parameter in characterizing ocean plastics from space.

Potential Application for Studying Ocean Toxicity

The presence of persistent bioaccumulative toxins (PBTs) in ocean plastics is a well-documented phenomenon and has been shown to exist in concentrations high enough to threaten animal life and impact human health once transferred through bioaccumulation (6, 7, 8, 9). Given this, tracking the presence of such chemicals becomes extremely valuable in the pursuit of better informing food chain protection efforts. While identifying and tracking the aforementioned toxins from space using spectroscopy is an under-studied area of research, there is a surplus of documentation for similar efforts in labs on the ground. OSPREY is equipped with the potential to effectively fill this deficit in research. The HyperScape 100 onboard is prepared to provide 4.5m in GSD (or less at OSPREY's intended orbit) and will provide extremely high-resolution spectral image data. When combined with algorithms akin to the Fourier Transform, the chemical constituents of OSPREY's data can be deciphered and cross-referenced with spectral databases to reveal either the presence of specific toxins that have leached into the water or simply the types of plastics in the sample. If only the plastic type can be discerned, OSPREY can then leverage previous research which establishes a clear connection between certain types of plastics and the presence of various toxins (7, 8, 9). The plastics in the PVC, PUR, and PLA families as well as phthalates (and plasticizers like them) have been documented by the above research to induce the highest toxic responses from living organisms and, further, have been marked by the Endocrine society as most threatening to human hormonal and developmental function (8). Once OSPREY can identify any such chemicals a direct assertion can be made about the toxicity induced in the environment by these plastics.

Potential Application for Studying Harmful Algal Blooms

OSPREY is equipped with hyperspectral imaging capabilities that extend beyond the detection and analysis of oceanic plastic pollution to include the crucial environmental task of monitoring harmful algal blooms (HABs). This secondary application aims to utilize advanced remote sensing techniques to observe, categorize, and analyze the occurrence of algal blooms in coastal and offshore waters. Through the precise measurement of chlorophyll-a (chl-a) concentrations and other key water quality indicators, OSPREY will provide valuable data that is essential for understanding the ecological impacts of algal blooms, aiding in mitigation efforts, and ensuring the safety of aquatic ecosystems and human health.

Detecting Algal Blooms from Space with OSPREY

In the context of the OSPREY CubeSat mission, detecting algal blooms from space becomes a feasible and critical environmental monitoring application. Leveraging the Visible and Near-Infrared (VNIR) spectral range of its hyperspectral imaging system, OSPREY is uniquely positioned to monitor and analyze harmful algal blooms (HABs) in coastal and offshore waters. Key to this capability is the use of several spectral indices, such as the Normalized Difference Chlorophyll Index (NDCI), which is a spectral index akin to the well-known NDVI.

OSPREY's hyperspectral imager, the HyperScape100, is capable of capturing detailed spectral data across the VNIR range, allowing for the precise identification of chlorophyll-a (chl-a) concentrations—a primary indicator of algal bloom presence. The NDCI utilizes specific spectral bands within the VNIR range to accurately detect algal blooms, even in turbid and productive waters where blooms are most prevalent. By focusing on bands at 665 nm (red) and 708 nm (red-edge), OSPREY can effectively map and monitor the spatial and temporal distribution of algal blooms, circumventing the influence of confounding factors like colored dissolved organic matter (CDOM) and total suspended solids (TSS).

Project Organization

OSPREY is a project being developed by the Lehigh University Space Initiative, a student-run organization that specializes in projects in astronautics and robotics with over 30+ active members. OSPREY is developed entirely by students enrolled in various engineering disciplines.

Development is led by a systems engineer who is responsible for integrating all subsystems, and specifies the system-level requirements. There is also a deputy systems engineer who coordinates with each subsystem to make sure that the system-level requirements are met.

Each subsystem has its own lead. There are seven subsystems for: Primary Scientific Payload, Structures, Avionics, Attitude Determination and Control System, Communication Systems, Power, and Ground Station. Within the team there are 7 members who are each responsible for their own subsystem, as well as one systems engineer and deputy systems engineer. Tabulated below are the team leads of each subsystem.

Member	Role(s)
Zemikael Gebeyehu	Lead Systems Engineer & Project Manager
Mikael Asfaw	Payload Lead & Deputy Systems Engineer
Nathaniel Dudko	Communications Systems Lead
Jack Smiley	Power Systems Lead
Harrison Jenkins	ADCS Lead
Martin Wu	Avionics Lead
Abylaikhan Mujhamejanov	Structures Lead
Courtney Baker	Ground Station Lead

Table 1: Staffing and Organizational Breakdown

CSLI Applicability

OSPREY's overall mission fits well within both NASA's overall organization objectives and the agency's 2022 strategic plan. More specifically, OSPREY holds true the goal of observing and analyzing ocean plastics and their impacts on the world around us, offering significant data for both NASA and the worldwide scientific community.

Firstly, strategic objective 1.1 states that "Only from space can we make the observations of the complex Earth system that can illuminate connections between short and long time scales, fine and global spatial scales, and chemical, physical, and biological processes." OSPREY's mission seeks to expand this, using high resolution and extremely high quality imaging tools to image the Earth and analyze the presence of ocean plastics, considering where they are, their motion over time, and their concentration in different parts of the world. Additionally, objective 1.1 addresses the fact that NASA aims to "understand, model, monitor, and ultimately predict climate and environmental change." The effects of ocean plastic and water pollution on maritime climates are well documented, and are a significant part of understanding climate change throughout the world.

Secondly, strategic objective 1.3 covers NASA's agency-wide goals to enable and provide more open access to data and information which can be used to better and improve the world as a whole. OSPREY's mission will focus on the areas of the world most affected by ocean pollution, specifically plastic pollution, with the overarching goal of being able to consider, diagnose, and eventually predict, the causes and consequences of widespread distribution of ocean plastics. As such, OSPREY's mission would be a notable support to this strategic goal, as the primary goals are to help those groups who have experienced the worst and most long-term effects of large scale ocean pollution and the destruction of maritime ecosystems which comes with it.

Finally, strategic objective 4.3 addresses NASA's desire as an agency to support STEM education, and create more opportunities for younger students to become more involved with projects and events happening in the fields of space and space exploration. While it is somewhat self-explanatory, LUSI is entirely student run, and every element of OSPREY's mission has been student-selected and/or student-designed. Furthermore, every aspect of the LUSI program is student run and student managed. As such, OSPREY offers a unique opportunity to connect a student group with the opportunities that can only be provided by organizations like NASA, and by doing so, help bring even more students into the work done by NASA to advance our understanding of the world, and the greater universe, around us.

Compliance Requirements

The OSPREY design fully adheres to the following standards and specifications:

- CubeSat Design Specification REV 14.1 CP-CDS-R14.1

The 3U CubeSat structure, supplied by EnduroSat, is a NASA-recognized module lauded for its lightweight, sturdy design. The specifications are as follows: Dimensions: Fits the 3U CubeSat criteria with a size of 100x100x340.5 mm according to CubeSat Design Specification Rev. 14.

It also has been tested and verified for launch conditions, following the ESA standard ECSS-E-ST-10-03C and GEVS: GSFC-STD-7000A, ensuring its resilience and reliability through qualification tests on the Engineering Model.

- NanoRacks CubeSat Deployer (NRCSD) Interface Definition Document (IDD)

All the components (UHF transceiver, hyperspectral VNIR imaging system, integrated ADCS, On-board Computer (OBC), and 4-pack modular electrical power system (IMEPS)) are COTS and certified for a launch. OSPREY satellite fully satisfies all of the requirements of NRCSD: Structural and Mechanical Systems Interface Requirements, Electrical System Interface Requirements, Environmental Interface Requirements, Safety Requirements, Jettison Requirements, and Documentation Requirements.

- Launch Services Program Level Dispenser CubeSat Requirements Document (LSP-REQ-317.01 B)

For the OSPREY project, the development timeline includes a series of environmental tests. These tests are planned in alignment with the Launch Services Program Requirements Document (LSP-REQ-317.01).

- Radio Frequency (RF) Licensing by International Amateur Radio Union

In our licensing process, we will engage with the International Amateur Radio Union (IARU) for radio frequency coordination, a critical step for obtaining our satellite's frequency assignment. This collaboration involves submitting a detailed frequency coordination request to the IARU, ensuring our satellite's compliance with international frequency allocation standards and avoiding interference with other satellite communications. The IARU's response, a coordination letter, will be a key component in our subsequent FCC licensing application, outlining the specific frequency band allocated to our satellite.

Development Schedule

OSPREY progress is managed on a weekly basis, with a routine status meeting held every week and if required a second meeting. Currently, the project management timeline being used is a Gantt Chart that tracks the OSPREY's progression and production plan. Planning and designing of the The Gantt Chart considers time for testing of the electronics using a testbed and environmental testing on flight hardware. On the current schedule, OSPREY is scheduled for launch in fall of 2026. Even though the official proposal writing and detail design started at the beginning of 2023, the CubeSat development has been in progress since the start of the club back in fall 2021. LUSI will be able to complete fully detailed design by the end of fall 2024 for Critical Design Review (CDR). Launch-ready CubeSat will be assembled and tested in the Spring Semester of 2025, after a successful CDR. This will conclude with flight-ready CubeSat being ready for launch by November of 2026. The proposed lifetime of OSPREY is 2 years. With in this mission duration, the Hyperscape imaging system will campture various multi-spectral images from Low Earth Orbit (LEO).

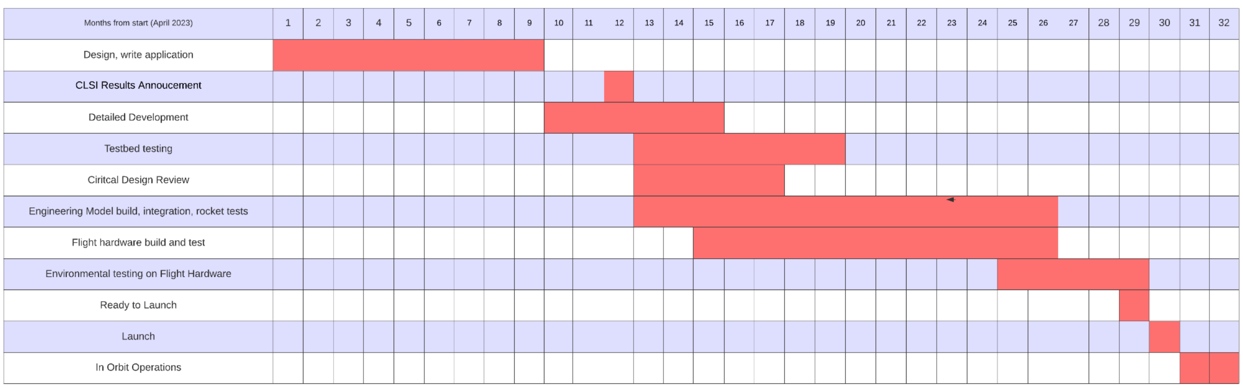

Table 2: OSPREY Development Timeline

Additional Documents

Technical Details: Primary Scientific Payload

The specifications for OSPREY's payload are driven by the scientific requirements for detecting ocean plastics from space. Two key parameters have been deemed the most important in OSPREY's payload selection: the Ground Sample Distance (GSD) and the spectral range. The ground sample distance refers to the distance between the centers of two consecutive pixels measured on the ground. Based on these parameters, and form-factor, the 1.5 U HyperSpace100 VNIR Camera was deemed as the best-fit for the mission requirements.

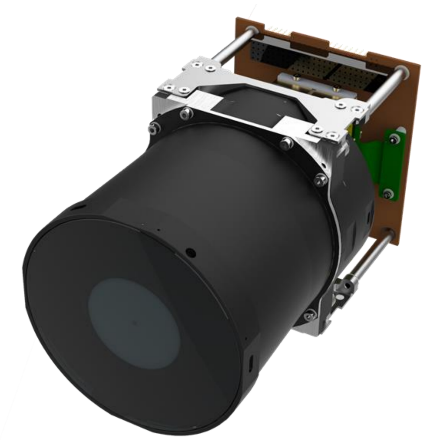

Figure 1: Simera Sense Hyperscae 100 Imager

The HyperScape100 features a CMOS image sensor and a custom continuously variable optical filter in the visible and near-infrared (VNIR) spectral range. The device is capable of line-scan imaging in up to 32 spectral bands, each with digital time delay integration (dTDI), and offers a panchromatic band along with over 1000 hyperspectral bands. These bands have central frequencies ranging from 442 nm to 884 nm. The HyperScape100's optical front-end (OFE) is designed to provide a ground sampling distance (GSD) of 4.75 m at an orbital height of 500 km. It is engineered to maintain performance across a wide temperature range and is optimized for integration into 3U or larger CubeSat structures

Scientific & Payload Requirements

The hyperspectral capabilities of the HyperScape100 meet the scientific requirements for tracking ocean plastics from space. It is possible to track ocean plastics by using a Normalized Difference Vegetation Index, which is a measure of vegetation health in a region based on the reflectivity of NIR and red light. The HyperScape100 can capture 32 spectral bands within a spectral range of 442-884 nm, which includes the NIR and red spectral bands needed for NDVI. Below is the equation used to calculate NDVI as well as the classification of material types by only using NDVI as developed by Beirman et al.

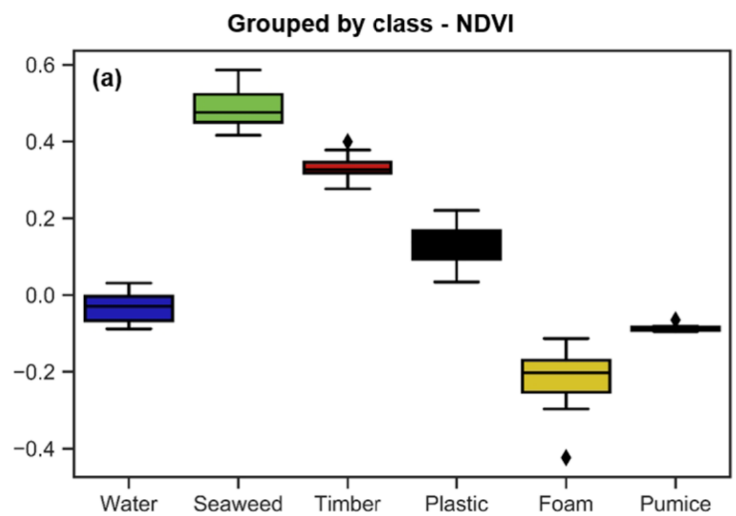

Figure 2: NDVI Classification of Floating Debris (Bierman et al.)

Spatial Resolution Requirements

Many studies investigating ocean plastics from space use spectral data from the Multispectral Instrument (MSI) aboard the Sentinel-2 satellite, and spectral data from the Landsat Mission. In each of these missions, the spatial resolution was limited to 10m. The HyperScape100 boasts a GSD of 4.75m from an altitude of 500 km, meeting the requirement for producing high-quality data to study ocean plastics from LEO.

Payload Integration with OSPREY

The payload must integrate with the rest of the OSPREY's requirements in mass, size, power, ADCS, onboard data-handling, and communication. The HyperScape100 has a form factor of 1.5U and weighs 1.1kg. It uses 2.7 to 2.9 W during idle mode, 7.0 to 7.4 W during imaging mode, and 2.7 to 2.9 W during readout mode. The camera has 128 gigabytes of storage capacity. There are several options for outputting image data, such as LDVI, SpaceWire, and USART. Control options include I2C, SPI, SpaceWire, and RS-422.

Technical Details: Structure & Mass Budget

Internal & External Geometry

OSPREY includes a 3U CubeSat structure with 4 non-deployable solar panel patches and a deployable antenna array, mounted at the top of the CubeSat. Internal components include a UHF transceiver, hyperspectral VNIR imaging system, integrated ADCS, On-board Computer (OBC), and 4-pack modular electrical power system (IMEPS).

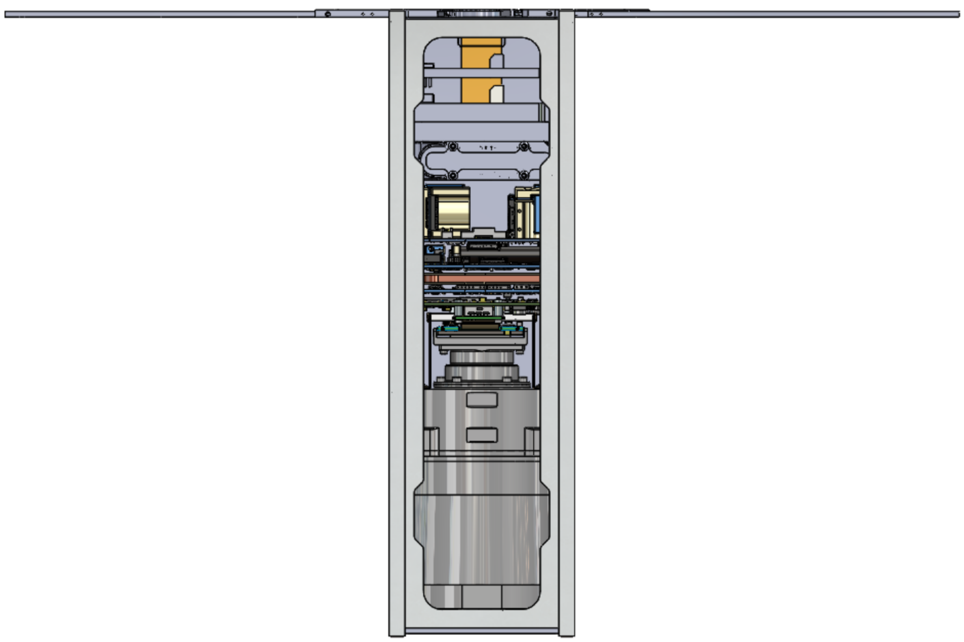

Figure 3: OSPREY Internal CAD

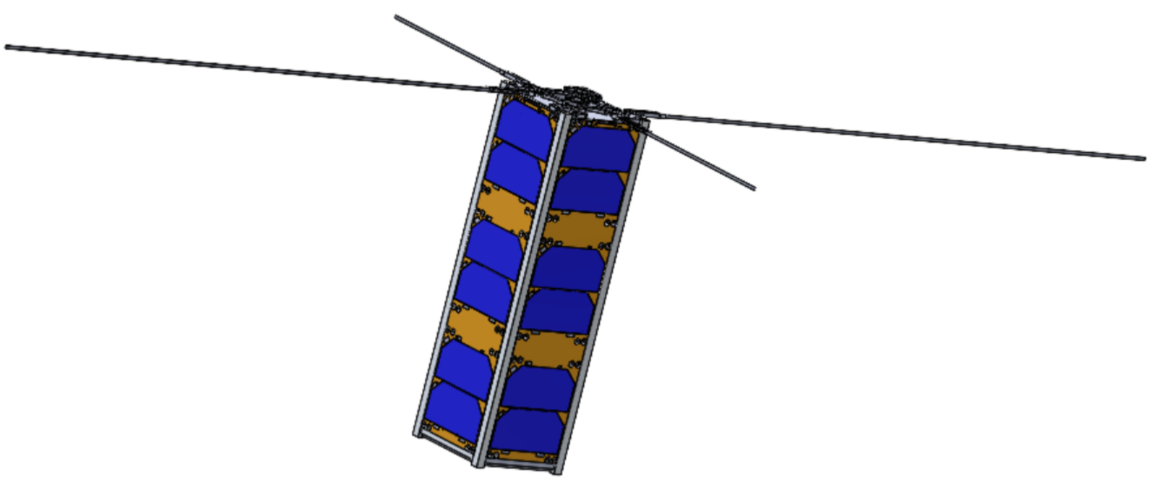

Figure 4: OSPREY External CAD

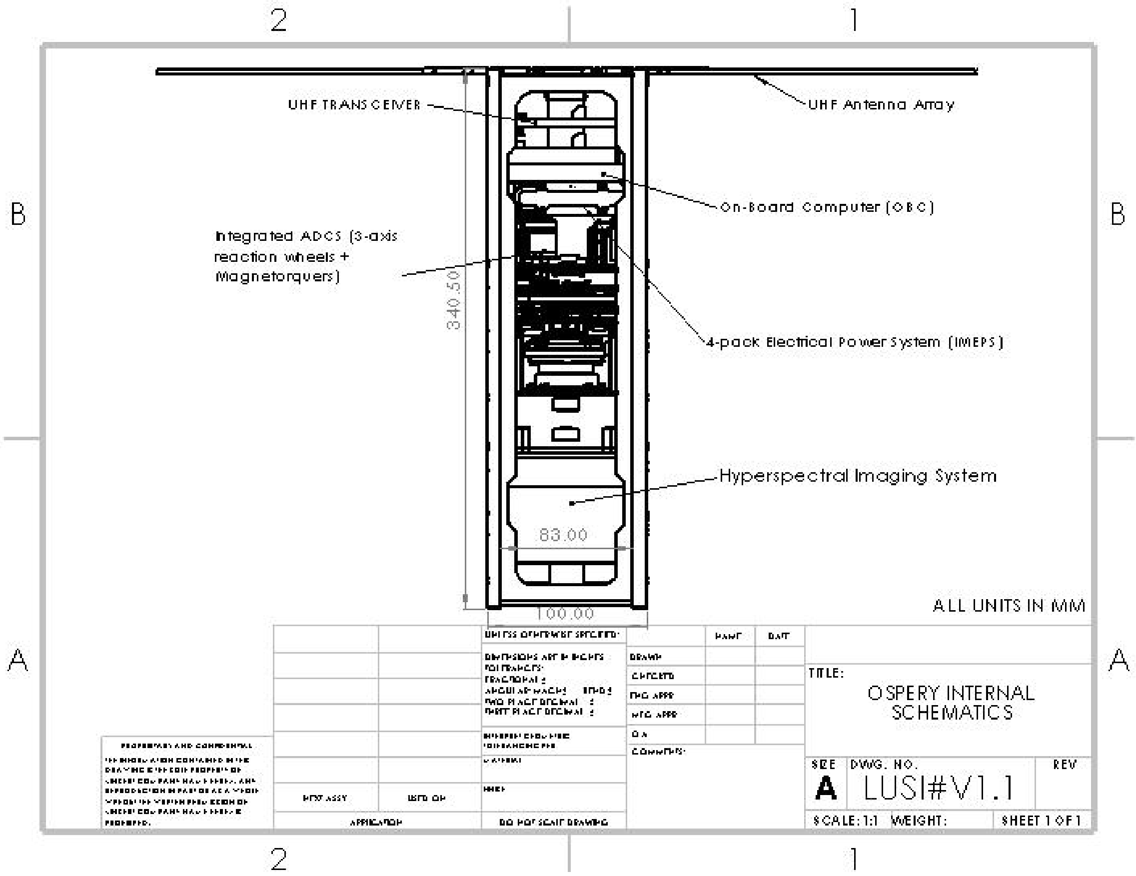

Figure 5: OSPREY Internal Schematics

Figure 6: EnduroSat Chassis

The goal is to seamlessly incorporate the HyperScape100 optical payload into a 3U CubeSat structure. The focus is to maintain the unity of all subsystems while meeting the CubeSat design standards and physical limitations.

The 3U CubeSat structure, supplied by EnduroSat, is a NASA-recognized module lauded for its lightweight, sturdy design. The specifications are as follows:

- Dimensions: Fits the 3U CubeSat criteria with a size of 100x100x340.5 mm according to the CubeSat Design Specification Rev. 14.
- Material: Manufactured from Aluminum 6061 or 6082, chosen for their space-grade durability.
- Weight: The total mass is under 285 grams, including fasteners, assisting in keeping within the mass allowance.
- Design Features: The design is modular, sporting a pearl finish and a hard-anodized exterior, which simplifies the assembly process and allows for customization. It includes options for one or two kill switches and can accommodate two separation springs if needed.

- Standards Compliance: It aligns with the PC104 and CubeSat standards, ensuring compatibility with common deployment mechanisms.

The chosen CubeSat structure has been rigorously tested and verified for launch conditions, following the ESA standard ECSS-E-ST-10-03C and GEVS: GSFC-STD-7000A, ensuring its resilience and reliability through qualification tests on the Engineering Model.

For the integration, the HyperScape100 optical payload will occupy 1.5U of space. The arrangement of the CubeSat's internal subsystems — like the communication system, electrical power system, attitude determination and control system, and onboard computing — will be designed to maintain the CubeSat's balance and to facilitate unobstructed functioning.

OSPREY Bus	Structure	1	285	285
	Solar Panels	4	150	600
	Electrical Power System (IMEPS)	1	310	310
	Integrated ADCS (Reaction Wheels + Magnetorquer + Sun Sensor)	1	258	258
	UHF Transceiver	1	95	95
	UHF Antenna Array	1	85	85
	On-Board Computer	1	130	130
	Wiring + Fasteners	1	75	75
Payload	HyperScape 100	1	1100	1100
Miscellaneous	Contingency	-	75	75
Total Mass				**3013**

Table 3: OSPREY Mass Budget

Technical Details: Avionics

The avionics system of OSPREY encompasses a range of components, including an onboard microcontroller, memory slots, and ports designed for communications and power.

For the OSPREY project, our choice is the Endurosat OBC Type I, delivered by Endurosat. This robust system features the energy-efficient ARM Cortex M7 core processor. It draws only 0.9 watts of power, yet provides high computational capacity with a clock frequency peaking at 480 MHz, well above our system requirements while accommodating for contingency. The board offers dual UART interfaces, dual I2C interfaces, and an SPI bus, which is compatible with our imaging sensor. Furthermore, it has 2MB of Flash RAM for housekeeping data (such as programs for power usage and temperature measurements), a micro-SD slot, and 8 GB of onboard memory for additional storage requirements. With proven viability under extreme environmental conditions, such as severe space radiation, extreme thermal variations, and high G-forces, these microcontrollers have been used in numerous CubeSat missions.

The chosen operating system we plan to use is FreeRTOS, which features an embedded multitask scheduler, enabling the efficient execution of multiple independent programs, a crucial aspect when the satellite is operational. FreeRTOS's compatibility with numerous open-source IDEs, such as Visual Studio Code and Atmel Studio 7 is also another key advantage. Our coding will primarily utilize the C programming language, given its low-level nature and ease of learning, particularly for low-level programmers.

Figure 7: EnduroSat OBC Type I

In FreeROTS, we will need to program a few tasks to allow the OBC to receive and send data, while also monitoring sensor health and other crucial components.

The collection function is called when the magnetotorquer indicates that the satellite camera is pointing at the correction region. Then this function tells the camera to collect the data. The collection function will also monitor the health sensors and other components and can call the fault response function if needed.

The communications function is called when the transceiver indicates that it has received a signal from a ground station. It will then send the data collected to the ground until all of the stored data has been sent or the transceiver detects that the beacon signal has been lost, indicating that the satellite has passed out of communication range. The communications function can also monitor satellite health and can call the fault response function if needed.

Finally, the fault response function is called if any other functions detect anomalous health readings. It summons the appropriate health function, such as the "overheating" temperature function or the "excessive voltage" function.

Figure 8: EnduroSat OBC Type I

Technical Details: Attitude Determination and Control System

Attitude Control System

In order to ensure that OSPREY's mission concept can be fully realized, a precise, agile, and robust ADCS is required while balancing our various budgets (cost, mass, and power). These requirements were first specified through a series of calculations. Each calculation used the maximum stress conditions to ensure that our worst case scenario could be easily handled if the requirement was satisfied. Using this method, it was determined that our system should have no less than 1.972 mNm of torque to provide the agility required to pan between our various locations of interest (taking into account the orbital velocity of our expected orbit). Furthermore, our system is permitted to have a pointing error of no more than 1.046˚ off the intended aiming point to ensure our target locations stay fully within the swath of the NIR detector. Finally, we needed a robust and reliable system which had flight heritage to prove it was able to withstand the various physical burdens associated with our mission and thus mandated a TRL of 9.

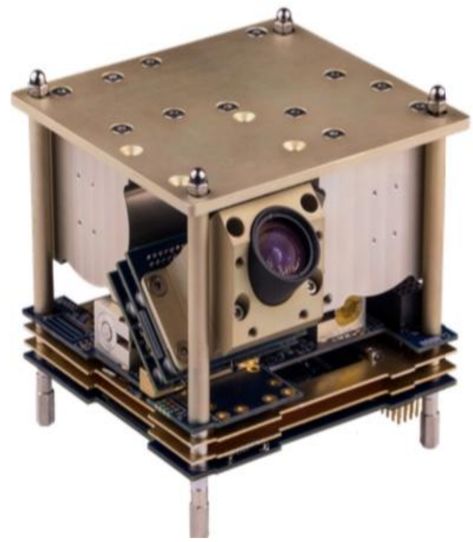

Figure 9: Gen 1 CubeADCS 3-axis with CubeSense Earth

Given the requirements laid out above, it was decided that the most apt ADCS for our mission would be the "Gen 1 CubeADCS 3-axis with CubeSense Earth" from CubeSpace. This TRL 9 system includes 3 reaction wheels each capable of producing over 4 mNm of torque which is more than sufficient to quickly pan our detector to even the furthest of target locations before we pass over it. The system also includes 3 magnetorquers (for additional stabilization, detumbling, and fine control), a radiation tolerant computer complete with all necessary software and control algorithms to operate the system, and a sun sensor which can accurately determine pointing direction to within 0.2˚.

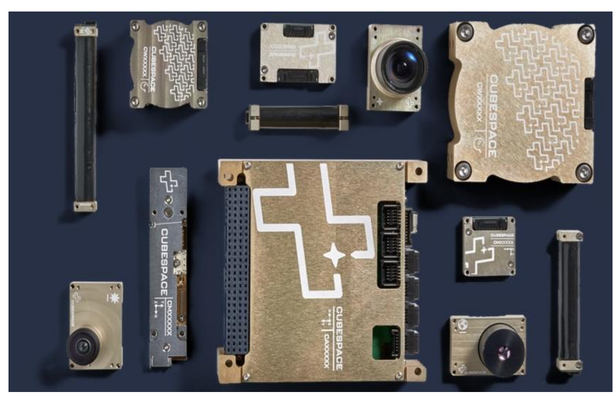

Figure 10: CubeSpace ADCS Gen II

To support the sun sensor while OSPREY is eclipsed in eclipse from the sun's light, we will add in an infrared horizon sensor which is capable of pointing accuracy to within 1˚(which satisfies even our most rigorous and conservative assumptions). Finally, this entire system has proven flight heritage, fits within 1U and will be under 1 kg, which allows room (both mass and volume) for our other systems to fit within our 3U-6kg form factor.

Technical Details: Communication Systems

The communication system will operate in the UHF. This is because of fewer regular constraints and more options for commercial communication systems. UHF will allow us to achieve the greatest potential of our mission.

We will be using EnduroSat's UHF TRANSCEIVER II for our communication with the ground Station (Fig. XX). We chose this transceiver because of the ease of use and the low power consumption and mass. The transceiver has flight heritage and was featured in Ames Research Center's State-of-the-Art report in October 2021.

The Antenna array is also from EnduroSat. Specifically, it is the UHF ANTENNA III (Fig. XX). The antenna array operates within usable amateur wavelengths and has a relatively low mass and power consumption. A circular polarization antenna was chosen because of the better reception while in orbit, and this specific antenna was chosen because of the integration with the transceiver and the triple deployment redundancy.

System	Attribute	Value
Communication Link	Frequency	435.0 MHz
	Link Margin	25 dB
	Specified B. E. R.	1.00E-05
	Demodulator Type	2GFSK
Primary Mission	Eb/No Threshold	10 dB
	BW bdf	12.0 MHz
	Bit Rate	19,200 bps
	Lp (Loss from Free Space)	120.8 dB
	Total Link Losses	138 dB
Miscellaneous	Tx Antenna Gain	24 dB
	Loss Total Line	3.81 dB
	Loss PBF	1.0 dB
	Power Tx(RF)	1 Watt
	Polarization	RHCP

Table 5: OSPREY Communication System

Figure 11: EnduroSat Transceiver II

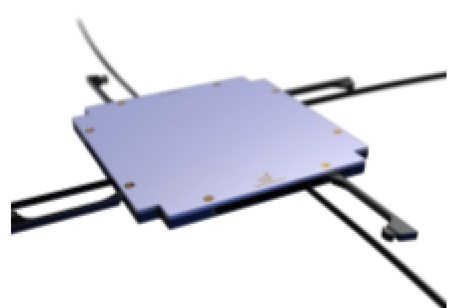

Figure 12: EnduroSat UHF Antenna III

Technical Details: Power Systems and Power Budget

The power subsystem is composed of both the ISIS Small Satellite Solar Panels and the ISIS Compact Electrical Power System. Both of these components have flight heritage and are compatible with a 3U form factor.

The solar array will consist of 4 non-deployable panels. The panels include embedded sensors that will work in conjunction with the ADCS to keep the satellite oriented for maximum power yield. The total energy supplied by these panels is 42.78 (39.215 if changed) Whr when in direct sunlight. (600g, 550 if changed)

The electrical power system (EPS) is used to provide power to all the satellite's components. It contains a maximum power point tracking system (MPPT) which monitors the energy requirements of all components at all times to ensure maximum energy efficiency. It also contains hardware and over-current protection systems to reduce the risk of component failure. The EPS is capable of providing a maximum of 45 Whr to the satellite.

Below is the satellite's estimated power budget. Each value in the Max Whr column was calculated by multiplying the component's maximum power consumption by the satellite's orbital cycle time of 1.55 hours, plus a 10% contingency. The total energy requirement of the satellite is estimated to be 33.759 Whr, but this is an overestimate, as each component will not be constantly consuming power at its maximum rate. Based on the maximum energy supply values of 45 Whr and 42.78 Whr for the EPS and solar array respectively, the power requirements of the satellite are able to be met.

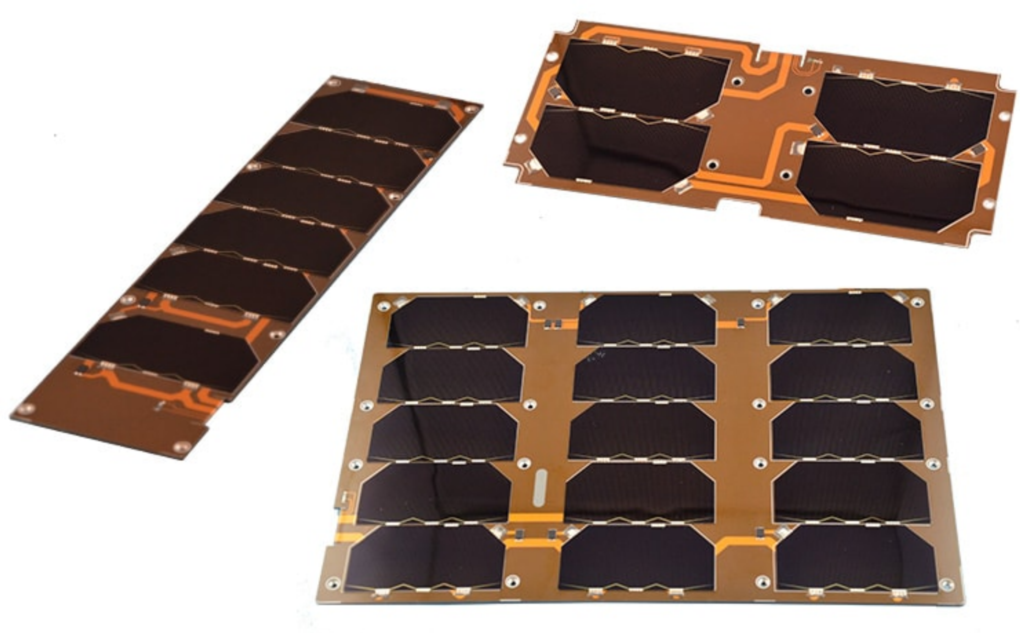

Figure 13: ISIS Space 3U Solar Panels

Power Budget

System	Component	Qty.	Max W	Max Whr	Ext. (Whr)
HawkSat-1865 General	Computer	1	5	7.75	7.75
	Reaction Wheels	4	0.2	0.31	1.24
	Magnetorquers	3	0.2	0.31	0.93
Communications Array	Antenna Array	1	2	3.1	3.1
	Duplex Transceiver	1	4	6.2	6.2
Primary Mission	Camera	1	7.4	11.47	11.47
Miscellaneous	Contingency (10%)			3.069	3.069
Total Power					33.759

Table 6: OSPREY Power Budget

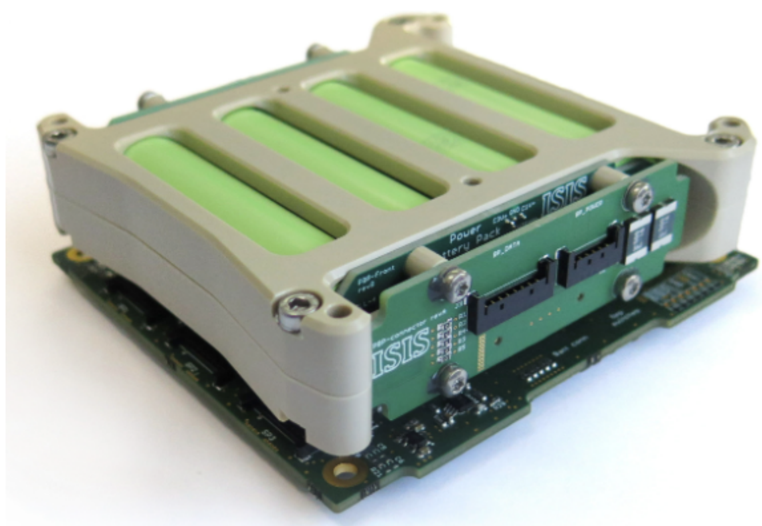

Figure 13: ISIS Space 4-pack Electrical Power System

Prototyping & Testing

The first prototypes in the our team's CubeSat development were geared towards understanding the overall system integration and custom development of some components of a 1U CubeSat. Our team developed HawkSat-1, a 1U test bed for custom Attitude Determination and Control System (ADCS). HawkSat-1 was built from a PLA 3D printed chassis with custom plates for laying the avionics components. The CubeSat used a Raspberry Pi 3B+ as an on-board computer and four hobby brushless motors to rotate custom steel reaction wheels. The control system was designed to incorporate a 9 DOF IMU for a closed-loop control attitude control.

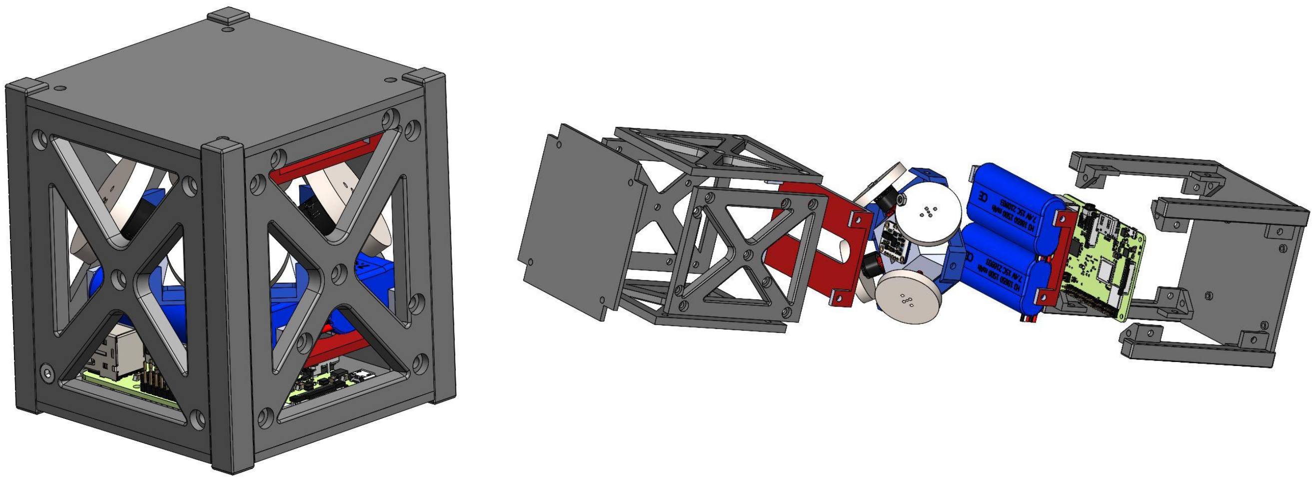

Figure 14: HawkSat-1 CAD & Exploded View

HawkSat-1 was tested aboard a Zero-Gravity flight with Aurelia Institute's Horizon Maiden flight in May 2022. The data gathered during the flight provided learning points for ADCS design and overall satellite system integration, which aided our design process for OSPREY.

Figure 15: Zemichael Gebeyehu testing HawkSat-1 aboard Aurelia Institute's Zero Gravity Flight. Credit: Steve Boxall, Zero G Corp

The Wilbur Powerhouse has been instrumental in our design and prototyping, specifically the makerspace is home of Additive Manufacturing Labs, Maching, and various manufacturing tools in-house. In addition to Wilbur Powerhouse, the Dravo student shop and Mohler Lab provide unparalleled in-house manufacturing capabilities ranging from CNC mill and Lathe to injection molding and composite manufacturing. For mechanical testing, specifically for vibration testing, the team will be utilizing the Advanced Technology for Large Structural Systems (ATLSS) at Lehigh University, a national center with world class structural testing facilities.

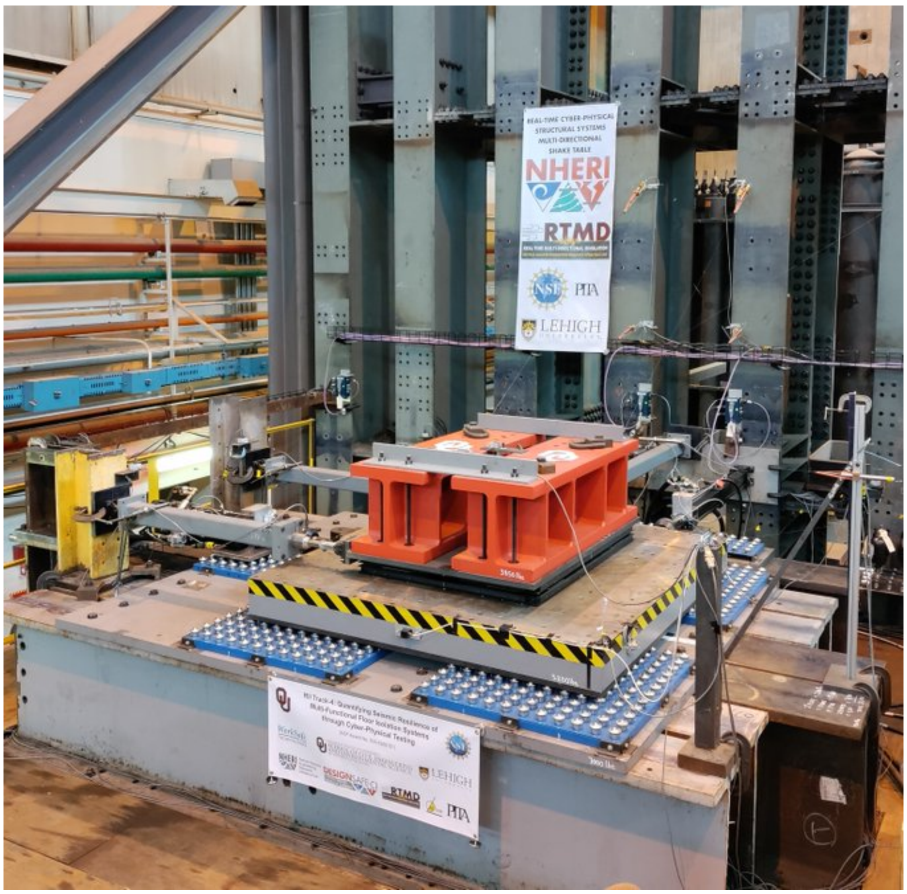

Figure 16: ATLSS's Multi-Directional Experimental Lab

As part of ATLSS, the Multi-Directional Experimental Laboratory, one of the largest of its kind in North America, provides state-of-the-art vibration with a 30.5 m by 12.2 m testing floor. The system operates with hydraulic actuators with computer-driven control systems. Additional thermal and radio testing will be conducted with the aid of Lehigh's Mechanical Engineering & Mechanics, Electrical & Computer Engineering, and Material Science & Engineering department facilities.

Technical Details: Ground Station

Our team will be utilizing one ground station to communicate with the satellite. This station will be located on our campus on an open field in order to minimize the losses. The ground station operates in UHF, specifically in the 435-438 MHz frequency range. For the onboard Telemetry and Command (T&C), up and down communications on the UHF will be used. The second function provided by the ground station is the S-band downlink communications. This will be in conjunction with the spacecraft camera data and payload .

A RHCP and LHCP helical antenna from Wimo that operates in the 430-440 MHz range will be used. This range captures the 435-438 MHz frequency emitted by the satellite. The helical antenna has a circular polarization and is rear mounted to an Azimuth and Elevation antenna positioner. A helical antenna was chosen because of its capabilities to receive our satellite's signals from a long distance, and it provides high gain, specifically, 11.6 dBi. The antenna is attached to a reflector which directs the electromagnetic energy forward. The antenna does not require a satellite dish. To transmit, a Power Amplifier (PA) will be used, and to receive signals a Low Noise Amplifier (LNA) will be used. The antenna will be connected to the LNA and PA by coax switches. UHF RF Input and output signals will be given by a Software Defined Radio, in which the two previously mentioned amplifiers are connected to.

The SDR that will be used is the RTL_SDR V3, due to its low cost, easy to use USB device, and great capabilities for satellite applications. It operates in the UHF band, specifically the frequency range is 500 kHz-1766 MHz and has a bandwidth of up to 2.4 MHz stable. The software we will be using along with the SDR is from Airspy called SDRSharp software. This software will be installed and used in our Ground Station computers.

The Positioner systems from ARA will be used to control the antenna, as it supports SATCOM applications. It operates in two axes: Azimuth and Elevation. An advanced digital motion control system is used for the positioner, which is connected to the antenna. This will be connected to the EasyComm control protocol. The Antenna Control Unit (ACU) controls the positioner. The positioner controller can control the direction of the antenna, in which we will use the EasyComm control protocol available on the HamLib control library. The SatNOGS Open Source hardware/software project is the basis of the positioner controller. It allows for GPredict to be used for local tracking control through the SatNOGS Network software. The GNU Radio ModCod blocks are used to pass information in and out of the ground station, which will help us to receive payload data and raw IQ sample files. Doppler shift will be accounted for in real time using the GNU radio and the tracking software.

There are two ways the T&C subsystem transmits telemetry data to the ground: in response to a command request, a BPSK modulated data frame is used, and if no activity is detected for some time a satellite ID and short Morse code modulated telemetry sequence is used. The general amateur radio community can identify our satellite through this Morse code ID. Satellite housekeeping commands include controlling the following: turning off all RF transmissions if necessary, attitude and payload functions, power. For security purposes, commands from the ground station to the satellite are encrypted.

Failure Scenarios

The table below outlines the risks and mitigation strategies for the OSPREY CubeSat mission, aiming to enhance its success probability.

Risk Category	Specific Risk	Probability (1-5)	Severity (1-5)	Risk Index	Acceptable?	Solution
ADCS System	ADCS Torque System Failure	1	5	5	Yes	Conduct extensive pre-launch simulations and incorporate backup systems.
Deployment	Antenna Array Fails to Deploy	1	5	5	Yes	Pre-launch testing and backup deployment mechanisms.
Communications	Communications Failure	1	3	3	Yes	Employ multiple channels and conduct environmental testing.
Radiation Impact	Radiation Degradation of Electronics	2	2	4	Yes	Error detection and correction techniques in software.
Structural Integrity	Radiation Degradation of CubeSat Structure	1	3	3	Yes	Construct with certified, radiation-resistant materials.
Imaging	Limited Spatial Resolution in Monitoring Marine Plastics	2	3	6	Yes	Advanced imaging technology (HyperScape 100).
Data Transmission	Data Transmission Failure or Limitations	3	2	6	Yes	Redundant data transmission systems and regular ground checks.
Imaging System	Imager Fails to Detect Correct Wavelengths	2	3	6	Yes	Rigorous pre-launch testing under simulated conditions.

Table 7: Failure Mode Effect Analysis

Based on the Compliance Requirements section, all potential risks associated with the satellite mission have been thoroughly considered and are not deemed critical. This assurance is provided through rigorous testing and certification of all systems, as discussed previously. The design of the entire system prioritizes ensuring that the mission objectives will be met.

Detailed Financial Budget

System	Component	Qty.	Price	Ext.
OSPREY Bus	Structure	1	$4200	$4200
	On-Board Computer	1	$5100	$5100
	UHF Transceiver	1	$5900	$5900
	UHF Antenna Array	1	$4700	$4700
	Integrated ADCS (Reaction Wheels + Magnetorquer + Sun Sensor)	1	$32,000	$32,000
	Solar Panels	4	$5,000	$25,000
	Electrical Power System (IMEPS)	1	$5,000	$5,000
	Wiring + Fasteners	-	$100	$100
Payload	HyperScape 100	1	$26,000	$26,000
Ground Station	Primary and Secondary Ground Stations	1	$4725	$4725
Testing	Environmental Testing	-	$2000	$2000
Miscellaneous	Contingency	-	$4,000	$4,000
Total Price				$118,725

Table 8: Detailed Financial Budget

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