The AEROS Mission: Characterizing Multi-Spectral Ocean Measurements through Small Satellite Connectivity

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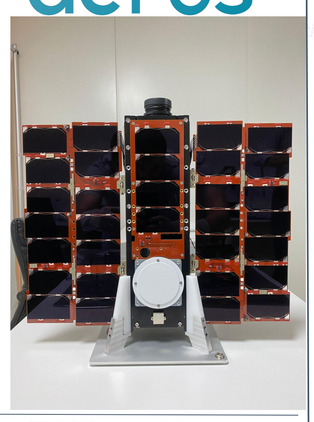
Introduction: The AEROS nanosatellite mission concept centers on imaging the ocean across spatially distributed areas, spectral wavelengths, and time. By understanding the ocean environment across these critical variables, we can better understand ocean health and humanity's impact on it, particularly within the context of our planet's changing climate. While the current AEROS project is just one satellite, it is a demonstration mission serving as a precursor to a future constellation focused on applying spectroscopic techniques to measure and monitor ocean health. This project is funded by the MIT Portugal Partnership 2030 (MPP2030). The work supports both the multinational "Atlantic Interactions" research efforts and UN Sustainable Development goals.

I. AEROS Mission Overview

- **High-level mission objectives:**
  - Monitor essential ocean variables via a suite of nanosatellite payloads
  - Develop precursor satellite for a future ocean-sensing constellation
  - Advance technical know-how of Portuguese research entities
- **Desired capabilities:**
  - Ocean imaging via a miniaturized hyperspectral imaging payload
  - Demonstrating a flexible software-defined communication module
  - Communications relay demonstration for in-situ platforms such as biotagged marine life and autonomous vehicles
- **Science objectives:**
  - Measure ocean color to forecast oceanfront and fauna locations, as well as derive useful data products for determining ocean health
  - Monitor water quality and oceanographic features such as upwelling regions and mesoscale eddies
  - Support monitoring of Marine Protected Areas (MPAs) and the distribution of marine megafauna (whales, sharks, etc.)

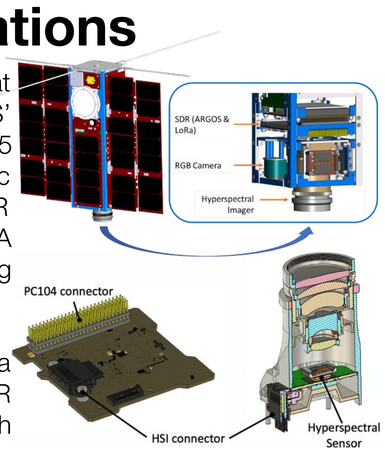


AEROS Spacecraft image courtesy of CEiiA

II. Mission and Payload Specifications

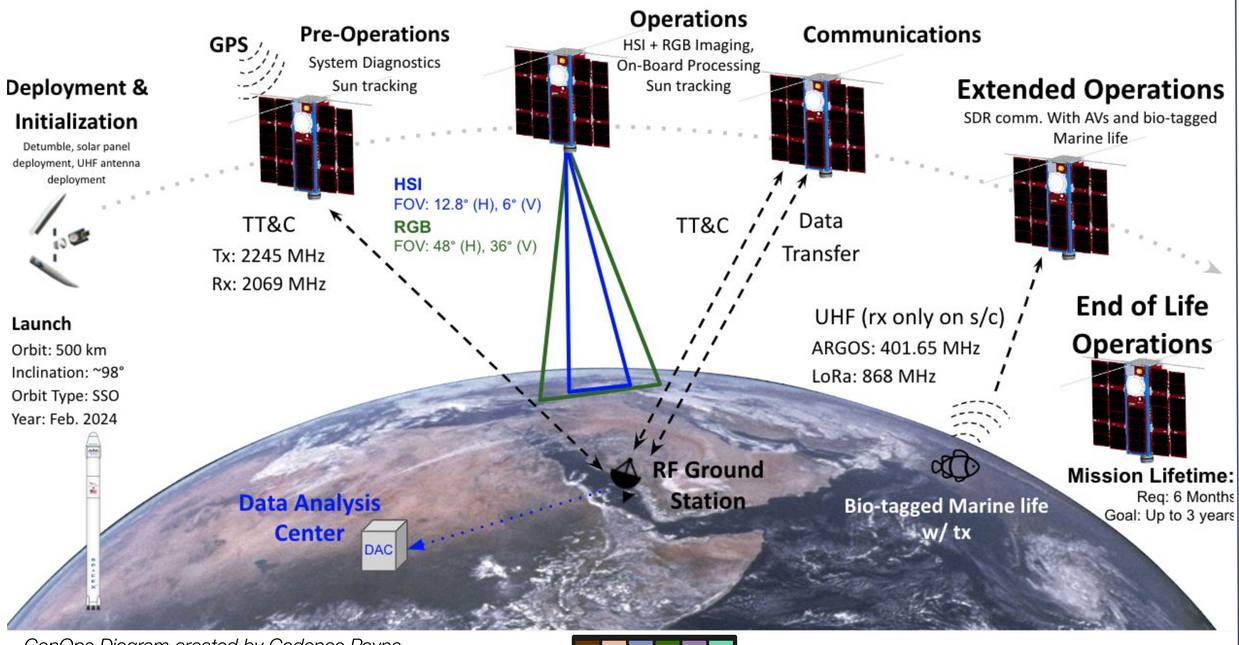
AEROS is a 3U (10 x 10 x 30 cm^3) CubeSat hosting three payloads that support the mission's science and communication objectives. AEROS' primary payload is a low-power (5W max), compact (70.8 x 70.8 x 105 mm^3) hyperspectral imager (HSI) developed by Spin.Works. It uses a static spectral filter integrated on top of a CMOS detector to achieve 150 VIS/NIR measurement bands from 470 - 900 nm, each with 10 nm bandwidth. A CrystalSpace RGB imager will provide contextual imagery of overlapping ground scenes for the HSI and serve as a viewfinder for HSI tasking.

AEROS also hosts a software defined radio (SDR) configured based on a Zynq-7000 system-on-a-chip and uses the GNU Radio software. The SDR supports AEROS' objectives of improving flexible connectivity with autonomous vehicles and biologging tagged marine life.



CAD rendering of spacecraft with payload locations labeled (top) & cross-sectional view of HSI (bottom). Images from CEiiA

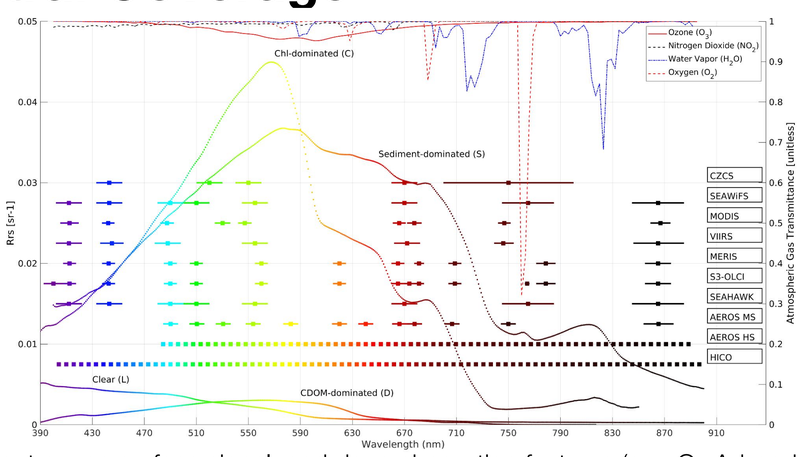
III. Concept of Operations



ConOps Diagram created by Cadence Payne

IV. AEROS Spectral Coverage

This figure shows the AEROS HSI measurement band coverage in the VIS/NIR spectral range with respect to a set of legacy multispectral and hyperspectral imagers (see vertical labels), common atmospheric constituents, and dominant optical constituents in coastal waters. The atmospheric constituents' transmittance spectra, including O_3, NO_2, H_2O and O_2, are derived from the SMART radiative transfer modeling tool. These features are removed during the atmospheric correction process to recover the target ocean surface signal, and deep absorption features (e.g. O_2 A-band at ~760 nm) are excluded from target measurements. Last, four hyperspectral remote sensing samples from the GLORIA in-situ database (labeled, C, D, L and S) for coastal waters in the north-atlantic region are shown to demonstrate feature coverage in the AEROS spectral sensing range.



V. Mission Use Cases

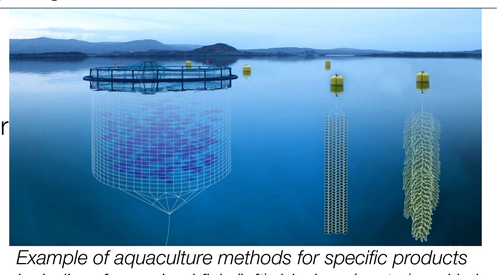
Fisheries and Aquaculture Management

Scheduled observation of user specified target areas to monitor water quality using ocean color data such as:

- Chlorophyll –a concentration
- Total suspended matter
- Color dissolved organic matter

Applications include:

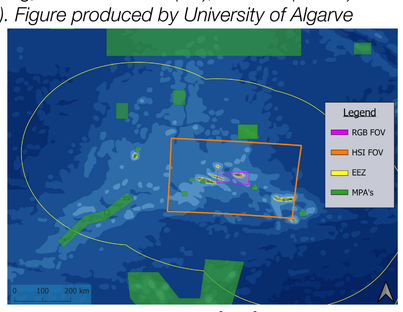
- Monitoring harmful algae blooms
- Improved waste management practices
- Promote sustainable use of marine resources



Example of aquaculture methods for specific products including, farm raised fish (left), bivalves (center) and kelp (right). Figure produced by University of Algarve

Monitoring Ecosystem Health and Marine Protected Areas

Threats such as eutrophication, plastic pollution, oil spills, climate change, and the risk of invasive species threaten MPAs and ecosystem health. HSI reflectance measurements enable monitoring and detection of nutrient estimation, eutrophication conditions, the onset of harmful algal blooms, and the impacts of terrestrial pollution in these protected areas.



FoV of AEROS's HSI (12.8˚ x 6˚ full angle, 112 km x 60 km) and RGB Camera (48˚x 36˚ full angle) in relation to the Azores Archipelago.

VI. HSI Macbeth Test

The HSI measured spectral reflectance across it's full response range (470 - 900 nm) while imaging each block in the test pattern based on the Macbeth ColorChecker, a commonly used color calibration target. Given that the colors featured have precise, known spectral reflectances, this test allows for comparison between well-calibrated spectra and our measurements to determine the performance of the HSI and the necessity for additional calibration. The figure shows the resulting spectra mapped to each color block.

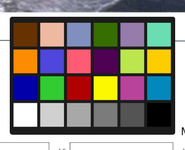
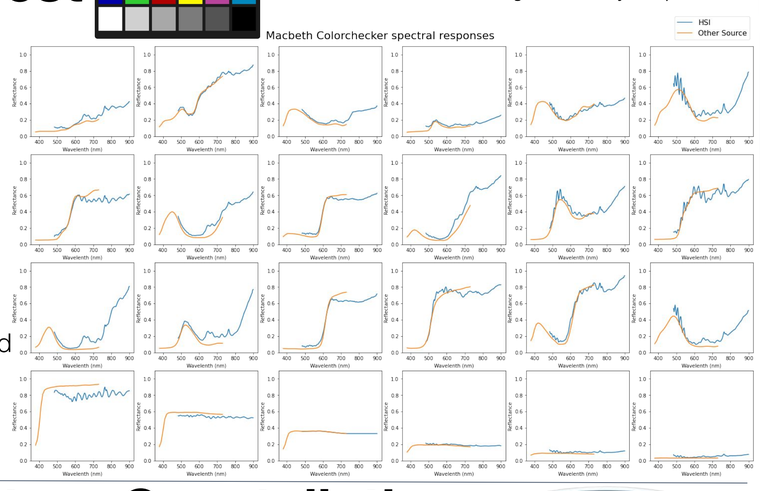
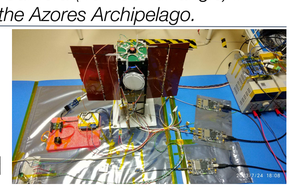


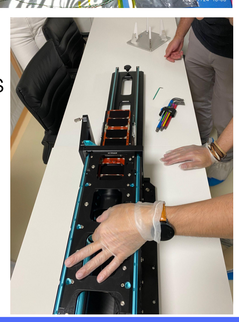
Figure courtesy of Spin.Works



VII. Current Status & Future Work

- FlatSat tests will be completed by September 1st, 2023. By this date, the full spacecraft system must be operational.
- The first half of September is dedicated to the integration of all components and payloads into the AEROS spacecraft structure. The satellite must be in its final configuration by September 15, 2023.
- AEROS will undergo final environmental testing in the second half of September. This campaign comprises vibration, thermal, and vacuum tests to simulate spacecraft operation in a space-like environment. All test results and documentation must be complete and delivered to the launch provider by December 1st, 2023.
- Satellite integration into the deployer is scheduled for December
- The integrated system will be shipped to SpaceX (launch provider) in January 2024.
- **AEROS will launch on SpaceX's Transporter-10 mission (Falcon 9) in February 2024.**





VIII. Towards a Future Constellation

- AEROS is a precursor to a future ocean-sensing CubeSat constellation that could enable:
  - Improved temporal resolution for rapid monitoring and more frequent detection & tracking of megafauna
  - Increased flexibility in target observation
  - Increased regional coverage
  - Improved coverage of near real-time developments (e.g. growth of harmful algal blooms that can double in mass in a day)

Co-funded by:

AEROS Project Partners

under the Flagship Project: AEROS Blue Ocean Constellation | Earth Systems: Oceans to Near Space