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

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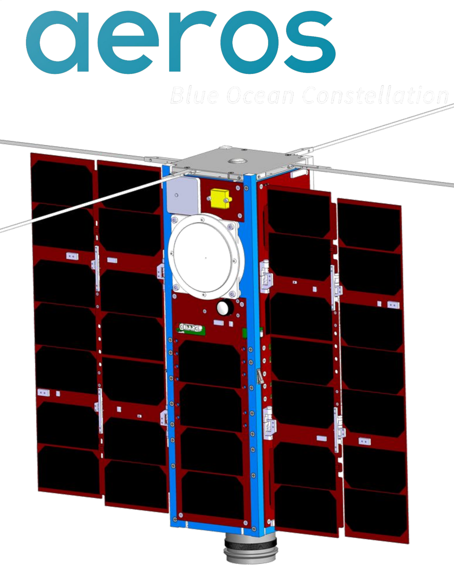
Intro to the AEROS CubeSat Mission: The AEROS nanosatellite mission concept centers on imaging the ocean across spatially distributed areas, spectral wavelengths, and time. By understanding the ocean environment across these critical variables, we can better understand ocean health and humanity's impact 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.

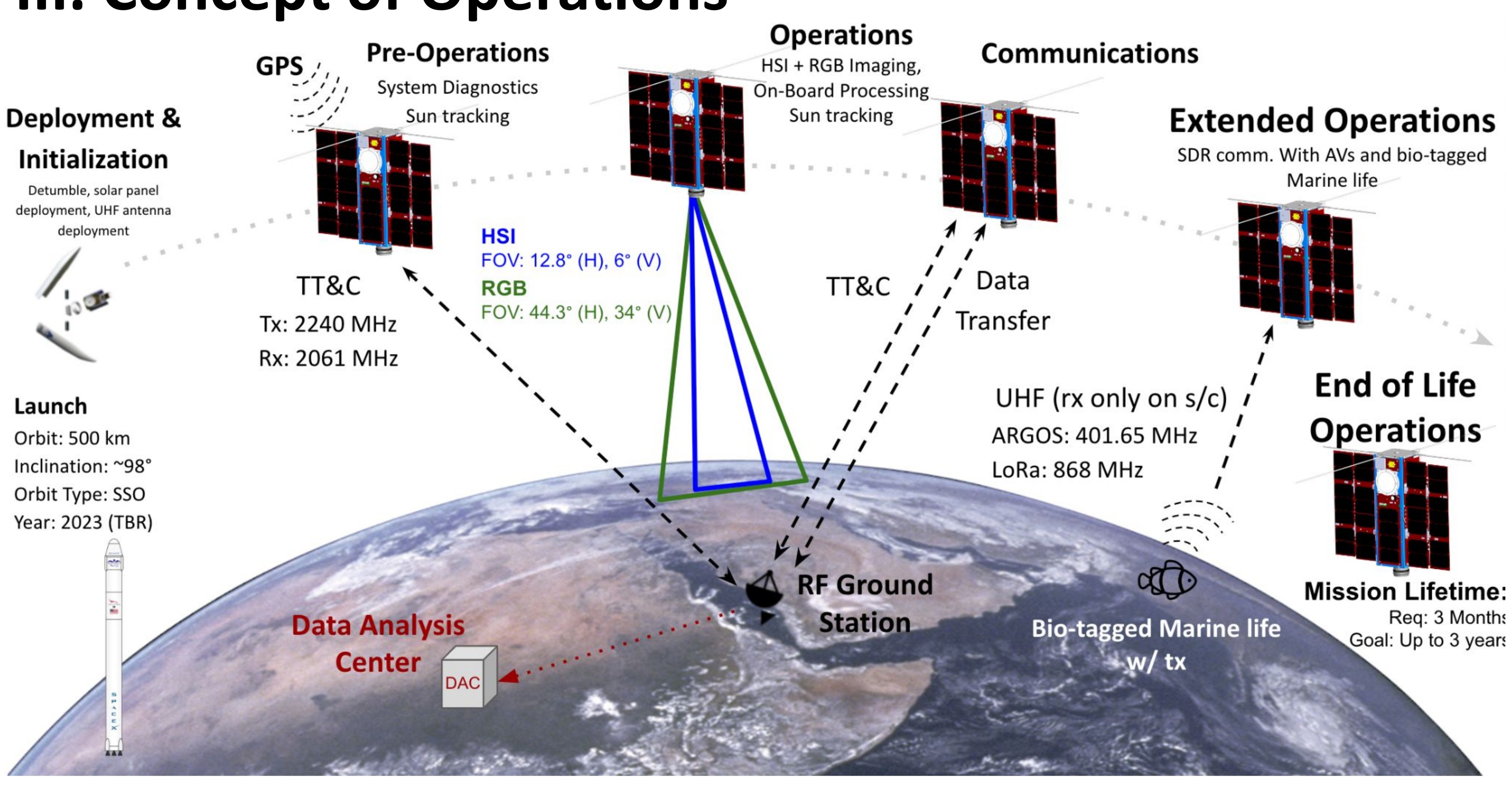
I. AEROS Mission Overview

- **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
  - Flexible software-defined communication modules
  - Communications relay demonstration for in-situ platforms such as biotagged marine life and autonomous vehicles
- **Science objectives:**
  - Measure ocean color to determine oceanfront and fauna locations, and to extract Sea Surface Salinity (SSS) data products
  - 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 CAD Rendering courtesy of CEiiA

III. Concept of Operations



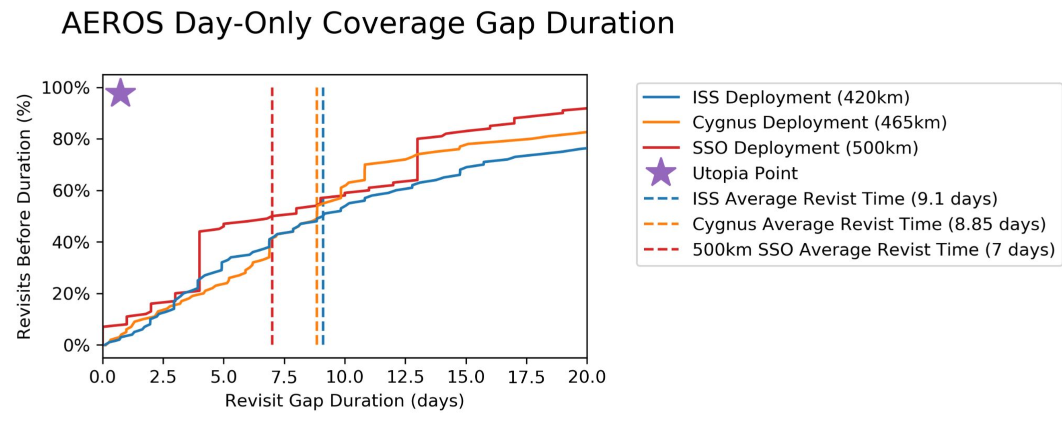
ConOps Diagram created by Cadence Payne

IV. Orbital Analysis

We anticipate injection into a Sun-Synchronous Low Earth Orbit with an approximate altitude of 500 km

This figure (bottom) shows the overlapping field-of-view for the HSI and RGB imagers. *Figure created by Miles Lifson*

AEROS Day-Only Coverage Gap Duration



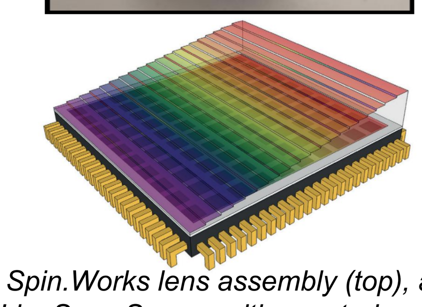
This graph (top) shows the distribution of revisit rates across the ROI. A steeper positive slope corresponds to more frequent coverage. *Figure created by Miles Lifson*

This figure (right) depicts the mission's primary region of interest (ROI), consisting of the Portuguese exclusive economic zones and extended continental shelf. Also depicted are the two ground stations that will be used for most communication with the spacecraft. *Image created by Miles Lifson using STK*

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.

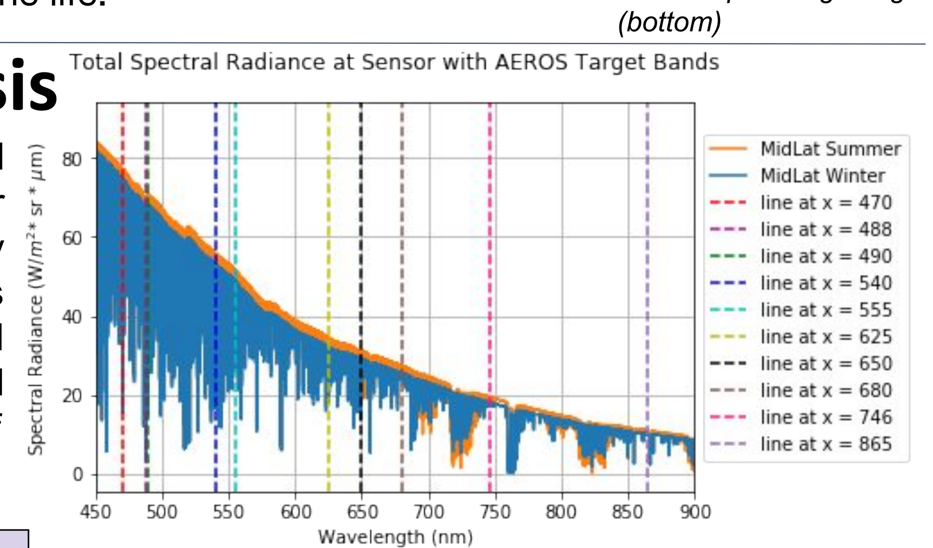
AEROS also hosts a software defined radio (SDR) configured based on a Zynq-7000 system-on-a-chip and uses the GNU Radio software. The SDR supports AEROS' objectives of improving flexible connectivity with autonomous vehicles and biologging tagged marine life.



Spin.Works lens assembly (top), and LineScan Sensor with spectral grating (bottom)

V. HSI Performance Analysis

Radiometric analysis simulates the spectral sensitivity (represented as signal-to-noise ratio) for measurement bands that are proxies for key oceanographic features. The analysis considers HSI parameters (bandwidth, FOV, etc.), anticipated source signal strength (radiance), and simulated atmospheric conditions for the AEROS' region of interest outputted from MODTRAN.



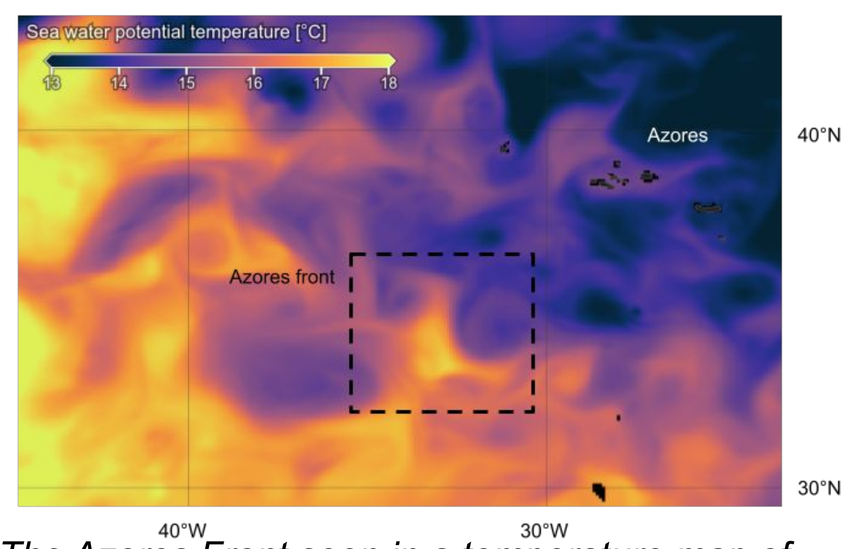
Band Center (nm)	Band Proxy	SNR Summer (linear)	SNR Winter (linear)
470	Ocean Color	53	52
625	Ocean Color, SSS	40	39
746	Atmospheric Correction	33	31

Figure (top) shows simulated radiance of AEROS' ROI for key HSI measurement bands. Table (left) shows examples of radiometric analysis output in the form of Signal-to-Noise Ratio (SNR) for ocean color, SSS, and atmospheric correction proxies. Radiometric analysis, atmospheric modeling and figure performed/produced by Cadence Payne.

VI. Ocean Remote Sensing

a. AI Detection of Ocean Fronts

Ocean fronts form at boundaries of water with different properties (such as temperature and salinity), and have significant interest for cetacean detection and other research end-users. **A trained Deep Learning (DL) model will be used to identify ocean front behavior over time using AEROS imagery, such as the Azores Front (right).** No current satellite data center that provides this information. DL methods avoid noise present in gradient-based methods, and can distinguish between fronts and water-land edges.

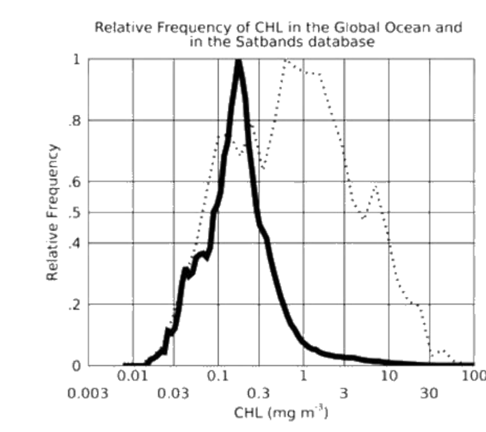


The Azores Front seen in a temperature map of a depth of 300 m on October of 2021 (global ocean forecast obtained from Copernicus). Generated with Copernicus MyOcean Viewer by Marcos Tieppo.

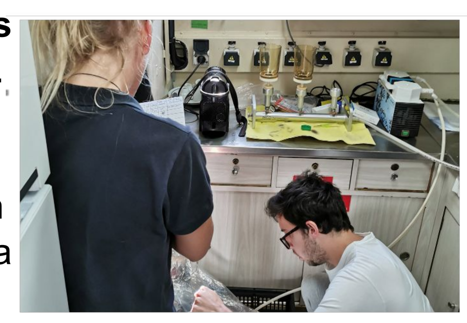
b. Chlorophyll-a Estimation

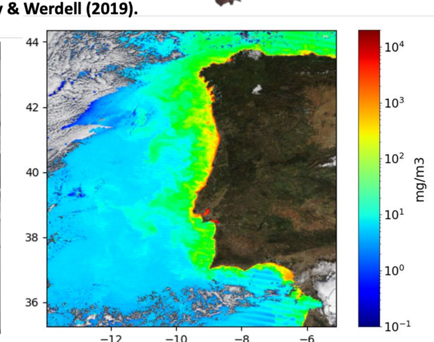
In coastal waters, Chlorophyll-a (Chl-a) concentration is a phytoplankton biomass proxy and important water quality indicator to assess eutrophication. Current algorithms to derive Chl-a from remote sensing (RS) reflectance produce underperform in coastal waters, due to light absorption and scattering from terrestrially-originated materials. Local Chl-a data is required for RS calibration and validation.

Ship-borne Chl-a fluorometers are normally used, but involve high operating costs. **AEROS will research the suitability of Autonomous underwater vehicles (AUV) to calibrate and validate Chl-a RS products.** AUVs are cheaper and more flexible than traditional alternatives. This work is supported by an existing AUV coastal monitoring program on the South Iberian coast and by using OLCI-Sentinel-3 and MODIS-Aqua observations.



Relative frequency distributions of CHL for the in situ database used to tune the algorithms (dotted curve) and for the forty-year geometric mean of SMI pixels from CHL data for the period from 1978-10-30 to 2018-03-16, based on 24,455 NASA Level-3 global daily SMI images from: CZCS, OCTS, SeaWIFS, MODIS-Terra, MODIS-Aqua, MERIS & VIIRS (solid black curve). Adapted from O'Reilley & Werdell (2019).





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