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The SPectral Ocean Color (SPOC) Small Satellite Mission: From Payload to Ground Station Development and Everything in Between

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SUMMARY

This work introduces the mission concept, technologies, and development status for the SPectral Ocean Color (SPOC) small satellite mission, which will use a hyperspectral imager to map sensitive coastal regions and off coast water quality near the state of Georgia and beyond. SPOC, a 3U CubeSat, is being developed by the University of Georgia's (UGA) Small Satellite Research Laboratory (SSRL) through NASA's Undergraduate Student Instrument Project (USIP). UGA is working with Cloudland Instruments to develop a small scale <1000 cm^3 hyperspectral imager ranging from 400-900 nm for Earth science applications which will fly as part of the 2016 NASA CubeSat Launch Initiative. SSRL is working with Cloudland Instruments on the design of the payload, but SSRL is responsible for the building, troubleshooting, altering of the final design, calibration of the payload, and integration.

The project is led by undergraduates from a wide range of backgrounds and supervised by a multidisciplinary team of Principal Investigators. Using optical components, electronics boards, a grating spectrometer, and a CMOS array, the students will assemble and integrate the payload components and ensure their compatibility with the other subsystems. In-house development and assembly includes building the hyperspectral imager, as well integrating it with the other components of the satellite, and testing all the different subsystems of the satellite.

The CubeSat is set to be launched from the International Space Station which resides between 400 and 450 km above the Earth's surface. At an orbit of 400 km the resulting images from the SPOC payload will be 75 km x 90 km in size, with a 120 m spatial resolution, and spectral resolution of 2 nm. This work describes the mission objectives of SPOC, its subsystems, payload, and the development of a ground station here at UGA. Also included is a timeline focused on completed and upcoming reviews for the SPOC mission.

Figure 1: a) Rendering of the 3U satellite bus for SPOC, b) its swath over coastal regions, and c) different 3D rendering perspective.

MISSION OBJECTIVES

The primary mission objective of the SPOC Satellite is to acquire moderate resolution imagery across a range of spectral bands (400-900nm) to monitor coastal ecosystems and ocean color, see anticipated data in Figure 2. The SPOC mission will monitor coastal wetland status, estuarine water quality (including biophysical and phytoplankton dynamics), and near-coastal ocean productivity while training students in STEM related fields.

The primary target for SPOC is the Sapelo Island National Estuarine Research Reserve (Figure 3) which currently has numerous active data sets being collected from Gross Primary Productivity (GPP) to water quality. Our remotely sensed data will be compared with ground based measurements for quality verification and validation.

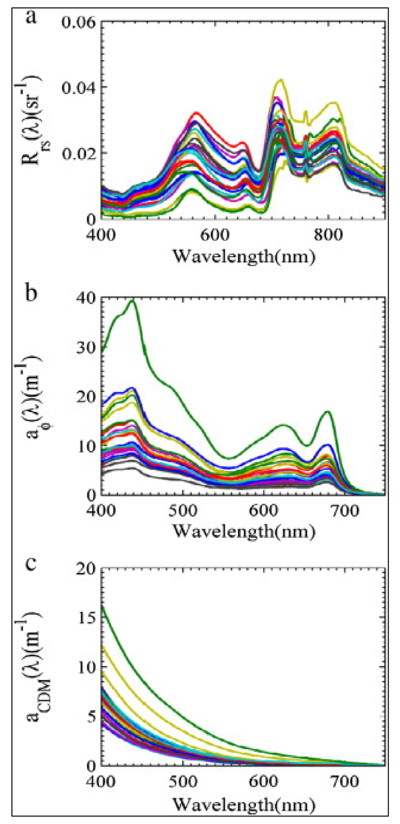
Specific quantities that will be derived from SPOC include:

- Gross primary productivity of coastal wetlands;
- Normalized Difference Vegetation Index of coastal vegetation;
- Chlorophyll-a reflectance of estuarine and coastal waters;
- Phycocyanin reflectance of inland and estuarine waters;
- Colored Dissolved Organic Material (CDOM) reflectance;
- Total Suspended Sediment reflectance.

The resulting datasets will also allow for spectral analysis comparisons with some of NASA's existing satellites such as MODIS and Landsat.

Figure 2: Examples of spectra anticipated to be collected by SPOC. a) $R_{rs}(\lambda)$ spectra from aquaculture ponds in July 2010 and April 2011, (b) phytoplankton absorption coefficients, $a_{\varphi}(\lambda)$, and (c) measured $a_{CDM}(\lambda)$ (Mishra et al., 2013).

Figure 2



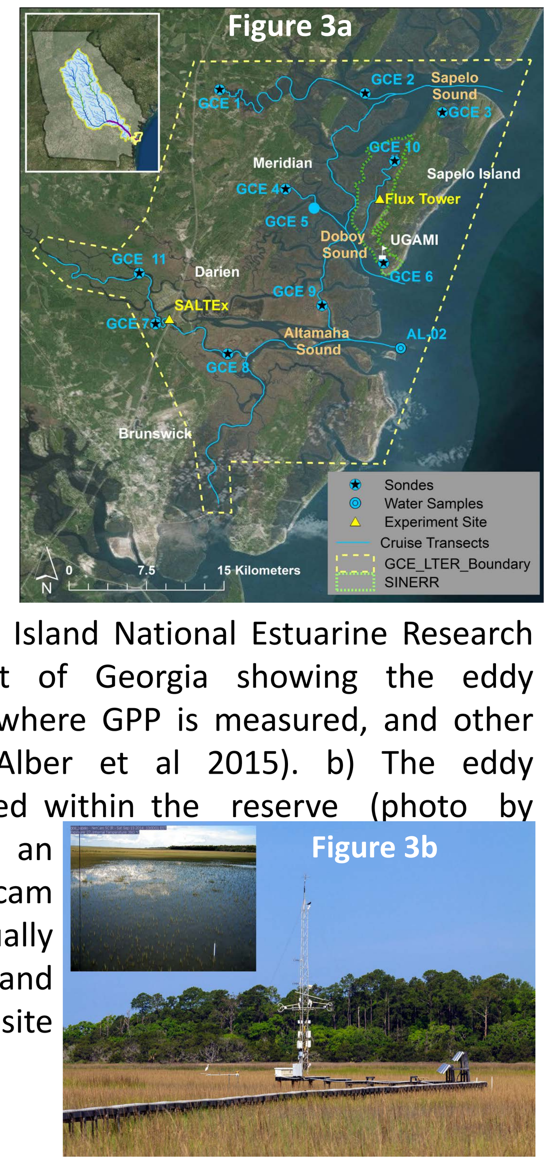


Figure 3: a) The Sapelo Island National Estuarine Research Reserve off the coast of Georgia showing the eddy covariance flux tower, where GPP is measured, and other measuring locations (Alber et al 2015). b) The eddy covariance tower located within the reserve (photo by Wade Sheldon) with an inset of the phenocam setup used to visually monitor plant growth and tidal patterns of the site (Alber et al., 2015).

SUBSYSTEMS

ADCS: 3-axis reaction wheel, 3-axis magnetorquer, and fine sun sensors. This combination of ADCS components will yield better than 0.5 degree pointing accuracy, fulfilling requirements for successful data collection

C&DH: Cortex-M3, 4 GB flash memory, Real Time Counter, Total Ionizing Dose, I2C, SPI, and CAN interface.

EPS: 20 Wh Battery, Maximum Power-point Tracking, Battery Charge Regulators, Over-Current Bus Protection, Battery Under-Voltage Protection, and CubeSat Kit compatible headers.

Communications: The satellite will be equipped with a VHF-uplink, UHF-downlink transceiver, and S-Band for data transmission. Secondary transceivers are being investigated as backup systems. Possible communication avenues being explored are:

- Collaborations with other Universities for S-Band data downlinks;
- Using NASA Near Earth Network to downlink data through S-band;
- UGA hosted ground station will provide telemetry downlink and command uplink;
- Potentially utilizing GlobalStar satellite constellation as emergency communication backup.

PAYLOAD

- Grating spectrometer - 150 line per mm grating blazed for 500 nm.
- 752x480 pixel CMOS array.
  - The 752 pixel wide slice is moved across the scene in a "pushbroom" scanner manner.
  - The wavelengths for the slice are dispersed across the height of the array, 480 pixels, with a resolution of ~1.042 nm per row.
  - Designed for low cost video applications, and runs at 55.55 frames a second (readout rate is about 17.5 milliseconds).
  - At ~400 km this is about 126 meters in the direction of motion.

Issues Pending Definition/Resolution

- Optics blur and motion blur could result in a star-like white spots covering 2-3 pixels.
- Data size
  - Currently set to be aggregated in the onboard processor by summing 4 rows together to produce 4.16 nm wide spectral data.
  - Other options for further data manipulation involve summing bands even further or downlinking only specific bands interest.
- Still finalizing data downlink possibilities.

GROUND STATION

- SSRL is currently refurbishing an old AM radio station antenna for use on our S-Band ground station.
- The dish is scheduled to be relocated to the UGA campus in 2017 where it will be attached to movable base that can be used to track our satellite as it passes overhead.

Figure 4: Current location of the old antenna that will be refurbished for the ground station, SSRL team member for scale.

TIMELINE

Preliminary Design Review	-	January 2017
Critical Design Review	-	March 2017
Range Readiness Review	-	September 2017
Fight Readiness Review	-	January 2018
Delivered to NASA	-	March 2018
Launch	-	Late 2018??
Length of mission	-	~ 1 year

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