SPOC: The Spectral Ocean Color Mission

Dr. David L Cotten, Hollis Neel, and Katie Summey
Small Satellite Research Laboratory
Small Satellite Research Laboratory

- Over 50 undergraduates work in the lab
  - 6 Graduate students
  - 4 high school students
- 12 faculty advisors from all over campus
- Founded in 2016
  - 2 Cube satellites under development

UGA Small Satellite Research Laboratory (SSRL)

Team at NASA Ames, July 2019

SPOC, June 2019
Some of the team

Nicholas Neel - SPOC Systems Engineer
Kaitlyn Summey - SPOC Payload Lead
Caleb Adams - SSRL Project Manager
Casper Versteeg - SPOC Thermal Lead
Nir Patel - SPOC Mechanical Lead
Kaelyn Deal - SPOC Integration

Jackson Parker - MOCI Systems Engineer
Alex Lin - SPOC Software
Tyler Murray - SPOC Software
Ryan O’Hara - SPOC Mechanical
Jack McDaniels - SPOC Integration
Allen Spain - Electronics
Mary Clarke - SPOC Optics
Megan Arogeti - SPOC Mission Ops
SPOC

• NASA USIP (Undergraduate Student Instrument Project)
  • Funded in 2016
  • CSLI
• 3U CubeSat
• ISS orbit
• ELaNa 25
Mission Objectives

• Acquire moderate resolution imagery of coastal ecosystems and ocean color
• Acquire image data between 450 and 800 nm
• Use multispectral image products to monitor status of coastal wetlands, including estuarine water quality and ocean productivity
• Train students
  • Satellite design, integration, and testing
  • Data transmission techniques
  • Georeferencing images
  • Image processing
  • Community outreach

LandSat 8-OLI image of the Georgia Coast, October 13, 2016, post Hurricane Matthew. Courtesy of Abhishek Kumar
Satellite Specifics

- **SPOCeye**
  - Hyperspectral Imager
  - 422 nm – 880 nm
  - 0.95 nm spectral resolution
  - 130 m spatial resolution

- Clyde Space core avionics and solar panels
- F’Sati communication boards and S-band patch antenna
- ISIS antenna
- 4D-Systems finder scope
- Mass
  - 3.74 kg total mass
- Power
  - ~25W/~1.3W max/min power draw
  - ~6W average power generation
Communication System

• F’Sati UTRX transceiver (UHF uplink and downlink)
  • 430-440 MHz

• Innovative Solutions in Space deployable turnstile antenna
  • Tuned to 437.35 MHz

• F’Sati STX
  • Transmit-only module for S-band downlink
  • 2.40 - 2.45 GHz

• 8 dBi patch antenna
Payload

*SPOCeye*
- 752 x 480 pixel CMOS array
- 98 km x 130 m capture
- 0.950 nm per pixel
- 130 m x 130 m pixel for 18 ms exposure

*Finderscope*
- 500 m resolution imager
- Aid post data processing and acquire oblique satellite imagery
SPOCeye Specifics

• Optical layout designed by Cloudland Instruments
  • Diffraction style hyperspectral sensor from 422nm - 880 nm
  • CMOS - Onsemi Micron MT9V-034
    • 10 bit
  • PicoZed Board - PicoZed Z7020
    • 1 GB of storage
• Electronics Interface
  • UART
  • QSPI
Payload Problem

- Hyperspectral sensor from 422 nm - 880 nm
- 1 scene
  - 750 frames = 9,600 km² area
- **Data Size?**
  - Data downlink rates = 1Mb/s
    - 1 scene = 0.5 GB
    - Downlink 10.5 GB/year can be downlinked
    - 20 scenes per year
- **SNR?**
  - Is the signal to noise useful at that resolution?

Payload Solution

• “Smart” Multi Spectral Imager
  • **16 User defined bands**
    • Preprogrammed band definitions
    • Starting wavelength
    • Bandwidth
    • Defaults
      • 422 - 880 nm
      • Minimum 130 m spatial
      • Minimum 0.95 nm spectral resolution
  • Increase possible number of scenes
  • More cross calibration opportunities
  • Larger range of targets
    • Beyond initial project scope
  • SNR
    • Increased to >100 for most bands

---

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Bandwidth (nm)</th>
<th>SNR per 20 pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>443</td>
<td>20</td>
<td>181</td>
</tr>
<tr>
<td>490</td>
<td>20</td>
<td>185</td>
</tr>
<tr>
<td>510</td>
<td>20</td>
<td>171</td>
</tr>
<tr>
<td>555</td>
<td>20</td>
<td>157</td>
</tr>
<tr>
<td>670</td>
<td>20</td>
<td>139</td>
</tr>
<tr>
<td>750</td>
<td>20</td>
<td>83</td>
</tr>
<tr>
<td>865</td>
<td>20</td>
<td>63</td>
</tr>
</tbody>
</table>

Estimated SPOCeye SNR to corresponding SeaWiFS bands
Timeline

DEC 2018
Receive Flight COTS Components
All Core Avionic electronics received and integrated onto a “flat sat” for software development and testing.

MAY 2019
SPOCeye Calibration
SPOC payload taken to NASA Goddard for final calibration.

JULY 2019
Full Satellite T-Vac cycling and communication testing
SPOC taken to NASA Ames for environmental testing.

AUGUST 2019
Vibration Testing & Integration and Readiness Review
Take SPOC for final vibe testing and have integration readiness review.

SEPTEMBER 2019
SPOC Handoff to NanoRacks
Satellite delivery to NanoRacks.

Testing at NASA Goddard
Testing at NASA Ames
Working on SPOC in the UGA cleanroom
SPOC after initial integration, July 2019

Small Satellite Research Laboratory
Franklin College of Arts and Sciences
UNIVERSITY OF GEORGIA
www.smallsat.uga.edu
Pixel Alignment/Spectral Characterization

Spectral testing at UGA using various light sources

Spectral results using He and H sources
NASA Goddard

- Optical alignment
  - Locked down
- Polarization effects
- Stray light
- Exposure time non linearity
NASA Ames Test results of Comms

• Temperature and vacuum tests were nominal
• Reflections off of SPOCeye changed the gain pattern \(\sim -2.5 \text{ dB} \) on the X+ face
On orbit calibration

• Pseudo invariant targets
• Vicarious calibration
  • MODIS, SeaHawk, etc.
• Data validation
  • Using intensive field campaigns
• Wave front estimation

Hawkeye payload for SeaHawk
Insitu hyperspectral data collection
Sapelo Island LTER eddy covariance tower
Acknowledgments
To learn more come to our Booth!

• Booth U4
  • Upstairs in the Field house
Ground Segment Overview

- UGA Center for Orbiting Satellite Mission Operations (UGA-COSMO)
  - UHF, VHF, and S band capabilities
  - Hardware Defined Radio (HDR)
    - Kenwood TS-2000X transceiver
      - 138 MHz, 440 MHz, 1.2 GHz
    - Kantronics KAM-XL Terminal Node Controller
      - AX.25 Packets, GMSK Modulation
  - Software Defined Radio (SDR)
    - Ettus research USRP X310
      - SBX, UBX daughterboards
    - Oven Controlled Oscillator and GPS module
    - Khune 100W Power Amplifier (100-500 MHz)
  - Location:
    - Athens, Georgia, USA (33.9519° N, 83.3576° W)
SPOC Simulations

SPOC payload housing vibration simulations

SPOC payload housing thermal simulations
Payload Optics

1. Polarization scrambler
2. Long pass filter
3. Primary telescopic lens
4. First mirror fold
5. Secondary telescoping lens
6. Custom optical slit
7. Second mirror fold
8. Collimator lens
9. Diffraction grating fold
10. First camera lens
11. Focusing camera lens
12. CMOS Sensor