Small Satellite Research Laboratory
Franklin College of Arts and Sciences
UNIVERSITY OF GEORGIA

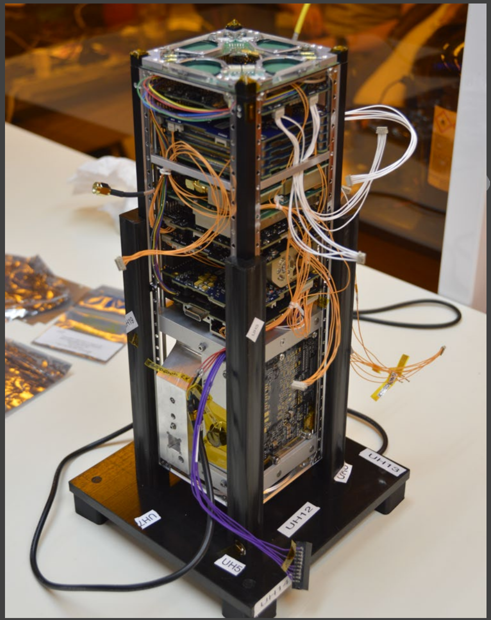
SPOC: The Spectral Ocean Color Mission

Dr. David L Cotten, Hollis Neel, and Katie Summey

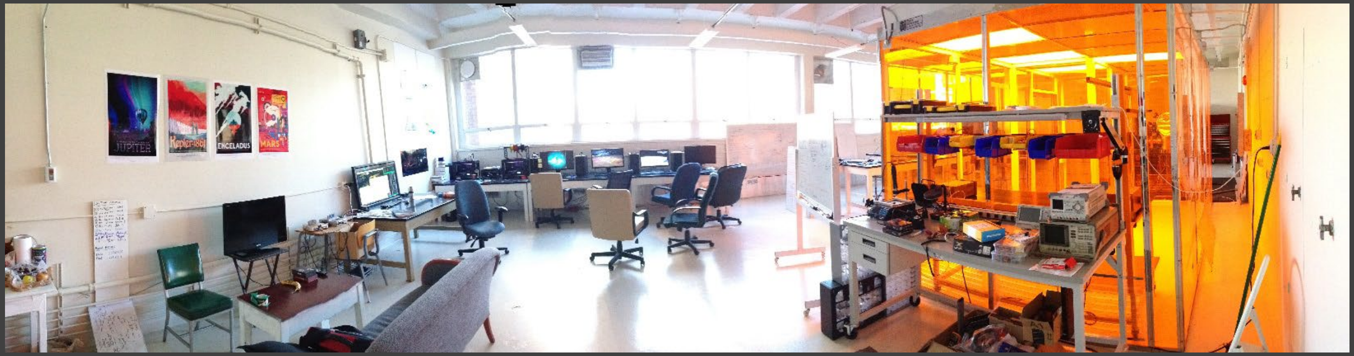
Small Satellite Research Laboratory

Small Satellite Research Laboratory

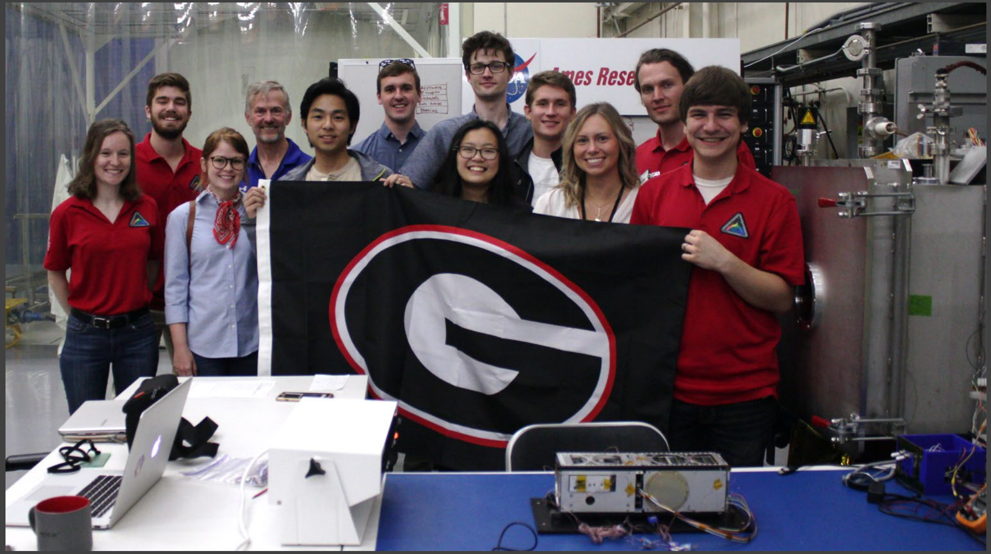
- Over 50 undergraduates work in the lab
  - 6 Graduate students
  - 4 high school students
- 12 faculty advisors from all over campus
- Founded in 2016
  - 2 Cube satellites under development



SPOC, June 2019



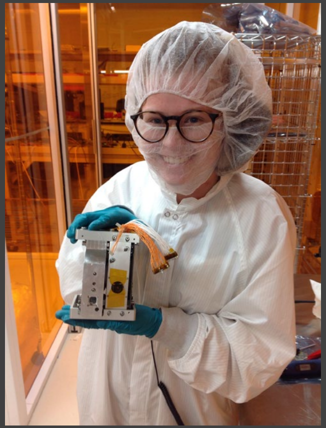
UGA Small Satellite Research Laboratory (SSRL)



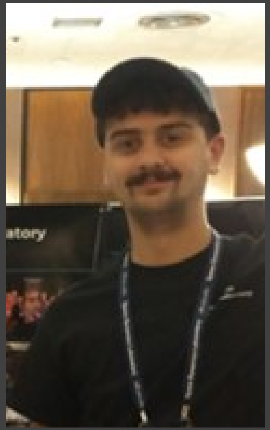
Team at NASA Ames, July 2019

Some of the team

Nicholas Neel-SPOC
Systems Engineer



Kaitlyn Summey
SPOC Payload Lead



Caleb Adams-SSRL
Project Manager

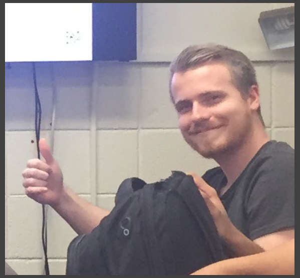
Casper Versteeg
SPOC Thermal Lead

Nir Patel-SPOC
Mechanical Lead

Kaelyn Deal
SPOC Integration

Jackson Parker-MOCI
Systems Engineer

Alex Lin
SPOC Software

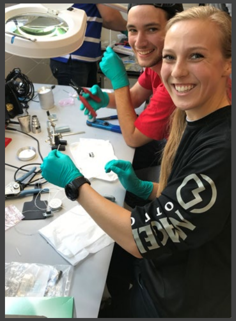


Tyler Murray
SPOC Software

Ryan O'Hara
SPOC Mechanical

Jack McDaniels
SPOC Integration

Allen Spain
Electronics

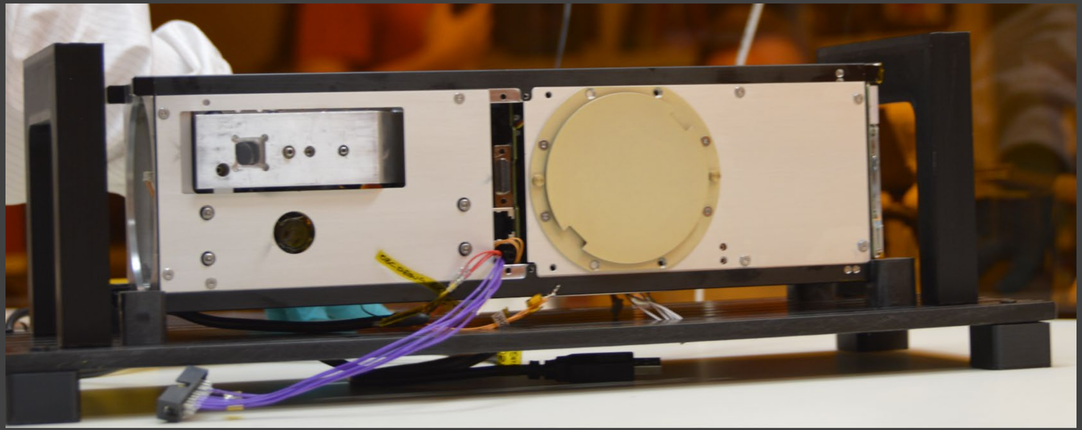


Mary Clarke
SPOC Optics

Megan Arogeti
SPOC Mission Ops

SPOC

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



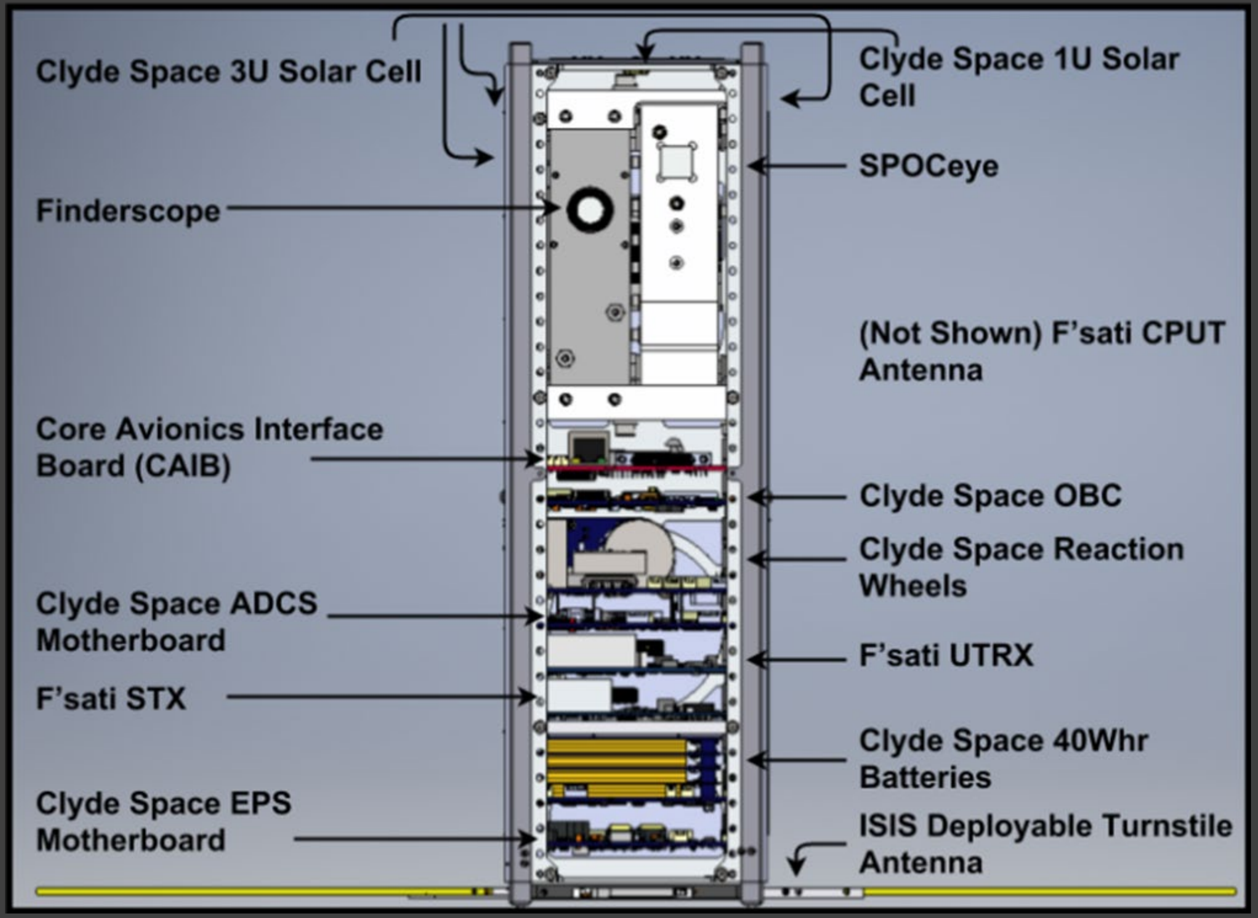
Mission Objectives

- 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
  - Georeferenceing images
  - Image processing
  - Community outreach

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

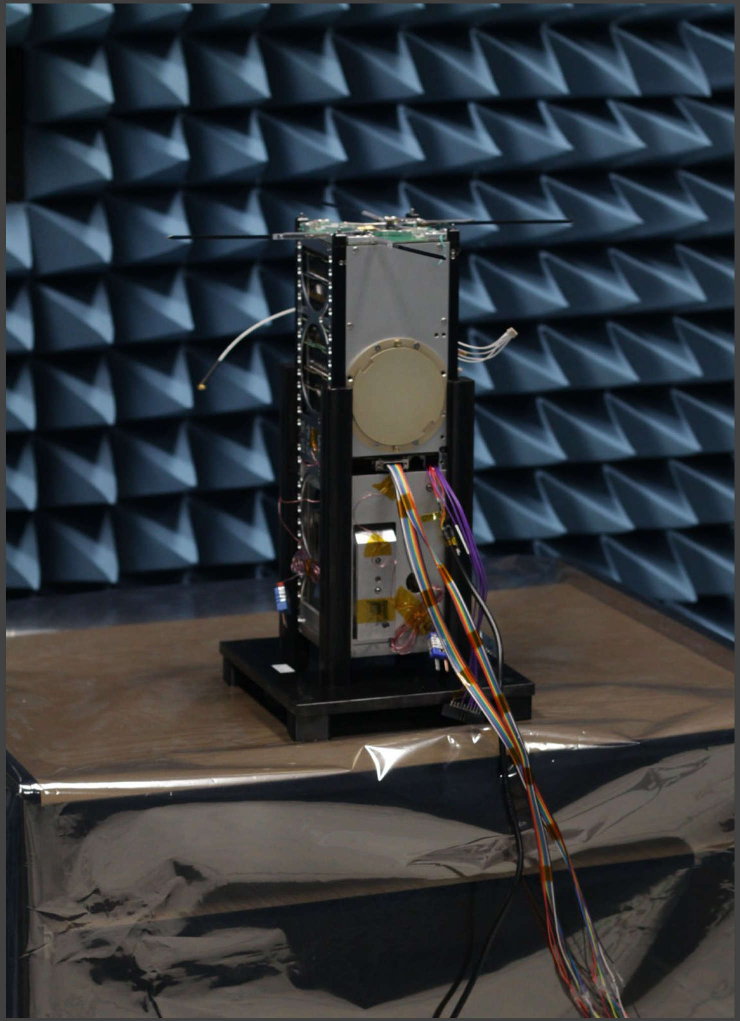
Satellite Specifics

- 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



SPOC in the NASA Ames EEL anechoic chamber

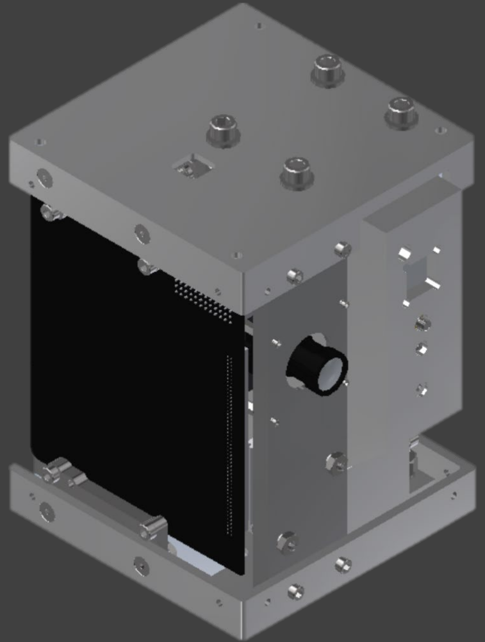
Payload

SPOCeye

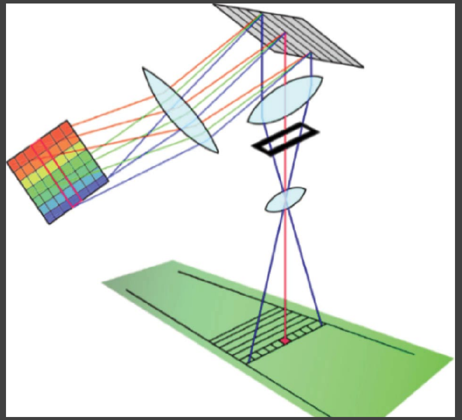
- 752 x 480 pixel CMOS array
- 98 km x 130 m capture
- 0.950 nm per pixel
- 130 m x 130 m pixel for 18 ms exposure

Finderscope

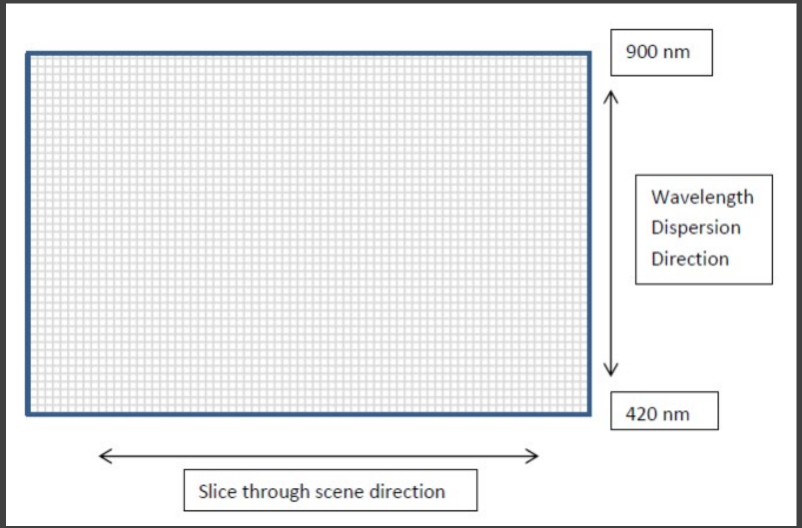
- 500 m resolution imager
- Aid post data processing and acquire oblique satellite imagery



SPOC payload housing



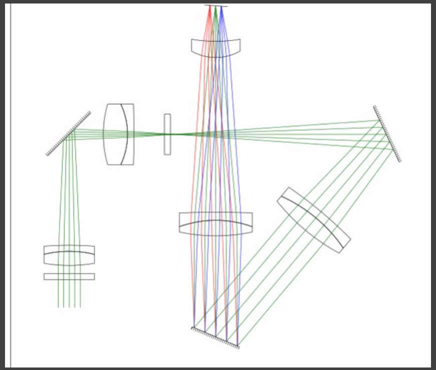
Example of SPOCs push broom scan orientation



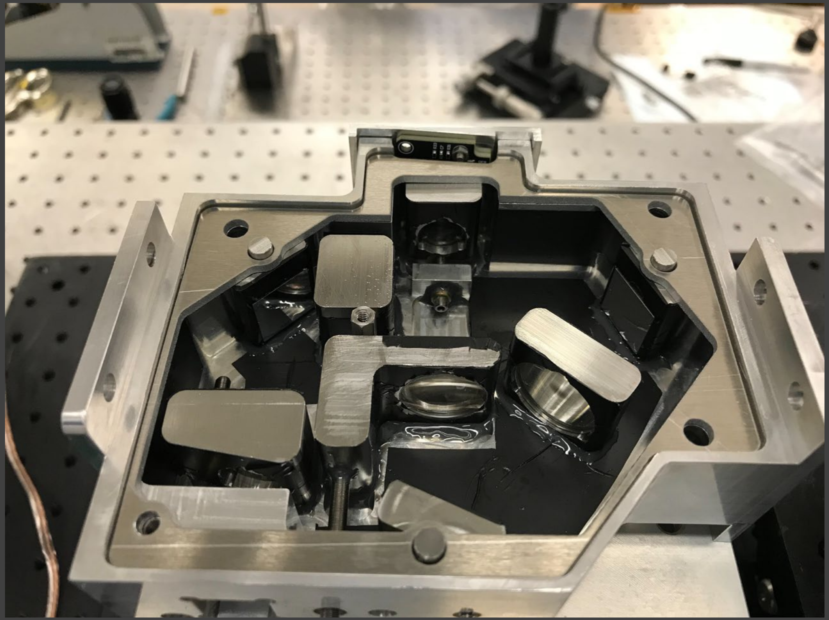
CMOS Sensor orientation and pixel configuration

SPOCeye Specifics

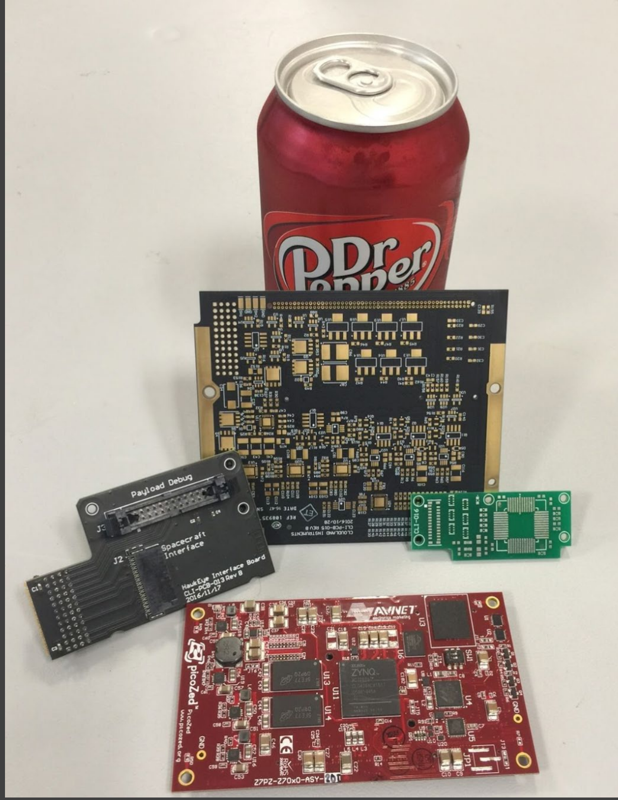
- Optical layout designed by Cloudland Instruments
  - Diffraction style hyperspectral sensor from 422nm - 880 nm
  - CMOS - Onsemi Micron MT9V-034
    - 10 bit
  - PicoZed Board - PicoZed Z7020
    - 1 GB of storage
  - Electronics Interface
    - UART
    - QSPI



SPOCeye optical layout



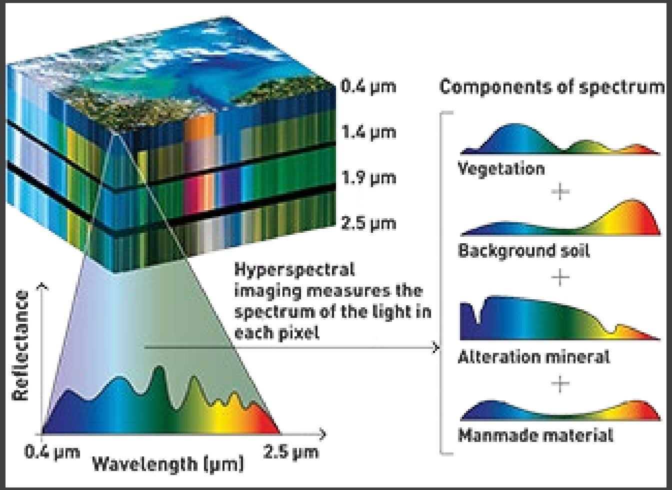
SPOCeye optical housing with adjustable lens mounts



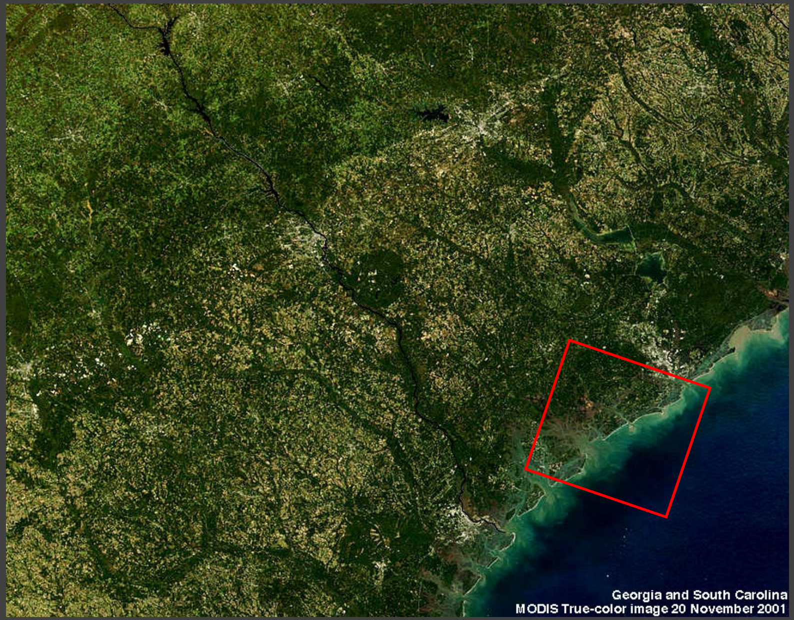
Cloudland Instruments provided PicoZed board and CMOS sensor for SPOCeye

Payload Problem

- Hyperspectral sensor from 422 nm - 880 nm
- 1 scene
  - 750 frames = 9,600km^2 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?



Coffey, 2015, "Hyperspectral Imaging for Safety and Security," Optics and Photonics News.



140,000 km^2 area, red insert represents 9,600 km^2

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

Wavelength (nm)	Bandwidth (nm)	SNR per 20 pixels
443	20	181
490	20	185
510	20	171
555	20	157
670	20	139
750	20	83
865	20	63

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.

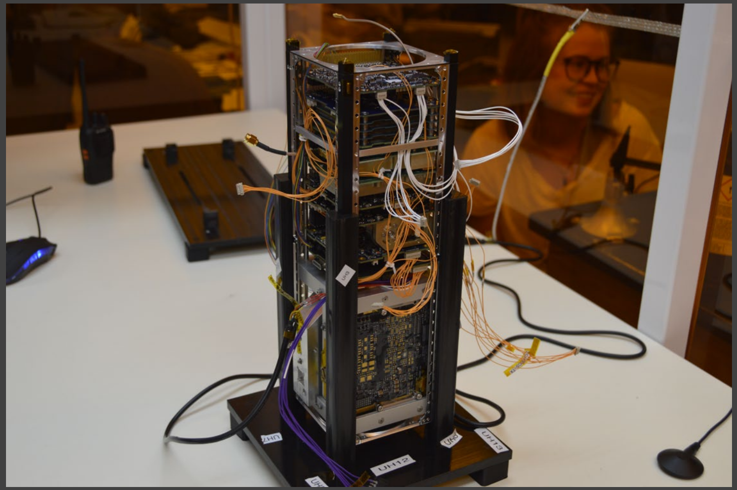
SEPTEMBER 2019

SPOC Handoff to NanoRacks

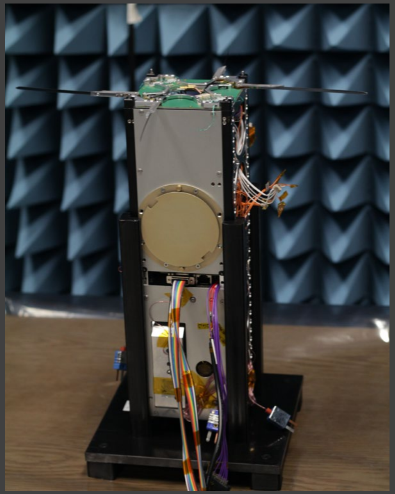
Satellite delivery to NanoRacks.

Testing at NASA Goddard

Working on SPOC in the UGA cleanroom

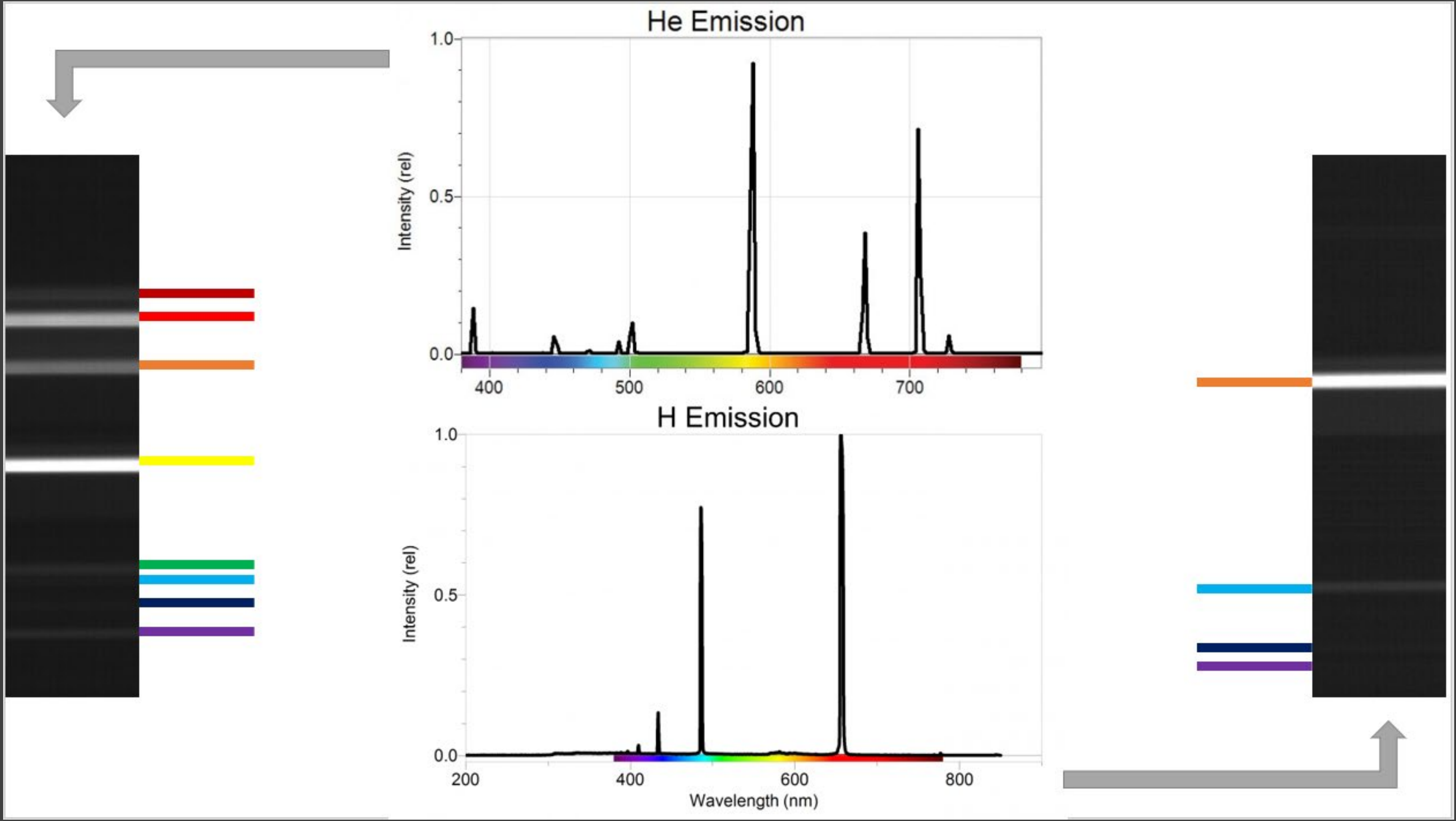


SPOC after initial integration, July 2019



Testing at NASA Ames

Pixel Alignment/Spectral Characterization

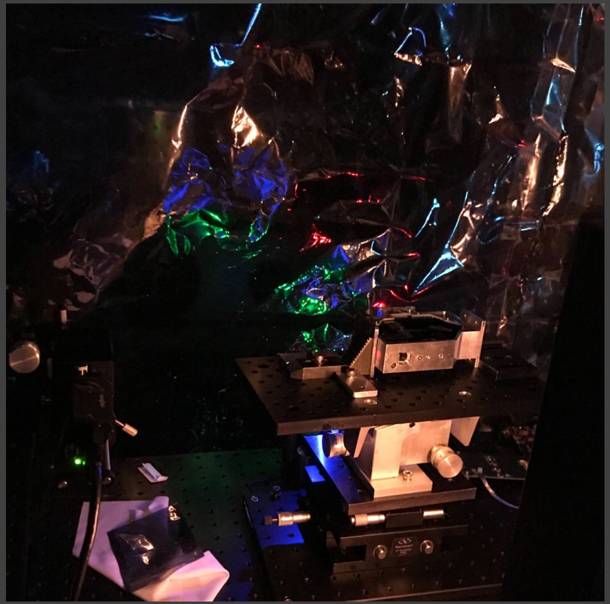


Spectral results using He and H sources

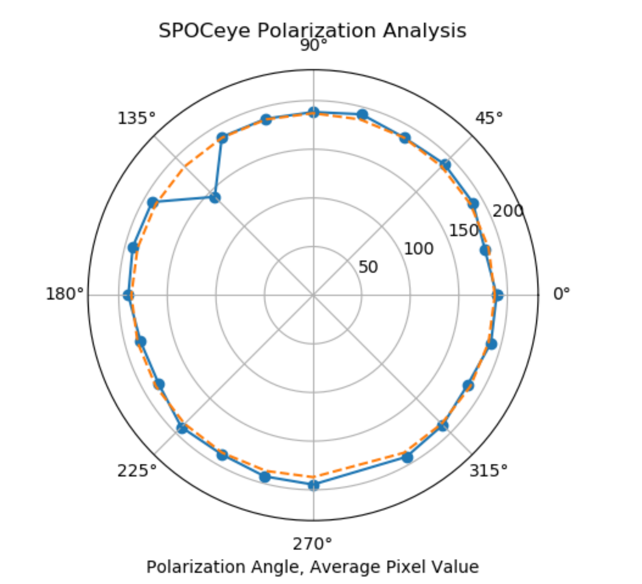
Spectral testing at UGA using various light sources

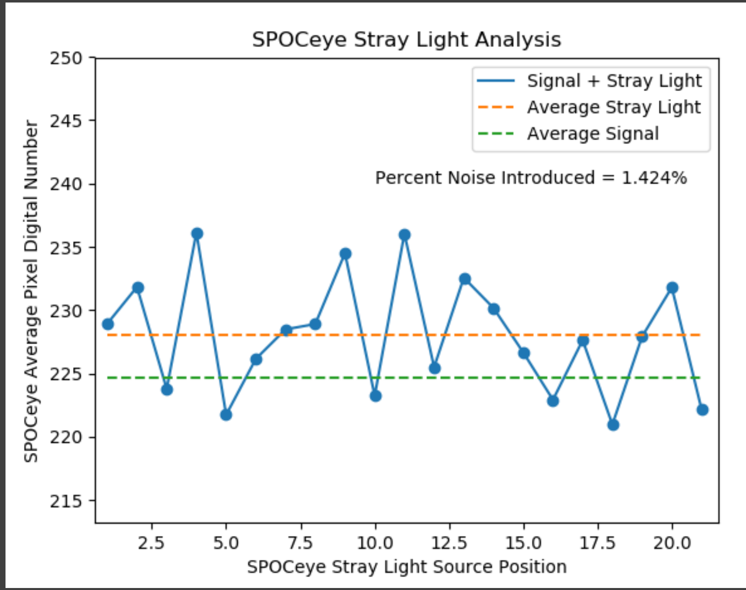
NASA Goddard

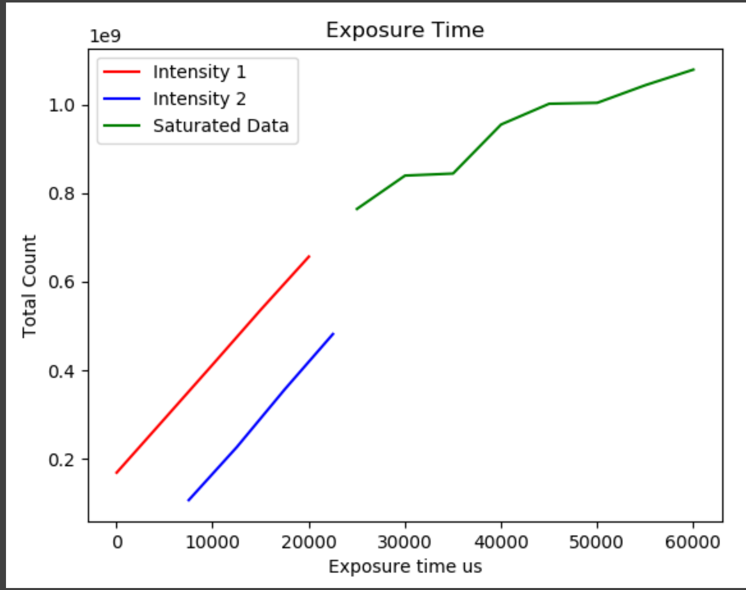
- Optical alignment
  - Locked down
- Polarization effects
- Stray light
- Exposure time non linearity



Optical testing of SPOCeye at Goddard Space Flight Center, May 2019







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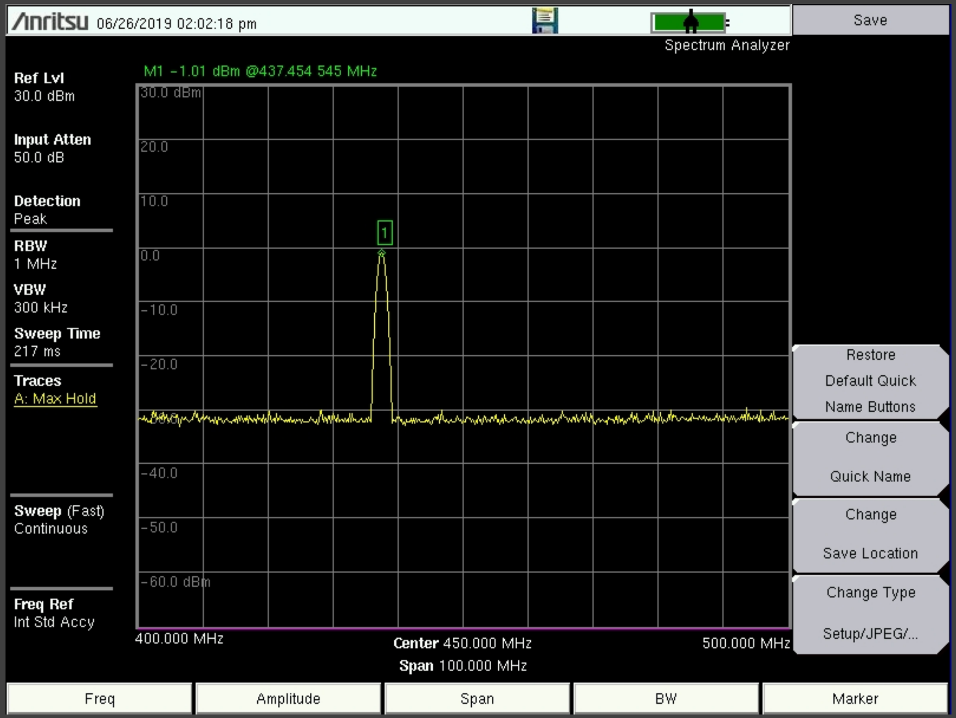
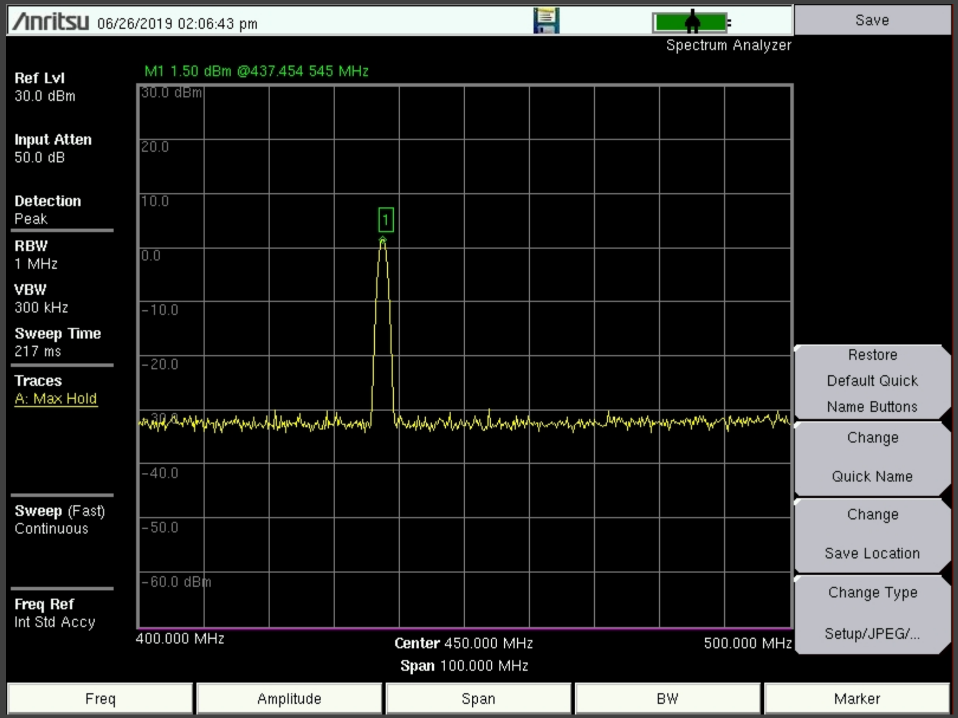
NASA Ames Test results of Comms

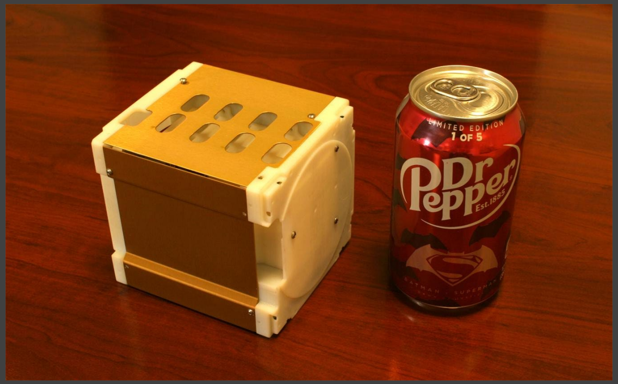
- Temperature and vacuum tests were nominal
- Reflections off of SPOCeye changed the gain pattern ~-2.5 dB on the X+ face





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

Ames Research Center

GEORGIA Space Grant Consortium

AFRL
THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER

NASA
Goddard Space Flight Center

Marine Extension and Georgia Sea Grant
UNIVERSITY OF GEORGIA
Sea Grant

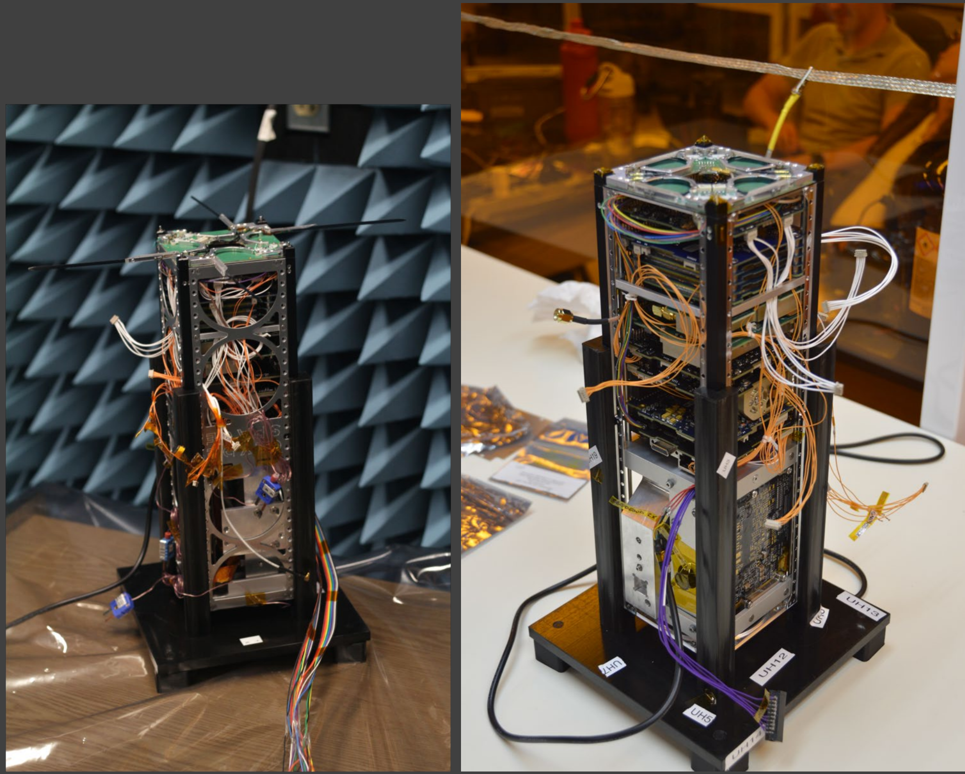
UNP UNIVERSITY NANOSATELLITE PROGRAM

To learn more come to our Booth!

- Booth U4
  - Upstairs in the Field house

Some of the SSRL students at the Flight Selection Review awards ceremony

Team at 2018 Small Sat Conference



SPOC in various stages

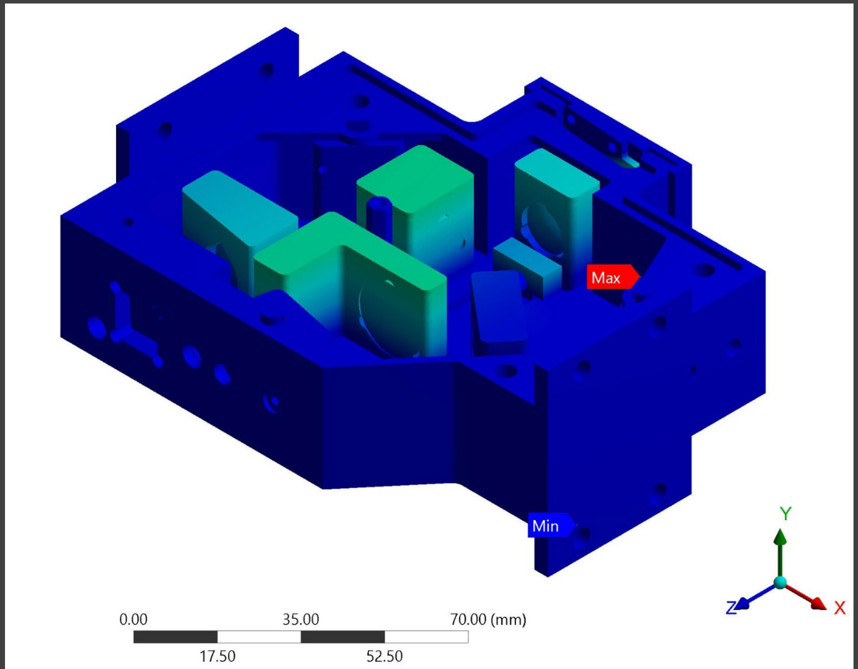
Ground Segment Overview

- UGA Center for Orbiting Satellite Mission Operations (UGA-COSMO)
  - UHF, VHF, and S band capabilities
  - <u>Hardware Defined Radio (HDR)</u>
    - Kenwood TS-2000X transceiver
      - 138 MHz, 440 MHz, 1.2 GHz
    - Kantronics KAM-XL Terminal Node Controller
      - AX.25 Packets, GMSK Modulation
  - <u>Software Defined Radio (SDR)</u>
    - 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)

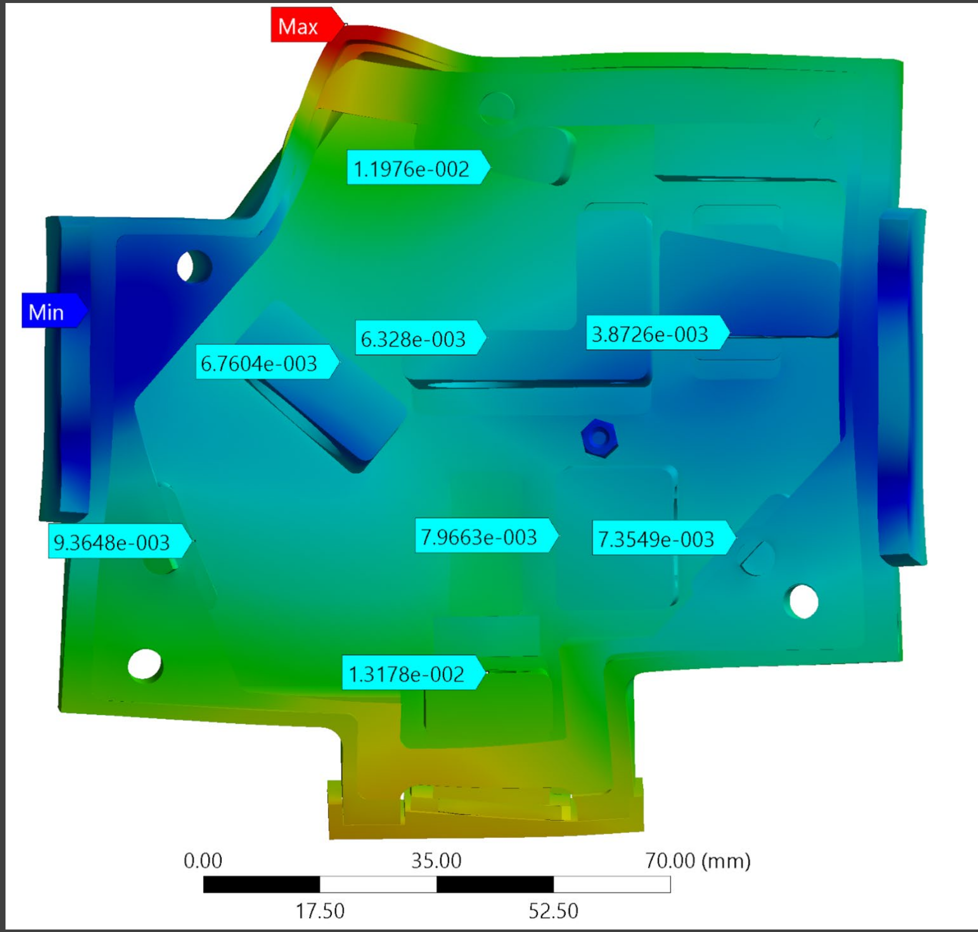

Antenna configuration on the lab roof.


Mission Operations center in UGA SSRL

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