Snow and Water Imaging Spectrometer (SWIS) Assembly and Test

Holly A. Bender, Pantazis Mouroulis, Christopher D. Smith[a], Justin M. Haag, Michael L. Eastwood, Thomas H. Painter, Heidi Dierssen[b], Byron E. Van Gorp, Johannes Gross

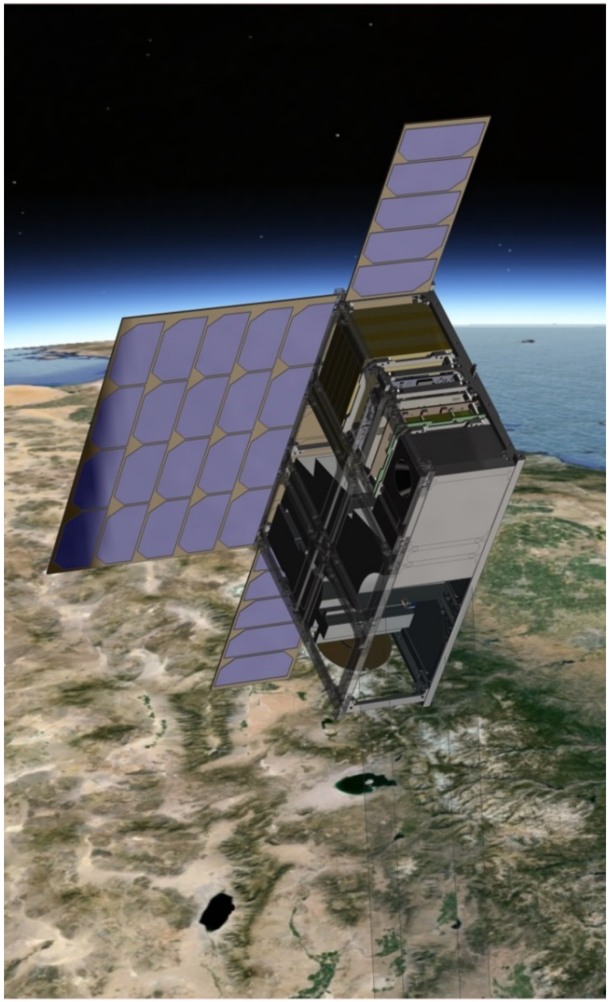
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA
[a]Sierra Lobo Inc., Pasadena, CA
[b]University of Connecticut

ESTF 2017

Overview

- Introduction
- Research and applications
- Mission requirements & instrument specifications
- Mission concepts
- CubeSat configuration
- Assembly and warm alignment

Goal: demonstrate the potential utility of CubeSats to make useful scientific contributions in imaging spectroscopy

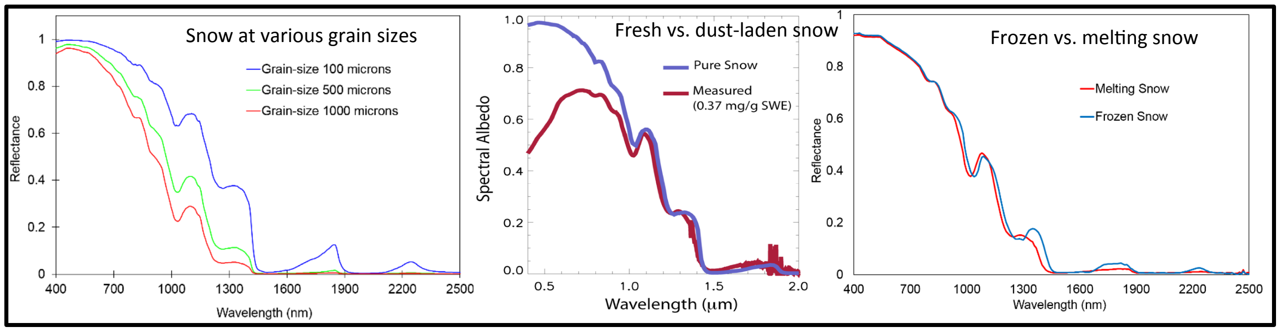


SWIS CubeSat, artist's concept

Research and applications

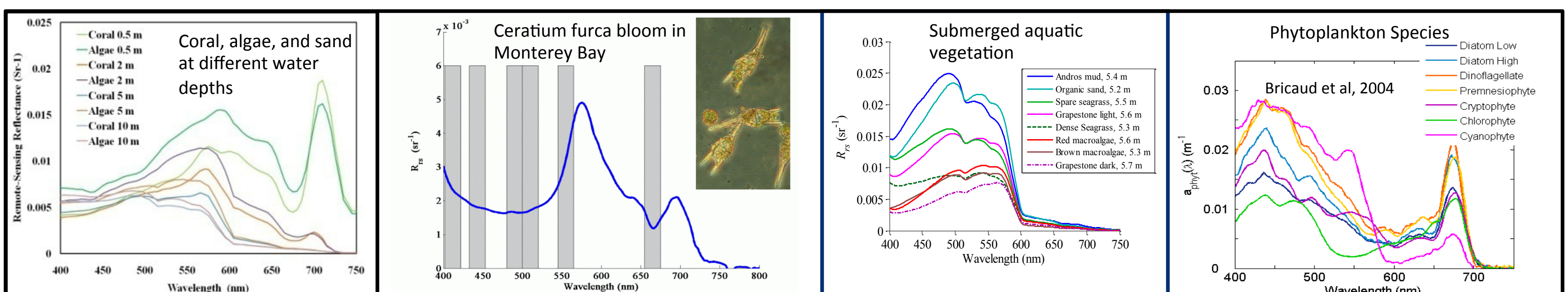
The CubeSat platform is particularly well-suited for two critical science applications with time varying properties that are distributed around the globe:

Snow cover monitoring



Snow spectral signatures contain critical features in **1000-1500 nm** range

Coastal ocean science



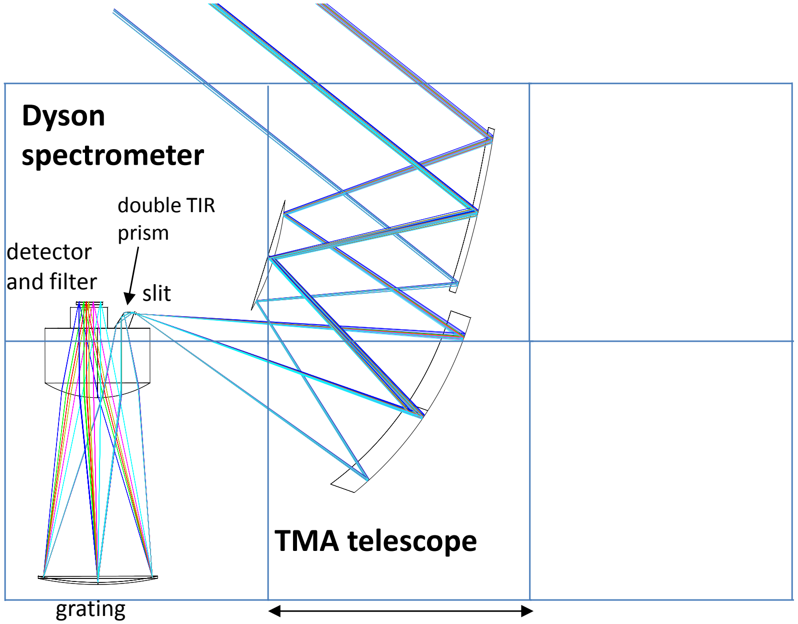
Coastal ocean spectral signatures mainly **below 900 nm**

Mission requirements

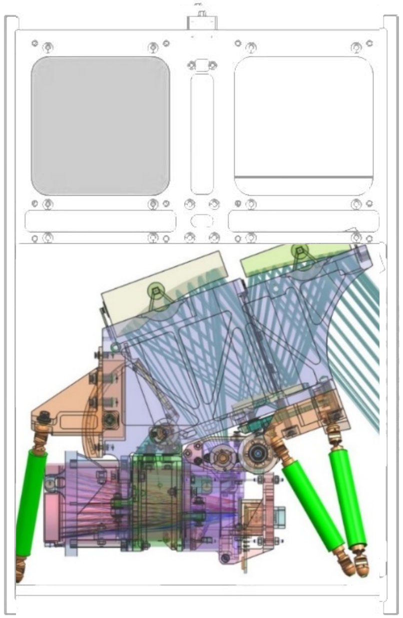
- **Near IR spectral coverage** for discriminating between atmospheric and surface water signatures.
- **High spectral resolution** for detecting subtle changes in the spectral signature of aquatic habitats.
- **High spatial resolution** to limit spectral mixing and resolve signals from ecologically important features.
- **High radiometric sensitivity / SNR** to tease out subtle spectral features from on-orbit radiance dominated by the intervening atmosphere.
- **Maneuverability** for viewing off-nadir targets and higher repeat coverage of key locations.
- **Calibration** using solar radiance and lunar views.

Instrument specifications

Spectrometer and telescope inside 6U CubeSat frame (20 x 30 x 10 cm)



Mouroulis et al, Proc. SPIE 9222, (2014)
Bender et al, Proc. SPIE 9611, (2015)



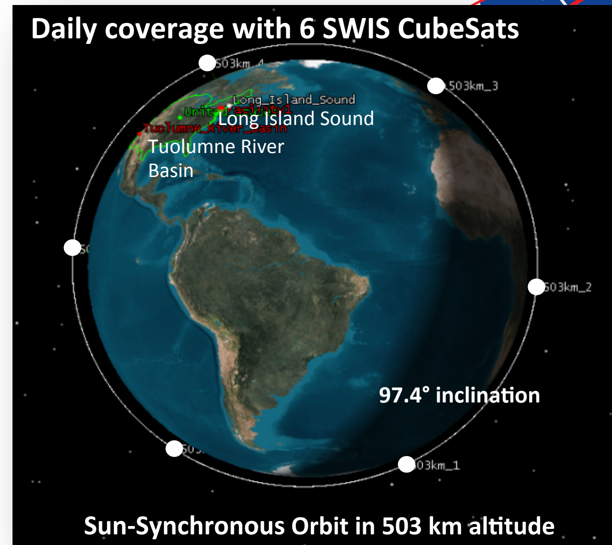
Optical assembly within 6U CubeSat structure

SWIS specifications	
Spectral range	350 – 1700 nm, single FPA
Spectral sampling	5.7 nm
Cross-track spatial elements	600 (+40 monitor)
Cross-track FOV	10° (±20° pointing)
Resolution	0.3 mrad
Detector pixel size	30 µm
Focal length	100 mm
F/#	1.8
Uniformity	95%

Mission examples

Global coverage: 6 CubeSats

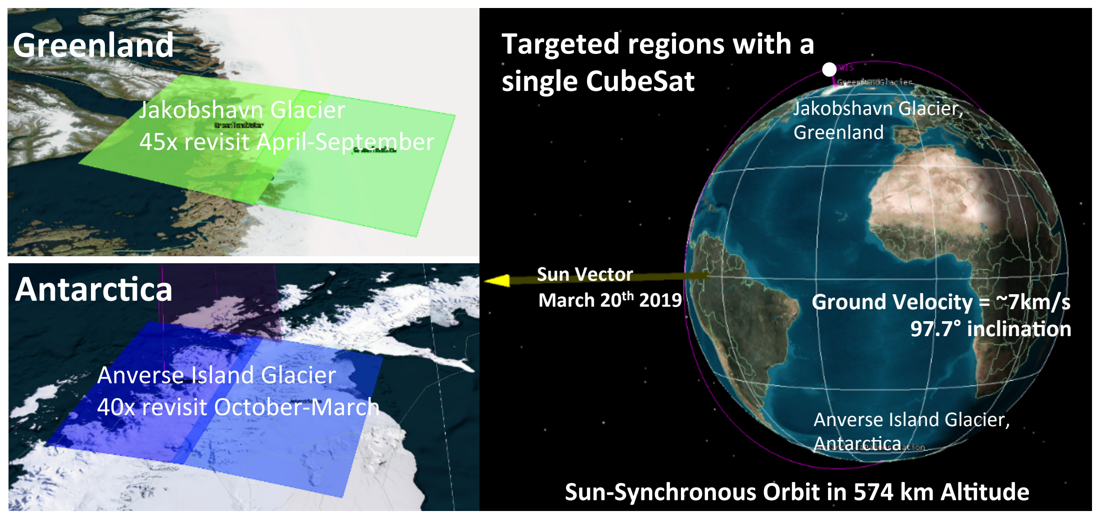
SWIS: Global access (6 CubeSats)	
Resolution	160m from 500km orbit
Mission lifetime	~2 years (no propulsion)
Target frequency	Global daily coverage with 6 CubeSats 10° FOV; 50° FOR with pointing
*Global coverage at low (~1 km) resolution subject to future data transmission rate improvements	



Targeted regions of interest: 1 CubeSat

Gradients from dry snow, to melting snow and ice, to melt-fed open ocean **span the most critical zones of climate change-impacted regions.**

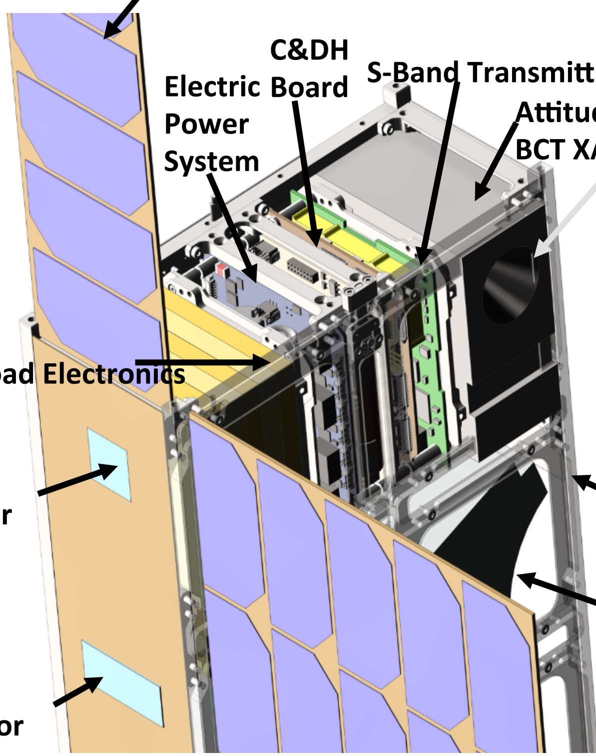
SWIS could **simultaneously map the controlling processes of melt and the response of ocean biology** to melt fluxes and nutrient loading.

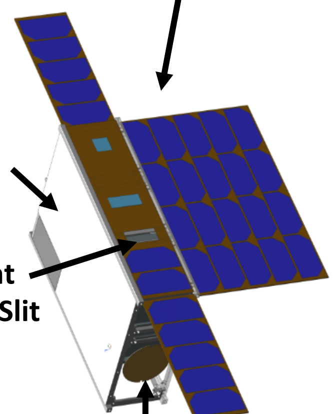


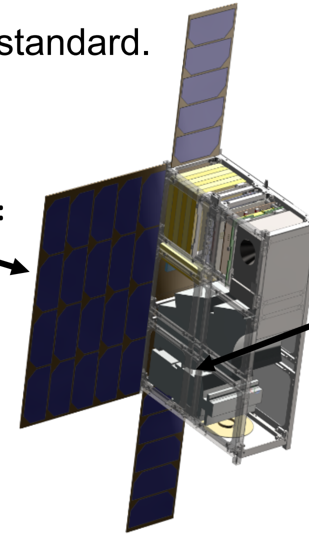
Bender et al, Proc. SPIE 9881, (2016)

6U CubeSat configuration concept

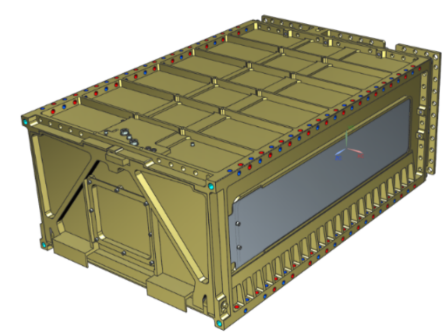
The current SWIS design has a good feasibility within a flexible CubeSat standard.





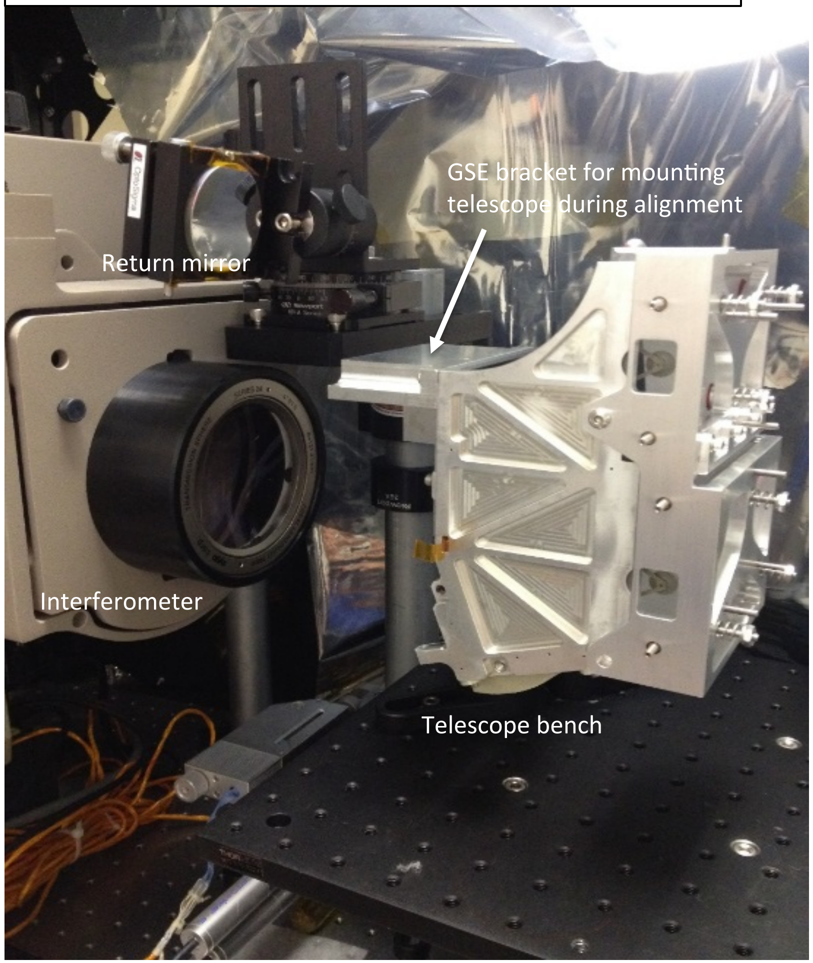


Spacecraft designed to fit within a standard 6U Canisterized Satellite Dispenser (current: Planetary Systems Corporation)

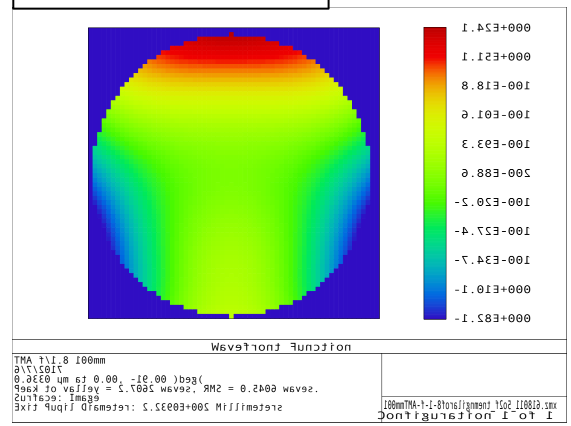


Telescope alignment

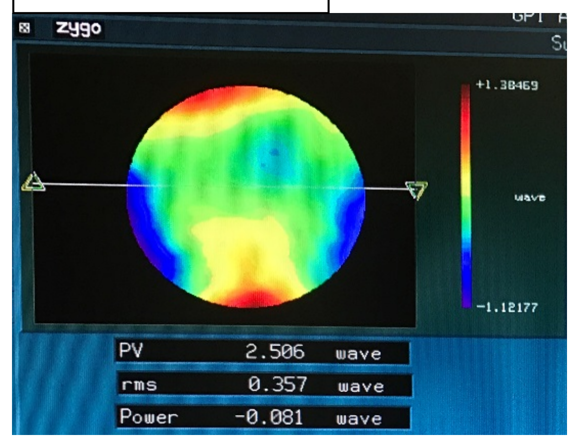
Telescope interferometric alignment



Model prediction:

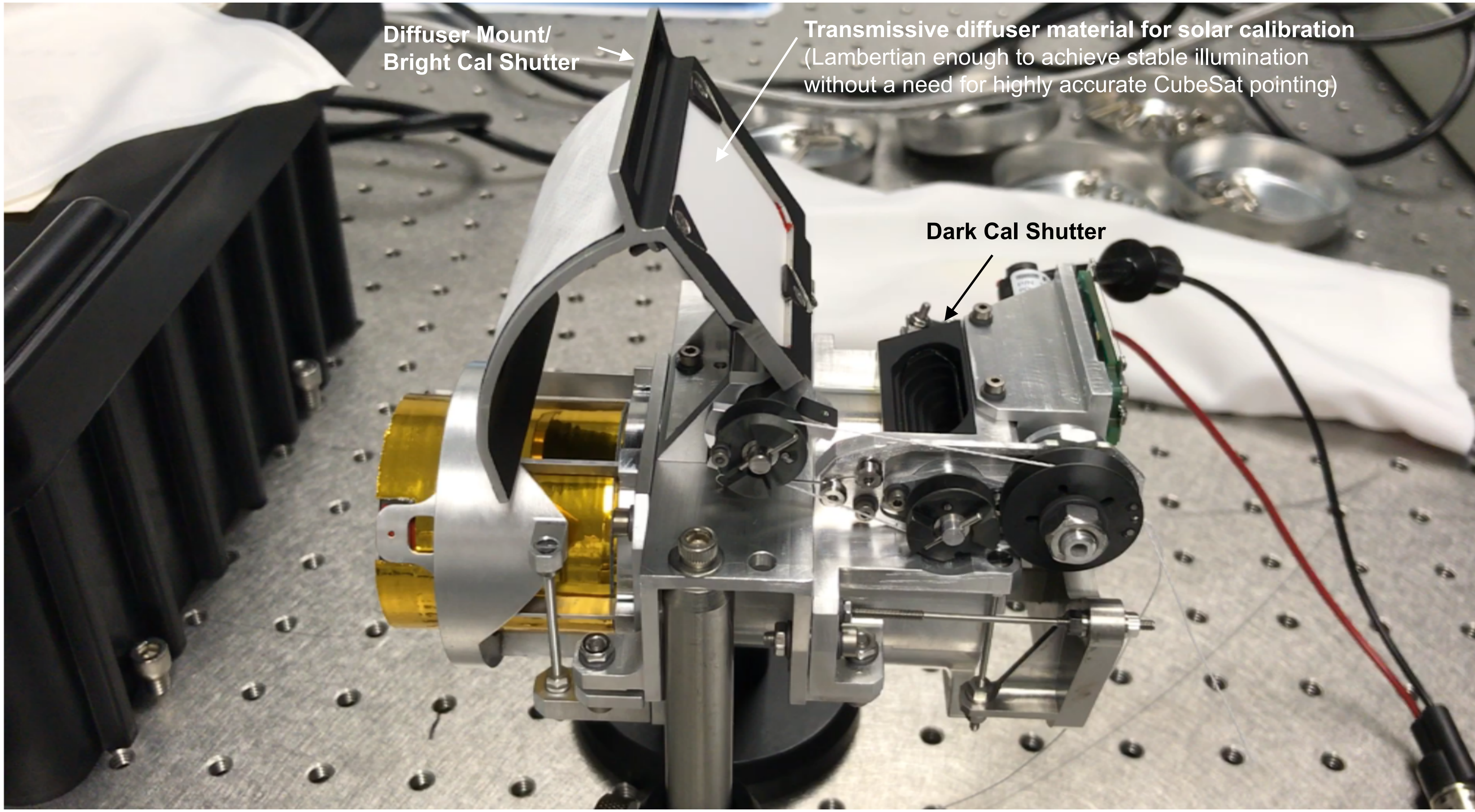


SWIS actual:



Spectrometer and calibration mechanism

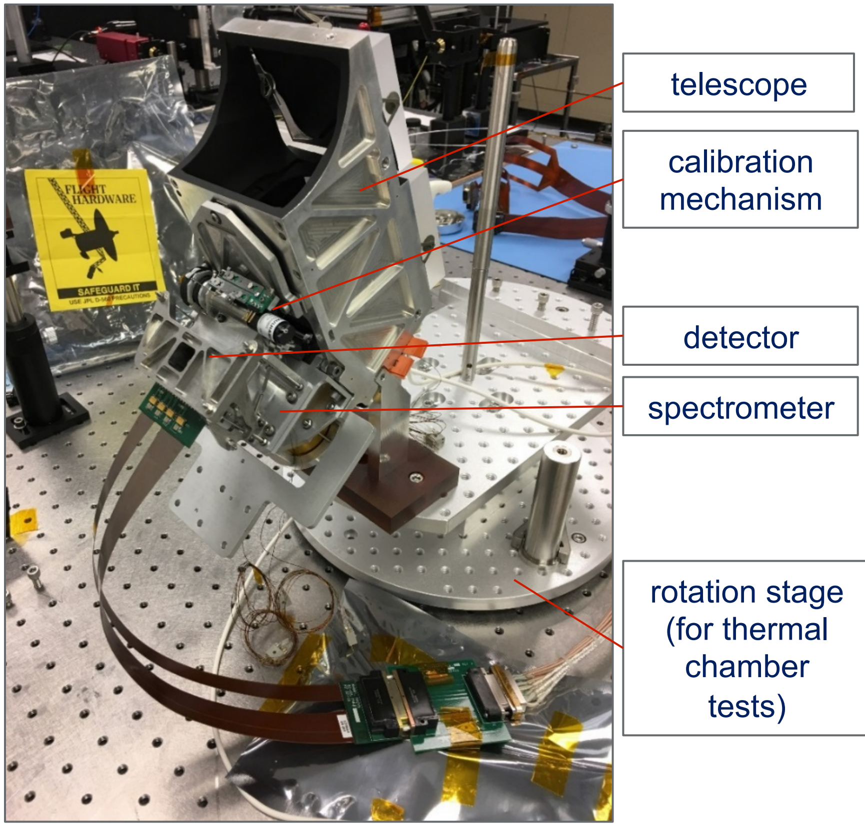
Single drive on-board calibration mechanism performs the dual function of positioning the on-board calibrator and providing a shutter for dark frames

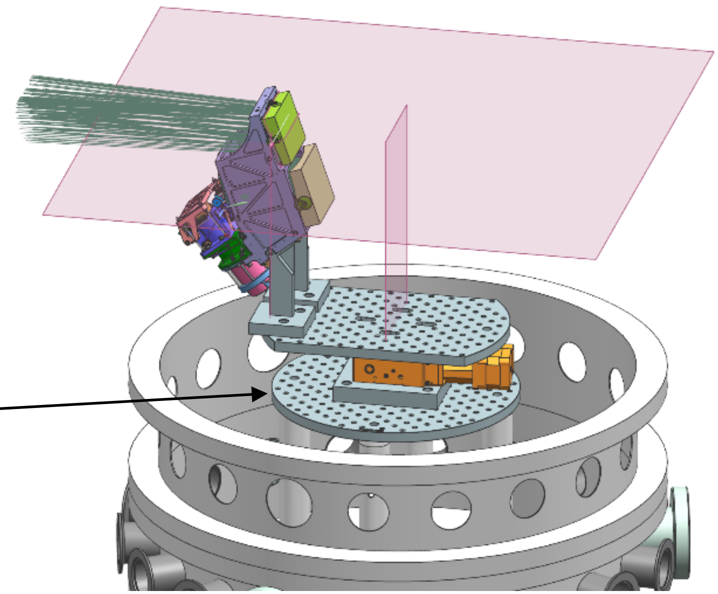


Assembled Dyson spectrometer with calibration mechanism in science position

Full optical assembly

Completed assembly

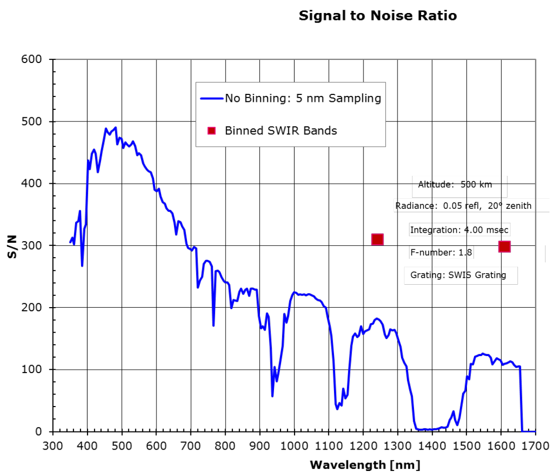


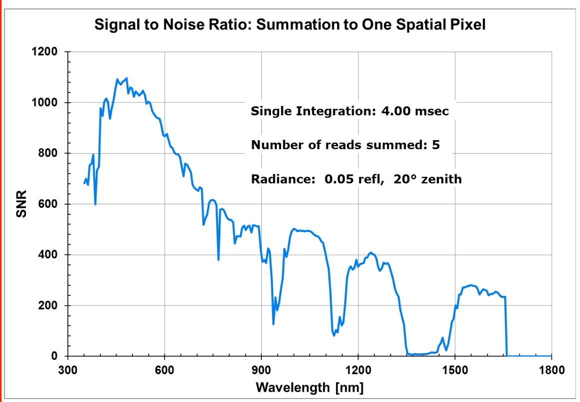


Thermal vacuum chamber mount design

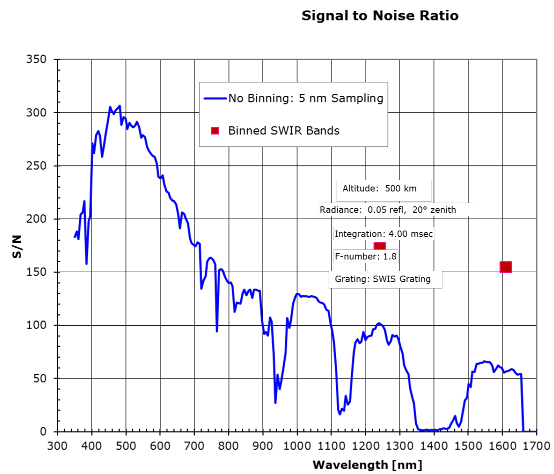
Detector QE and Projected SNR

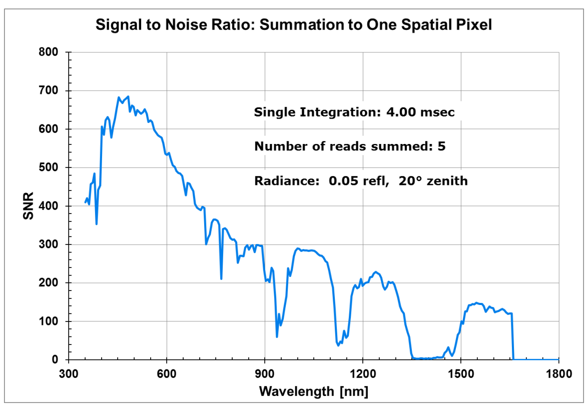
Proposed SNR:





Current projected SNR:

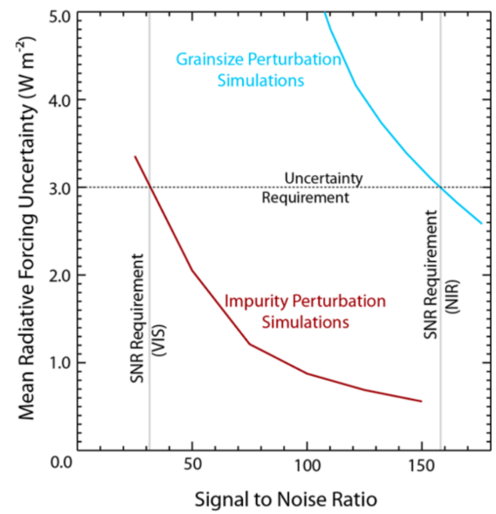




Science impact:

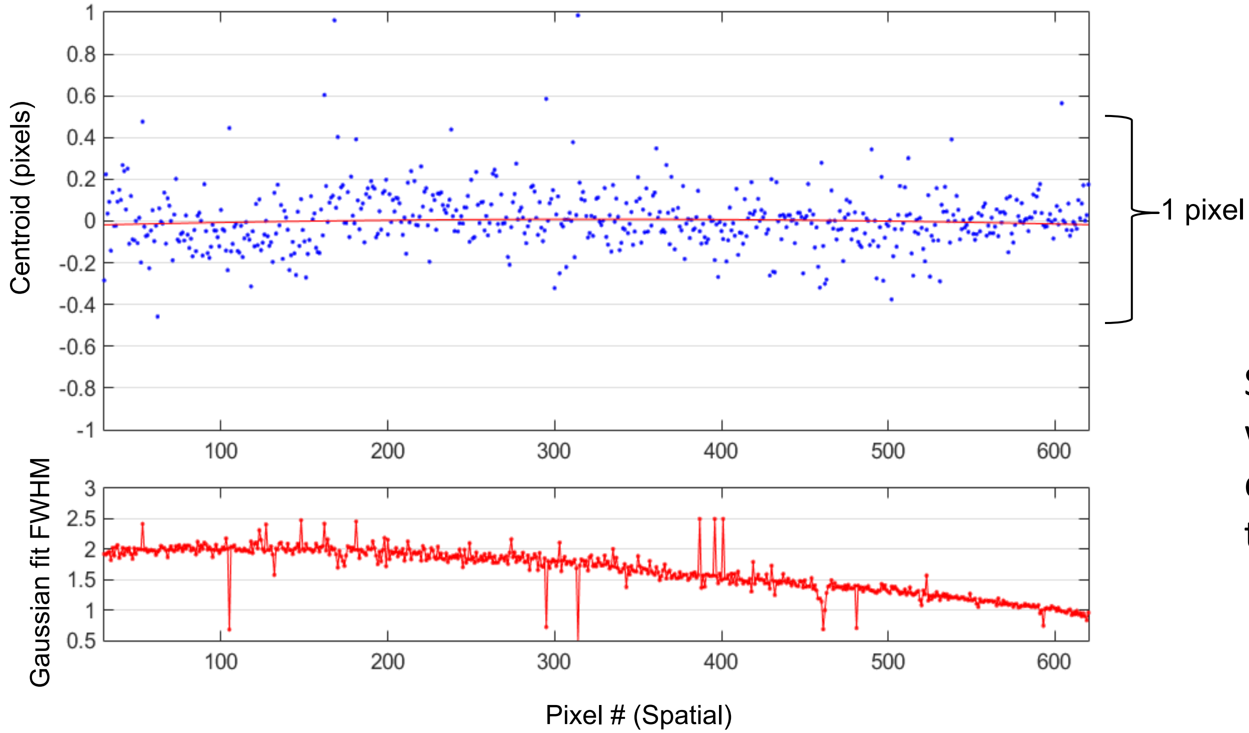
The two main controls on **snow albedo**:

- Grain size (impact in 900-1300 nm); SNR requirement > 160
- Radiative forcing by dust and black carbon (impact in 350-1000 nm); SNR requirement > 30.



Room-temperature preliminary alignment

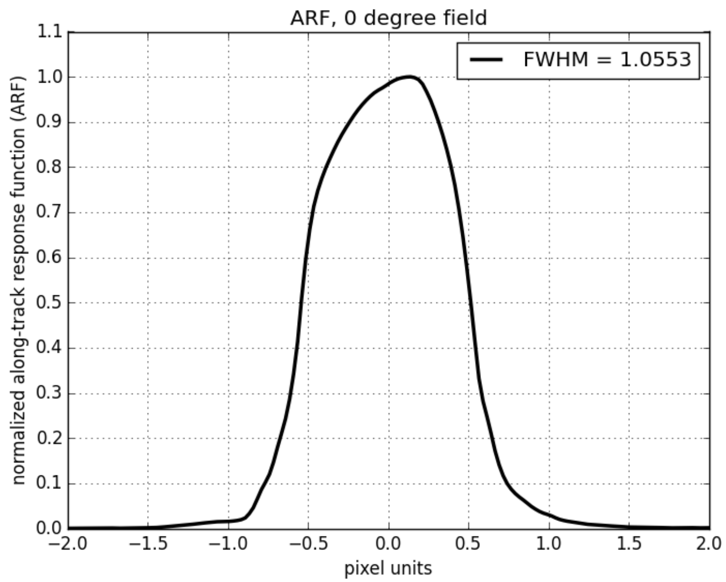
633 nm laser line



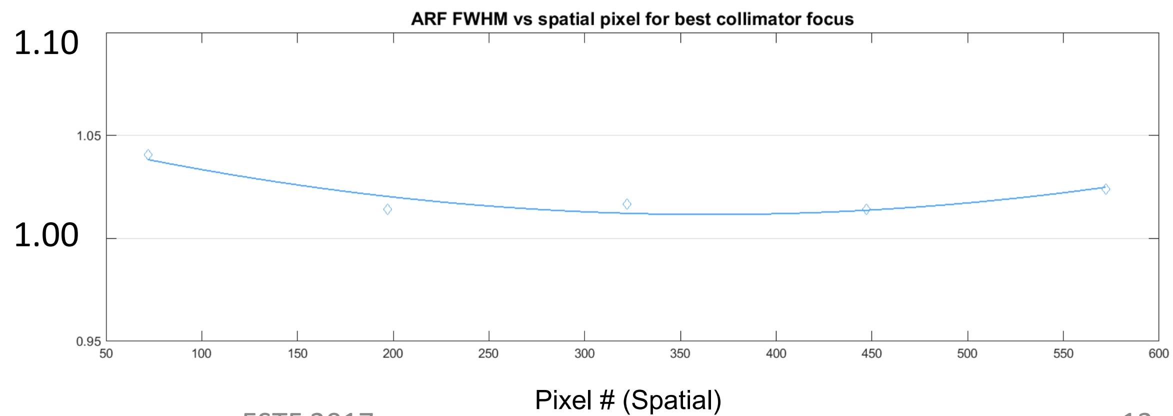
Scatter and bad pixels will improve when detector is at operating temperature <250K

Room-temperature preliminary alignment

Along-track response function (ARF)

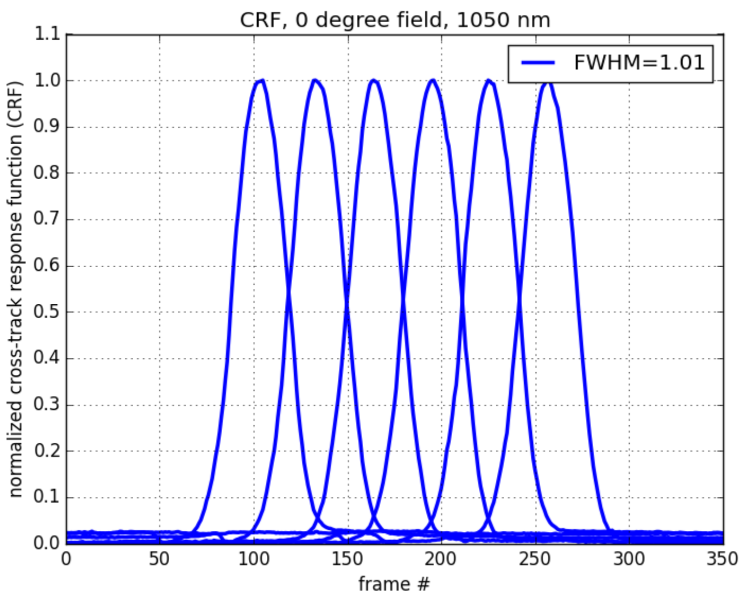


ARF FWHM vs Spatial Pixel



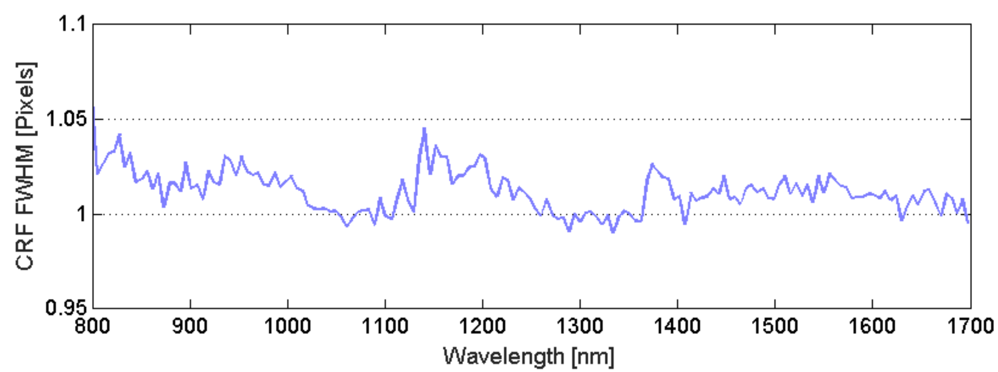
Room-temperature preliminary alignment

Cross-track response function (CRF)



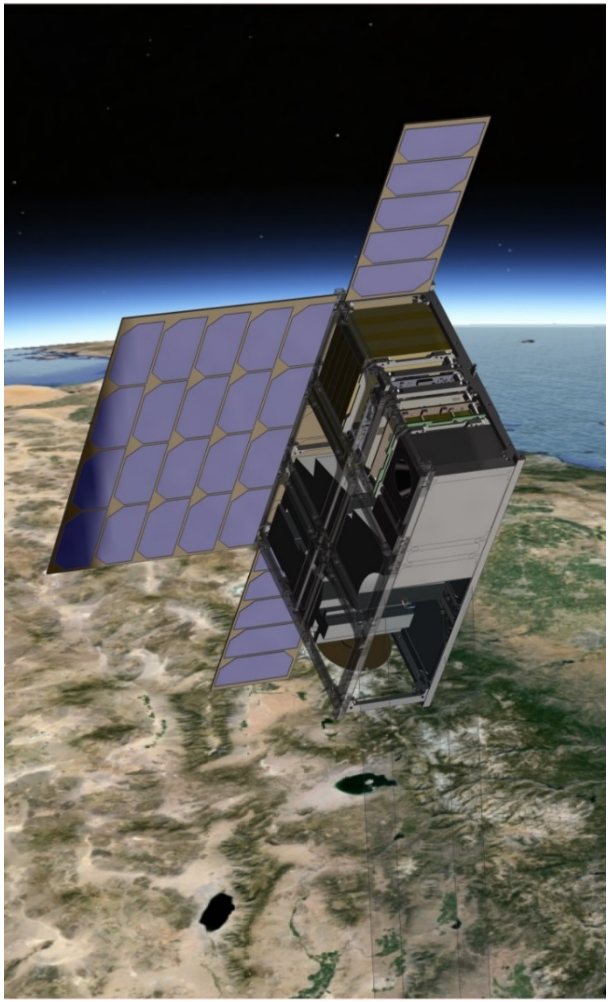
CRF Floor is artifact of high detector temperature

CRF FWHM vs wavelength



Summary

- Imaging spectrometer design suitable for CubeSat applications
- Advances the state of the art in compact sensors of this kind in terms of size and spectral coverage
- Innovative single drive performs dual mechanism function of positioning the on-board calibrator (OBC) as well as providing a shutter for dark frames
- Spacecraft configuration design favorable for accommodation in 6U CubeSat frame
- Useful missions can be designed with high spatial and temporal resolution to address targeted areas of the Earth's surface
- Optomechanical assembly complete with alignment underway
- Thermal and vibration testing of optomechanical assembly to be completed by end of FY17



SWIS CubeSat, artist's concept

Acknowledgments

The SWIS Project Team:

PI: Pantazis Mouroulis

Task Manager: Holly Bender

Co-Is: R. O. Green, T. Painter, H. Dierssen *(University of Connecticut)*, D. Wilson, M. Eastwood, B. Van Gorp, J. Rodriguez

Engineering Team: C. Smith *(Sierra Lobo, Inc)*, J. Haag, V. White, K. Yee, J. Gross, C. Hummel, C. H. Smith, P. Sullivan, E. Liggett, P. Pingree, E. Diaz, D. Preston, R. G. Sellar, Z. Small

Science Collaborator: Steve Ackleson, NRL

Industrial Partner: Teledyne Scientific & Imaging (Jianmei Pan, task manager)