Snow and Water Imaging Spectrometer (SWIS) Assembly and Test

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ESTF 2017

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

Fresh vs. dust-laden snow

Frozen vs. melting snow

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

Coastal ocean science

Coral, algae, and sand at different water depths

Ceratium furca bloom in Monterey Bay

Submerged aquatic vegetation

Phytoplankton Species

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)


**Optical assembly within 6U CubeSat structure**

**SWIS specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral range</td>
<td>350 – 1700 nm, single FPA</td>
</tr>
<tr>
<td>Spectral sampling</td>
<td>5.7 nm</td>
</tr>
<tr>
<td>Cross-track spatial elements</td>
<td>600 (+40 monitor)</td>
</tr>
<tr>
<td>Cross-track FOV</td>
<td>10° (±20° pointing)</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.3 mrad</td>
</tr>
<tr>
<td>Detector pixel size</td>
<td>30 µm</td>
</tr>
<tr>
<td>Focal length</td>
<td>100 mm</td>
</tr>
<tr>
<td>F/#</td>
<td>1.8</td>
</tr>
<tr>
<td>Uniformity</td>
<td>95%</td>
</tr>
</tbody>
</table>
Mission examples

Global coverage: 6 CubeSats

<table>
<thead>
<tr>
<th>SWIS: Global access (6 CubeSats)</th>
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</thead>
<tbody>
<tr>
<td><strong>Resolution</strong></td>
</tr>
<tr>
<td><strong>Mission lifetime</strong></td>
</tr>
<tr>
<td><strong>Target frequency</strong></td>
</tr>
</tbody>
</table>

*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.

6U CubeSat configuration concept

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

Telescope interferometric alignment

GSE bracket for mounting telescope during alignment

Model prediction:

SWIS actual:

Wavefront Function

TMA f/1.8 100mm

6/7/2017

0.6330 µm at 0.00, -19.00 (deg)

Peak to valley = 2.7062 waves, RMS = 0.5406 waves.

Surface: Image

Exit Pupil Diameter: 2.2390E+002 Millimeters
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.
Full optical assembly

Completed assembly

- telescope
- calibration mechanism
- detector
- spectrometer
- rotation stage (for thermal chamber tests)

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, 0 degree field

Normalized along-track response function (ARF)

pixel units

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1

-2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0

ARF FWHM vs Spatial Pixel

ARF FWHM vs spatial pixel for best collimator focus

Pixel # (Spatial)

0.95 1.00 1.05 1.10

50 100 150 200 250 300 350 400 450 500 550 600
Room-temperature preliminary alignment

Cross-track response function (CRF)

CRF, 0 degree field, 1050 nm

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
Acknowledgments

The SWIS Project Team:

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Science Collaborator: Steve Ackleson, NRL

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