Snow and Water Imaging Spectrometer (SWIS)

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Instrument specifications

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

**Optomechanical design within 6U CubeSat structure**

**Spectrometer and telescope**

- Dyson spectrometer
- Detector and filter
- Double TIR prism
- Slit
- Grating

**TMA telescope**

- 10 cm

**Instrument specifications**

**SWIS specifications**

<table>
<thead>
<tr>
<th>Characteristic</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 requirements

• **High spectral resolution** for detecting subtle changes in the spectral signature of aquatic habitats.

• **High radiometric sensitivity / SNR** to tease out subtle spectral features from on-orbit radiance dominated by the intervening atmosphere.

• **Near IR spectral coverage** for discriminating between atmospheric and surface water signatures.

• **High spatial resolution** to limit spectral mixing and resolve signals from ecologically important features.

• **Maneuverability** for viewing off-nadir targets and higher repeat coverage of key locations.

• **Calibration** using solar radiance and lunar views.
Bloom monitoring and assessment

- Assess location, frequency, and formation conditions for bloom occurrence
- Mechanisms for bloom initiation, growth, aggregation, demise
- Monitoring multiple and widespread events not possible from in-situ data

MODIS Terra map of dense *Mesodinium rubrum* bloom, Long Island Sound

HICO map of fluorescence line height from the phycoerythrin accessory pigment within *M. rubrum*

Distinctive spectral features of the bloom

Bloom monitoring and assessment

HICO map of Chlorophyll-a (mg/m³) of Lake Erie reveals patchy distribution of surface cyanobacteria bloom, common to this area.

- Single SWIS satellite can study isolated bloom
- 2-3 satellites can perform systematic assessment

Snow surface and properties

NIR/SWIR snow spectral albedo is sensitive to snow grain size.

VIS/NIR wavelengths sensitive to concentrations of impurities such as black carbon or dust.
Seasonal data

Time series of measured spectral evolution over entire melt season, Rocky Mountains, CO

SWIS will produce similar data sets, although on a global scale instead of single-point research stations.
Example spectroscopic fits using Hyperion data (EO1H2221282005350110KF)

Spectral fitting algorithm, applied to the SWIS 1400 – 1700 nm interval recovers variable ice and liquid absorptions.

Thompson et al, Atmospheric Measurement Techniques 2018
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.

Transmissive diffuser material for solar calibration is Lambertian enough to achieve stable illumination without a need for highly accurate CubeSat pointing.
Full system for testing

- telescope
- calibration mechanism
- detector
- spectrometer
- rotation stage (for thermal chamber tests)
## Measured performance of SWIS spectrometer

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral resolution (FWHM, typical)</td>
<td>1.1 x sampling</td>
</tr>
<tr>
<td>SRF FWHM variation with field (worst-case)</td>
<td>2.5%</td>
</tr>
<tr>
<td>Spectral error (worst case, all wavelengths)</td>
<td>4% (pixel unit)</td>
</tr>
<tr>
<td>ARF resolution (FWHM, typical)</td>
<td>1.1 x sampling</td>
</tr>
<tr>
<td>ARF FWHM variation with wavelength (worst case)</td>
<td>6%</td>
</tr>
<tr>
<td>CRF resolution (FWHM, typical)</td>
<td>1.0 x sampling</td>
</tr>
<tr>
<td>CRF FWHM variation with wavelength (worst case)</td>
<td>2%</td>
</tr>
<tr>
<td>Spectral/IFOV alignment error (worst case, all fields)</td>
<td>3% (pixel unit)</td>
</tr>
</tbody>
</table>
Test results

Spectral response functions

Cross-track spatial response functions for multiple wavelengths

6/13/18
Test results

Along-track spatial response function for various wavelengths

Spatial/IFOV alignment error through wavelength and spectral error through field

ARF of Spectral pixels 241→30, with Field pixels 71→73 averaged. Centered @ λ's=548/795/1202/1600nm

Spatial Pixel #

-0.2  0  0.2  0.4  0.6  0.8  1

-0.15  -0.1  -0.05  0  0.05  0.1  0.15  0.2

6/13/18  ESTF 2018  13
Revised spacecraft configuration
Conclusions

• SWIS Mission is proceeding both in terms of science definition as well as spacecraft configuration
• SWIS has demonstrated its original performance specifications, with confirmation of SNR pending improvements of detector and electronics
• Revised spacecraft configuration shows feasibility
• On-going study with Cal Poly SLO to finalize spacecraft design
Acknowledgments

The SWIS Project Team:

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