Initial Flights of the AVIRIS Next Generation Instrument and HyspIRI Concept Technology Validation

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Overview

• Context Objective and Approach
• Development
• Laboratory Characterization and Calibration
• Inflight Calibration Validation
• HyspIRI Validation
• Summary and Conclusions
The Airborne Imaging Spectrometer (AIS)

AIS Measurements

**IMAGE SPECTRA**

- **KAOLINITE**
- **ALUNITE**
- **BUDDINGTONITE**

- **RELATIVE REFLECTANCE**

- **WAVELENGTH, microns**

- **IMAGE DATA HAVE BEEN FLAT FIELD CORRECTED**

- **SPECTRA ARE FOR 3 BY 3 PIXEL AREAS**
Airborne Visible/Infrared Imaging Spectrometer

- AVIRIS-Classic (AVIRIS-C)

- AVIRIS-Next Generation (AVIRIS-NG)
Research and Applications

- Atmosphere: water vapor, clouds properties, aerosols, absorbing gases …
- Ecology: chlorophyll, leaf water, lignin, cellulose, pigments, structure, nonphotosynthetic constituents …
- Geology and soils: mineralogy, soil type …
- Coastal and Inland waters: chlorophyll, plankton, dissolved organics, sediments, bottom composition, bathymetry …
- Snow and Ice Hydrology: snow cover fraction, grain size, impurities, melting …
- Biomass Burning: subpixel temperatures and extent, smoke, combustion products …
- Environmental hazards: contaminants directly and indirectly, geological substrate …
- Calibration: aircraft and satellite sensors, sensor simulation, standard validation …
- Modeling: radiative transfer model validation and constraint …
- Commercial: mineral exploration, agriculture and forest status …
- Algorithms: autonomous atmospheric correction, advanced spectra derivation …
- Other: human infrastructure …
Objective and Approach

- **Objective:** Pursue important next generation Earth science and science applications
- **Secondary objective:** Test imaging spectrometer elements that may be used in space instruments.
- **Approach:** Develop state-of-the-art imaging spectrometer with exceptional uniformity, signal-to-noise ratio and calibration
<table>
<thead>
<tr>
<th>SPECTRAL</th>
<th>AVIRIS-Next Generation</th>
<th>AVIRIS-Classic</th>
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<tbody>
<tr>
<td>Range</td>
<td>380 to 2510 nm</td>
<td>380 to 2500 nm</td>
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<tr>
<td>Position</td>
<td>5 nm</td>
<td>10 nm</td>
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<tr>
<td>Response</td>
<td>1 to 1.5 X sampling</td>
<td>1 to 1.5 X sampling</td>
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<tr>
<td>Calibration</td>
<td>+-0.1 nm</td>
<td>+-0.1 nm</td>
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<tr>
<td>RADIOMETRIC</td>
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<tr>
<td>Range</td>
<td>0 to max Lambertian</td>
<td>0 to max Lambertian</td>
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<td>Precision (SNR)</td>
<td>&gt;2000 @ 600 nm</td>
<td>&gt;1000 @ 600 nm</td>
</tr>
<tr>
<td></td>
<td>&gt;1000 @ 2200 nm</td>
<td>&gt;400 @ 2200 nm</td>
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<tr>
<td>Accuracy</td>
<td>95% (&lt;5% uncertainty)</td>
<td>90% (&lt;10% uncertainty)</td>
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<td>Linearity</td>
<td>&gt;=99% characterization</td>
<td>&gt;=99% characterization</td>
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<td>SPATIAL</td>
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<tr>
<td>Range</td>
<td>34° field-of-view</td>
<td>34° field-of-view</td>
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<tr>
<td>Sampling</td>
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<td>1 milliradian</td>
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<tr>
<td>Response</td>
<td>1 to 1.5 X sampling</td>
<td>1 to 1.5 X sampling</td>
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<tr>
<td>Sample Distance</td>
<td>0.3 m to 20 m</td>
<td>4 m to 20 m</td>
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<td>Geom Model</td>
<td>Full 3 Axes cosines</td>
<td>Full 3 Axes cosines</td>
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<tr>
<td>UNIFORMITY</td>
<td></td>
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<tr>
<td>Spectral Cross-Track</td>
<td>&gt;95% across FOV</td>
<td>&gt;98% across FOV</td>
</tr>
<tr>
<td>Spectral-IFOV-Variation</td>
<td>&gt;95% Spectral Direction</td>
<td>&gt;98% Spectral Direction</td>
</tr>
</tbody>
</table>
AVIRIS-NG Uniformity

Depiction
- Grids are the detectors
- Spots are the IFOV centers
- Colors are the wavelengths

Cross-Track
- 95% spectral cross-track
- Required Uniformity
- Failure by "frown"
- Failure by Uniformity
- Failure by twist
- Failure by Spectral-IFOV-shift

Wavelength (nm)
AVIRIS Next Generation Optical Concept

Uniform Offner Spectrometer

e-Beam Optimized Grating

e-Beam Air slit

Advanced Two Mirror Telescope

Filter & Full Range Detector
Enabling Elements

High SNR and high uniformity imaging spectrometer designs (Mouroulis et al., 2000)*

Electron-beam lithography low-scatter tuned-high-efficiency gratings on curved surfaces for space

Ultra uniform 27 µm x 20 mm electron-beam lithography slit for space flight

Component mounts with 0.25 micron feedback adjustment that are lockable for space flight

Unique set of alignment and calibration sources and tools for imaging spectrometer development

AVIRIS Next Generation Spectrometer
Installation of First Mirror
AVIRIS Next Generation Telescope
Fully Aligned
Spectrometer to Thermal Shields
AVIRIS Next Generation Instrument in the Laboratory and First Light 14 Months from Funding Start

0.05 = 5% of a spectral Channel
AVIRIS-NG Alignment Cycle #2 and #3

- 22 March 2012
- Alignment from thermal vacuum #2 to #3.
- IFOV uniformity brought from 60% to requirement of \( \geq 95\% \).
AVIRIS-NG Spectral IFOV Uniformity > 95%
Radiometric Calibration

Standards and Equipment

NIST traced lamp panel 350-2500 nm
Stable variable intensity integrating sphere
Evolution of Laboratory Calibration Source

![Graph showing the evolution of laboratory calibration source with radiance (µW/cm²/nm/sr) on the y-axis and wavelength (nm) on the x-axis. The graph compares 1 Lamp and 3 Lamps plus Filter.](image-url)
AVIRIS-NG 380 to 2510 nm

\[ y = -5.0044x + 2685.5 \]

\[ R^2 = 1 \]
Example NGIS Spectral Response

VNIR Functions

SWIR
Example Spectral Response Function
Cross-Track Spectral Uniformity

>95% uniform in the flight environment
AVIRIS-NG Orthorectification Test

Raw Data

AVIRIS-NG Orthorectified

Successful Orthorectification
AVIRIS Next Generation Data Subsystem

- AVIRIS Next Generation computer in place
- ANG calibration modules testing
  - Spectral radiometric
  - Orthorectification
- ANG flight lines in AVIRIS website
- Plans for automated distribution of ANG data from website
AVIRIS-NG and HyspIRI VSWIR Concept

- Two mirror telescope
- Offner spectrometer
- Uniform SiN slit (eBL)
- Convex grating (eBL)
- Alignment mounts
- Alignment process
- All aluminum telescope
- Full range detector
- Order sorting filter
- Uniformity requirements
- Vacuum operation
- 140 K operation
• The science enabled by a high uniformity and high signal-to-noise ratio imaging spectrometer is well established
  - AVIRIS referred to in > 700 journal articles in the refereed literature

• A set of instruments requirements flowing from the science objectives and experience with AVIRIS-Classic were established

• ARRA funding became available 2009 AVIRIS-NG. The first spectra were acquired with 14 Months of funding start.

• The first flight was on the 22\textsuperscript{nd} of April 2012

• AVIRIS-NG validates a wide range of technology and implementation elements of the HyspIRI VSWIR concept

• AVIRIS-NG is expected to be available for science validation, research and application data acquisition in 2013
Global Science

**Ecosystems:** Global climate feedback, biochemistry, plant functional-type, and physiological condition, including agricultural lands.

**Fires:** Fuel status, burn severity, and patterns of recovery globally.

**Coral reef and coastal habitats:** Global composition and status.

**Snow and Ice:** Spectral albedo; black carbon/dust on snow/Ice including arctic.
Backup