HyspIRI Preparatory Airborne Campaign
and
30 m, 185 km
VSWIR Dyson

Robert O. Green and The HyspIRI Team
Current Preparatory Airborne Campaign
### HyspIRI Configuration on ER-2

<table>
<thead>
<tr>
<th>ER-2</th>
<th>AVIRIS</th>
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<th>MASTER</th>
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</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>Resolution</td>
<td>Swath</td>
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**AVIRIS (VSWIR)**
- 10 nm spectral resolution
- 224 bands
- 380-2510 nm
- 1 mrad IFOV
- 34 degree FOV

**MASTER (TIR)**
- 50 bands
- 0.4-13 um
- 2.5 mrad IFOV
- 85.92 degrees FOV
Campaign
- science team with 14 PIs
- Delivered Level 1 and Level 2 data products

Ecosystems, Seasonal, Climate, Coastal, Urban, Resources
- 6 zones, 3 seasons, 3 years

Objective: Advance HyspIRI Mission Science and Algorithm Readiness
- Ecosystem composition, function, biochemistry, seasonality, structure, and modeling
- Coastal ocean phytoplankton functional types, habitat
- Urban land cover, temperature, transpiration
- Surface energy balance
- Atmospheric characterization and local methane sources
- Surface geology, resources, soils, hazards
## Western US 14 Investigations

<table>
<thead>
<tr>
<th>PI</th>
<th>Organization</th>
<th>Investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul Moorcroft</td>
<td>Harvard</td>
<td>Linking Terrestrial <strong>Biosphere Models</strong> with Imaging Spectrometry Measurements of Ecosystem Composition, Structure, and Function</td>
</tr>
<tr>
<td>Dar Roberts</td>
<td>UC Santa Barbara</td>
<td>HySpIRI discrimination of <strong>plant species</strong> and functional types along a strong environmental-temperature gradient</td>
</tr>
<tr>
<td>Philip Townsend</td>
<td>UWI</td>
<td>Measurement of <strong>ecosystem metabolism</strong> across climatic and vegetation gradients in California for the 2013-2014 NASA AVIRIS/MASTER airborne campaign</td>
</tr>
<tr>
<td>Susan Ustin</td>
<td>UC Davis</td>
<td>Identification of <strong>Plant Functional Types</strong> By Characterization of Canopy Chemistry Using an Automated Advanced Canopy Radiative Transfer Model</td>
</tr>
<tr>
<td>Matthew Clark</td>
<td>Sonoma State</td>
<td>Spectral and temporal discrimination of <strong>vegetation cover</strong> across California with simulated HySpIRI imagery</td>
</tr>
<tr>
<td>Bo-Cai Gao</td>
<td>NRL</td>
<td>Characterization and <strong>Atmospheric Corrections</strong> to the AVIRIS-Classic and AVIRISng Data to Support the HySpIRI Preparatory Airborne Activities</td>
</tr>
<tr>
<td>Bernard Hubbard</td>
<td>USGS</td>
<td>Using simulated HySpIRI data for <strong>soil mineral mapping</strong>, relative dating and flood hazard assessment of alluvial fans in the Salton Sea basin, Southern California</td>
</tr>
<tr>
<td>George Darrel Jenerette</td>
<td>UC Riverside</td>
<td>Assessing Relationships Between <strong>Urban Land Cover, Surface Temperature, and Transpiration</strong> Along a Coastal to Desert Climate Gradient</td>
</tr>
<tr>
<td>Thomas Kampe</td>
<td>NEON</td>
<td>Synergistic high-resolution airborne measurements of ecosystem structure and process at NEON sites in California</td>
</tr>
<tr>
<td>Raphael Kudela</td>
<td>UC Santa Cruz</td>
<td>Using HySpIRI at the Land/Sea Interface to Identify <strong>Phytoplankton Functional Types</strong></td>
</tr>
<tr>
<td>Ira Leifer</td>
<td>Bubbleology</td>
<td>Hyperspectral imaging spectroscopic investigation of California natural and anthropogenic fossil <strong>methane</strong> emissions in the short-wave and thermal infrared</td>
</tr>
<tr>
<td>Shunlin Liang</td>
<td>UMD</td>
<td>Characterizing <strong>surface energy budget</strong> of different surface types under varying climatic conditions from AVIRIS and MASTER data</td>
</tr>
<tr>
<td>Jan van Aardt</td>
<td>RIT</td>
<td>Investigating the impact of spatially-explicit <strong>sub-pixel structural variation</strong> on the assessment of vegetation structure from HySpIRI data</td>
</tr>
<tr>
<td>Wendy Calvin</td>
<td>UNV</td>
<td><strong>Energy and Mineral Resources</strong>: Surface composition mapping that identifies resources and the changes and impacts associated with their development</td>
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</table>
Western US Finishing 2015

3 Seasons in 2013, 3 Seasons in 2014, Staring 2015
Data is Available


### AVIRIS Classic Data Volumes by Year

<table>
<thead>
<tr>
<th>Flight Year</th>
<th>L0 (GB)</th>
<th>L1B (GB)</th>
<th>L2 (GB)</th>
</tr>
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<tbody>
<tr>
<td>2010</td>
<td>1700</td>
<td>2669</td>
<td>-</td>
</tr>
<tr>
<td>2011</td>
<td>1769</td>
<td>2117</td>
<td>-</td>
</tr>
<tr>
<td>2012</td>
<td>331</td>
<td>318</td>
<td>-</td>
</tr>
<tr>
<td>2013</td>
<td>1498</td>
<td>1566</td>
<td>912</td>
</tr>
<tr>
<td>2014</td>
<td>1265</td>
<td>3630</td>
<td>844</td>
</tr>
<tr>
<td>Total (GB)</td>
<td>18377</td>
<td>19013</td>
<td>1756</td>
</tr>
<tr>
<td>Total (TB)</td>
<td>17.9 TB</td>
<td>18.6 TB</td>
<td>1.71 TB</td>
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![Map of AVIRIS flight locations](image)
In order to quantify ecosystem characteristics, composition and dynamics with measurements from the visible through thermal infrared. NASA has conducted a multi-season, multi-year science campaign over 6 large regions of the western United States in preparation for the future HyspIRI Mission. Full visible through short wavelength infrared imaging spectroscopy as well as thermal infrared images have been acquired. These data capture diverse surface types including the coastal zone, mountains, forests, deserts, agriculture, urban areas. Results span: ecosystem composition, function, biochemistry, seasonality, and modeling; coastal ocean phytoplankton functional types; urban land cover, temperature, evapotranspiration; surface energy balance; atmospheric characterization and local methane sources; surface geology, resources, soils, and hazards. The campaign captured the onset of the most severe draught in California’s history and includes the Rim and King fire impact zones. These data have already been used in post-fire mitigation, providing an early demonstration of the measurements’ great value for basic and applied sciences.
2016 HyspIRI Preparatory Airborne Campaign Continued:
Volcanoes & Coral Reefs

Robert O. Green and the HyspIRI Team
Coral Reefs and Volcanoes
Identified in Decadal Survey as
Key Elements of of HyspIRI
## HyspIRI Configuration on ER-2 for Hawaii

**PLUS possible PRISM and HyTIES**

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A.45 HYSPIRI PREPARATORY AIRBORNE ACTIVITIES AND ASSOCIATED SCIENCE: CORAL REEF AND VOLCANO RESEARCH

This NASA ROSES element is soliciting proposals for volcano and coral reef research resulting from a single campaign of flights in 2016 to the Hawaiian Islands by the ER-2 aircraft carrying the AVIRIS and MASTER instruments. For the purposes of this solicitation, Hawaiian Islands extends from the Big Island of Hawaii through the Northwestern Hawaiian Islands or Leeward Islands to Kure Atoll.

NASA anticipates the potential of using this planned campaign to evaluate further the performance and utility of a new generation of airborne spectrometers. These are the Hyperspectral Thermal Emission Spectrometer (HyTES) and the Portable Remote Imaging Spectrometer (PRISM)
Hawaii Preparatory Opportunity
Previous Shallow Water Spectroscopy
Corals

- Composition
- Condition
- Productivity
- Bathymetry
- Water quality

AVIRIS Image of Kaneohe Bay, HI
Classification of the bottom of coastal zones and coral reef types
Summary

- Planning to have a Science Team Announced by the end of September 2015
- 1st Science Team Meeting at October Workshop
- Flights in 2016 plan refined by Science Team
- All data products available
- Future Possible India Deployment of AVIRIS-NG for Asia Environments
This airborne campaign would provide the **first of their kind** high fidelity imaging spectroscopy measurement of a diverse set of Asian environments for NASA.

This campaign would enable new scientific and applications research in these unique environments:
- Natural ecosystems (Humid, Temperate, Dry)
- Water resources: Snow and Ice (Dust and black carbon)
- Geology and Natural Hazards (floods, droughts, fire ...)
- Coastal and inland waters, Coral reefs
- Agricultural lands and Urban areas

This campaign builds upon the current plan for AVIRIS-NG to fly on a US B-200 aircraft in 2015 (and ER-2 in 2016).
India B200 Aircraft with Port
Evolved HyspIRI
VSWIR Imaging Spectrometer

Following Guidance from HQ

185 km Swath and 30 m Sampling
Imaging Spectrometers & Advancements

- First Imaging Spectrometer AIS proposed in 1979, first flights in 1982
- AVIRIS imaging spectrometer > 700 refereed journal articles
- NIMS imaging spectrometer to Jupiter
- VIMS imaging spectrometer to Saturn
- MICAS Miniature Integrated Camera and Imaging Spectrometer to Comet
- Enabling partner in Hyperion-Earth, CRISM-Mars and ARTEMIS-Earth imaging spectrometers (gratings, designs, calibration, science)
- Proposed and Developed NASA Moon Mineralogy Mapper (M3)
- > 7 Airborne/Rover-type Imaging Spectrometer operating at cryogenic temperature and in a vacuum (2005-2014)
A key Technology Investment Area


1986: >200 kg
2005: 100 kg
2008: 8 kg
2014: 3 kg

JPL Offner Imaging Spectrometer

Single Blaze
Area Weighted Blaze
Concentric Blaze
Uniform Facet Blaze
Fully Structured Blaze

2000 Earth Hyperion
2005 Mars CRISM
2005 Earth Airborne
2008 Moon M3
2009 Earth ARTEMIS
2014 Ultracompact Development Model

Hydroxyl on the illuminated surface of the Moon
For 185 km Swath at 30 Sampling

Dyson Spectrometer is Optically Fast
F/1.8
State-of-the-art evolved Dyson spectrometer.

**Measurement Characteristics**

**Spectral**
- System: Single spectrometer, single detector
- Range: ≤380 to ≥2510 nm
- Sampling: 7 nm (uniform over range)
- Accuracy: ±0.25 nm

**Radiometric**
- Range & Sampling: 0 to max benchmark radiance, 14 bits
- Accuracy: ≥95% absolute radiometric
- Precision (SNR): ≥600 in VNIR and ≥400 SWIR

**Spatial**
- Cross-Track Samples: 6200
- Swath: 185 km nadir
- Ground Sampling: 30 m nadir
- Pointing: 30 m 1sigma Knowledge

**Uniformity**
- Spectral Cross-Track: ≥95% cross-track uniformity
- Spectral-IFOV: ≥95% spectral IFOV uniformity
VSWIR-Dyson Measurement
Signal-to-Noise Ratio

S/N

Wavelength [nm]

Radiance Level
- 1%, 45 deg
- 5%, 45 deg
- 25%, 23.5 deg
- 50%, 23.5 deg

Spectrometer: 240 K
FPA: 140 K
Integration: 4.39 ms
Δλ: 7 nm

30 m sampling
Uniformity, SNR and Calibration

- Uniformity (spectral, radiometric, spatial)
  - Enables spectroscopy across the image

- High Precision (SNR)
  - Information from spectra
  - Number of materials measurable and separable is a function of SNR

- Calibration (spectral, radiometric, spatial)
  - Required for the physics, chemistry, and biology of spectroscopy
  - Allows autonomous compensation for the atmosphere
HyspIRI is a global mission, measuring land and shallow aquatic habitats at 30 meters and deep oceans at 1km every 16 Days (VSWIR)

HyspIRI’s VSWIR imaging spectrometer directly measures the full solar reflected spectrum of the Earth from 380 – 2510 nm at 10 nm with a high signal-to-noise ratio
2015 HyspIRI Science Workshop
Workshop Objectives

- Interact with broad science community
- Review HyspIRI Mission Concept and next Decadal Survey
- Discuss ECOSTRESS TIR instrument headed to the ISS
- Present new relevant Science and Science Applications
- Review results from the 1\textsuperscript{st} and 2\textsuperscript{nd} year of the HyspIRI preparatory airborne campaign
- Discuss mission concepts for smallsat compatible HyspIRI measurement options (including options for the VSWIR at 30 m sampling and 16-day revisit)
- Report activities tied to Sustainable Land Imaging (SLI), including backward compatibility with bands of MSS, and LandSat 4, 5, 7, 8
Locked surface geology and composition. Does Europa's ocean have organics? What does surface chemistry tell us about habitability? Is Europa currently active? How do changes in ice crystal structure relate to the age of Europa's surface?

MISE Science Goals:
- **Goal 1**: Assess the habitability of Europa's ocean by understanding the inventory and distribution of surface compounds.
- **Goal 2**: Investigate the geologic history of Europa's surface and search for areas that are currently active.

JPL/APL Partnership:
- Imaging Spectrometer heritage from JPL (Discovery MP on India's Chandrayaan-1) and APL (CRISM on MRO).
- Joint JPL/APL team has been working on MISE concept since 2008.

MISE Team:
- PI: Diana Blaney (JPL)
- Deputy PI: Karl Hibbitts (APL)
- Project Manager: Carl Brown (JPL)
- Deputy Project Manager: Andrew Santo (APL)

Science Team:
- Rob Green, Instrument Scientist (JPL)
- Roger Clark (PSI)
- Brad Dalton (JPL)
- Ashley Davis (JPL)
- Matt Hedman (U. Idaho)
- Yves Langevin (U. Paris)
- Jonathan Linerle (Cornell)
- Tom McCord (Bear Flight).