HICO Science Mission Overview

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Optical Components of a Coastal Scene

- Multiple light paths
- Scattering due to:
  - atmosphere
  - aerosols
  - water surface
  - suspended particles
  - bottom
- Absorption due to:
  - atmosphere
  - aerosols
  - suspended particles
  - dissolved matter
- Scattering and absorption are convolved

Extensive studies using shipboard measurements and airborne hyperspectral imaging have shown that visible hyperspectral imaging is the only tool available to resolve the complexity of the coastal ocean from space. (Lee and Carder, *Appl. Opt.*, 41(12), 2191 – 2201, 2002.)
Properties of Coastal Imaging

- Water scenes are dark
- The sky is bright
- Dark ocean scene and bright sky requires high signal-to-noise ratio imager
- High sensitivity in the blue is required to sort out dissolved / suspended matter
- Coastal ocean scenes are large – thousands of square kilometers
Maritime Hyperspectral Program at NRL

Sensor Performance Modeling

Nonlinear Manifold Analysis

Pattern Recognition / Classification

Spectral Identification

Requirements Evaluation

Product Evaluation

Product Extraction

Data Processing

Sensor Development

Sensor Calibration

Flight Campaigns

Ground / Water Truth

Atmospheric Removal

Georectification

Signal to Noise Ratio

Wavelength (nm)

Signal to Noise

Wavelength (nm)

Reflectance x 10^4

Wavelength (microns)

PHILLS-1

Ground Truth ASD
Maritime Hyperspectral Imaging from Space

- Hyperspectral imaging from space is a natural next step
  - provides global repeat coverage unavailable from an aircraft
- 15 years of aircraft experience forms a solid foundation for hyperspectral from space
  - validated imager performance requirements
  - developed atmospheric correction algorithms
  - developed product algorithms

NRL Imager flown on Antonov AN-2 at 10,000 ft
Above 30% of atmosphere
Above most aerosols

NASA AVIRIS flown on ER-2 at 20 km
Above 95% of atmosphere
Usually above all significant aerosols
HICO is an Office of Naval Research sponsored program to develop and operate the first Maritime Hyperspectral Imaging from space.

As a Maritime Hyperspectral Imager, HICO must have:

- High signal-to-noise ratio for water-penetrating wavelengths
- Spectral range that includes all water-penetrating wavelengths
- Spectral binning of 10 nm or less
- Large area coverage for coastal scenes – only moderate spatial resolution required
The HICO Space Mission

- In the Spring of 2007, a combined payload of HICO and RAIDS (HREP) was manifested for the Japanese Experiment Module – Exposed Facility (JEM-EF) on the International Space Station

Payload Instruments:

- HICO – the topic of this presentation
- RAIDS (Remote Atmospheric and Ionospheric Detection System)
  - Comprehensive measurements of upper atmospheric airglow emissions
  - developed at the NRL Space Science Division

HICO is integrated and flown under the direction of DoD’s Space Test Program
HICO Mission Requirements

• Launch and operate the first spaceborne coastal Maritime Hyperspectral Imager (MHSI)
  – high signal-to-noise ratio for dark coastal scenes
  – large scene size and moderate spatial resolution appropriate for the coastal ocean
  – high sensitivity in the blue and full coverage of water-penetrating wavelengths

• Demonstrate scientific and naval utility of maritime hyperspectral imaging from space
  – bathymetry, water optical properties, bottom type, and terrain and vegetation maps

• Demonstrate new and innovative ways to develop and build the imaging payload
  – reduce cost
  – reduce schedule

• Goal: Serve as an innovative pathfinder for future spaceborne hyperspectral imagers
## HICO Performance Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-track pointing</td>
<td>+45 to -30 deg</td>
<td>To increase scene access frequency</td>
</tr>
<tr>
<td>Spectral Range</td>
<td>380 to 1000 nm</td>
<td>All water-penetrating wavelengths plus Near –IR for atmospheric correction</td>
</tr>
<tr>
<td>Spectral Channel Width</td>
<td>5 nm</td>
<td>Sufficient to resolve spectral features</td>
</tr>
<tr>
<td>Number of Spectral Channels</td>
<td>124</td>
<td>Derived from Spectral Range and Spectral Channel Width</td>
</tr>
<tr>
<td>SNR for water penetrating wavelengths</td>
<td>&gt; 200 to 1 for 5% albedo scene</td>
<td>Provides adequate Signal-to-Noise Ratio after atmospheric removal</td>
</tr>
<tr>
<td>Polarization Sensitivity</td>
<td>&lt; 5%</td>
<td>Sensor response to be insensitive to polarization of light from scene</td>
</tr>
<tr>
<td>Ground Sample Distance at Nadir</td>
<td>100 meters</td>
<td>Adequate for scale of coastal ocean features</td>
</tr>
<tr>
<td>Scene Size</td>
<td>50 x 200 km</td>
<td>Large enough to capture the scale of coastal dynamics</td>
</tr>
<tr>
<td>Scenes per orbit</td>
<td>1</td>
<td>Data volume and transmission constraints</td>
</tr>
</tbody>
</table>
**HICO Additional / Derived Requirements**

Performance for these requirements will be measured and accepted as-is

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<tr>
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<tr>
<td>Image Quality</td>
<td>MTF &gt; 0.35 at Nyquist spatial frequency of 0.5 cycles/pixel</td>
<td>To assure that the recorded signal is coming from the sampled GSD</td>
</tr>
<tr>
<td>Saturation</td>
<td>Will not saturate when viewing a 95% albedo cloud</td>
<td>To be able to image dark ocean next to bright clouds</td>
</tr>
<tr>
<td>Spectral stray light</td>
<td>&lt; 1% albedo error</td>
<td>To assure that the true spectrum is recorded</td>
</tr>
<tr>
<td>Long term stability</td>
<td>+/- 0.5% after calibration of the data</td>
<td>To assure a consistent data set over time for change detection</td>
</tr>
<tr>
<td>Jitter</td>
<td>&lt; 0.2 IFOV per integration period (dependent on spacecraft vibrations)</td>
<td>To assure that the scene is undistorted during the collection period.</td>
</tr>
<tr>
<td>Optical Vignetting</td>
<td>No vignetting at any view angle</td>
<td>Vignetting causes significant radiometric errors</td>
</tr>
</tbody>
</table>
HICO Launch to Space Station

Launch from Tanegashima Island Launch Site

- Launch
- 1st Stage Separation
- 2nd Stage Separation
- HTV Re-Entry (Burn Down)
- HTV Free Fly
- HTV Ready to Berth
- HTV Berth
HICO Location on Space Station

Location of HICO – RAIDS payload
On Japanese Experiment Module – Exposed Platform

System ORU
Exposed Facility Visual Equipment (EF-VE)
Exposed Facility Unit (EFU)
EF Experiment Payload

Space Station velocity direction
Inter-orbit Communication System (ICS-EF)
The HICO - RAIDS combined payload will be attached to the Japanese Experiment Module – Exposed Facility (JEM-EF)
HICO Solid Mechanical Model

Camera in sealed enclosure

Spectrometer

Rotation Stage to Point line of sight

Imaging line of sight
HICO Spectrometer

- Brandywine Optics model 3035 Spectrometer for spectral dispersion
  - commercially-available
- All-reflective Offner grating spectrometer
- High-efficiency grating
- Athermalized

Two Brandywine model 3035 Spectrometers on an Optical table
HICO Camera

- QImaging Rolera-MGi camera
  - commercially-available
- Science grade
- Back-side illuminated CCD
  - high quantum efficiency
- Confirmed linearity in our laboratory
- Confirmed planned HICO operation
  - read noise level
  - electron well depths
  - readout speed

Rolera MGi camera
Rotation Stage to Point Line of Sight

- Single-axis rotary mechanism to point HICO line of sight in cross-track direction
- Newport Research model RV120PEV6 rotation stage
  - commercially-available
- Vacuum compatible
Modeled HICO Signal to Noise Ratio

- Modeling assumes:
  - known performance parameters of spectrometer and camera
  - above-atmosphere spectral radiance from MODTRAN
    - 5% earth surface albedo, 45 degree solar zenith angle
Program Status and Schedule

Completed:

• Mission Requirements Review Completed February 28, 2006
• Mission Requirements Document Completed March 16, 2006
• HICO manifested on Space Station March 2007
• Preliminary Design Review Completed June 18, 2007
• Critical Design Review Completed November 8, 2007

Scheduled:

• HICO imager delivery March 31, 2008
• HICO test readiness review June 16, 2008
• HICO delivery to combined payload September 1, 2008
• Experiment Payload delivery to JAXA February 16, 2009
• Launch to International Space Station July 9, 2009
• On-orbit checkout complete September 25, 2009
Summary

- Maritime Hyperspectral Imaging is a unique discipline
- HICO will demonstrate the utility of Maritime Hyperspectral Imaging from space
- HICO is manifested for the International Space Station – Launch July 2009

The HICO program is well under way!