HICO

# HICO Science Mission Overview


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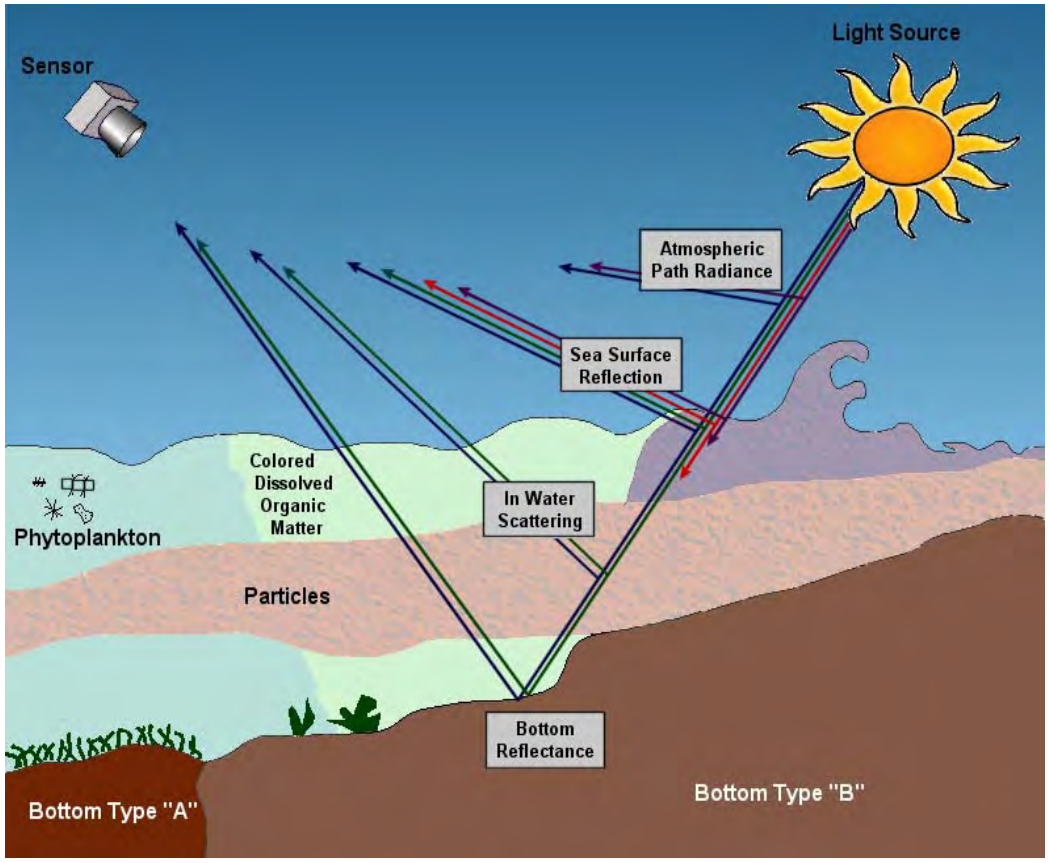
# Optical Components of a Coastal Scene

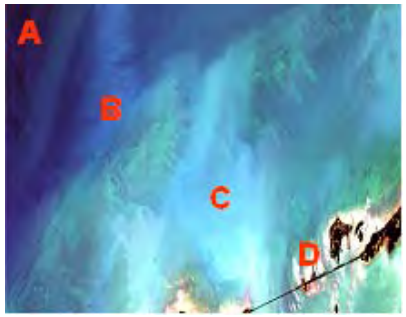


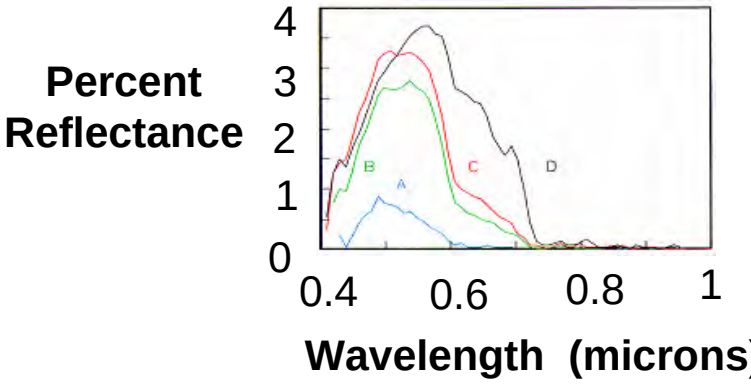

- Multiple light paths
- Scattering due to:
  - atmosphere
  - aerosols
  - water surface
  - suspended particles
  - bottom
- Absorption due to:
  - atmosphere
  - aerosols
  - suspended particles
  - dissolved matter
- Scattering and absorption are convolved

**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.)**

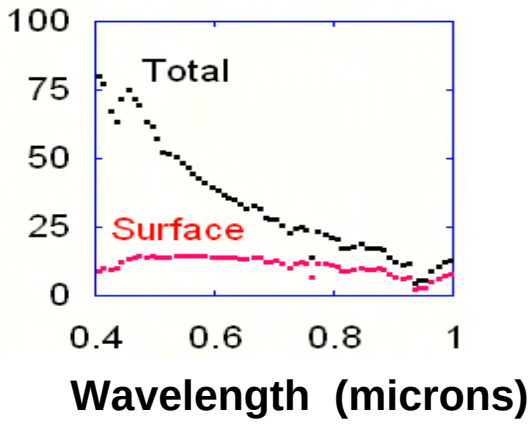
# Properties of Coastal Imaging

- **Water scenes are dark**



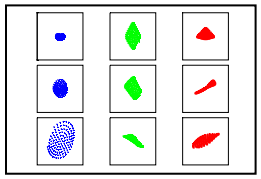

- **The sky is bright**

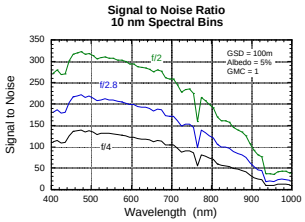


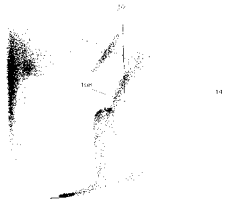

- **Dark ocean scene and bright sky requires high signal-to-noise ratio imager**
- **High sensitivity in the blue is required to sort out dissolved / suspended matter**
- **Coastal ocean scenes are large – thousands of square kilometers**

# Maritime Hyperspectral Program at NRL

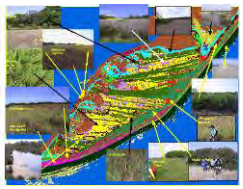
Sensor Performance Modeling



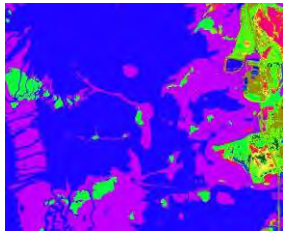


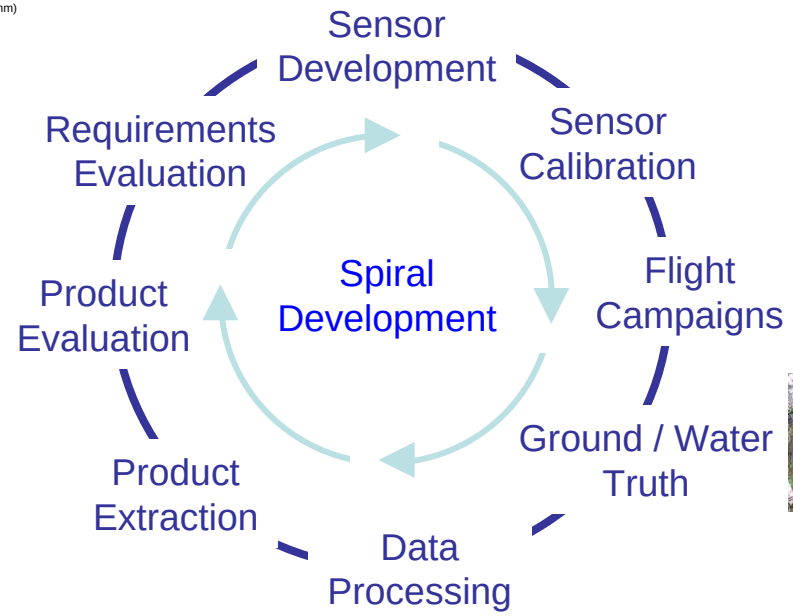
Nonlinear
Manifold
Analysis



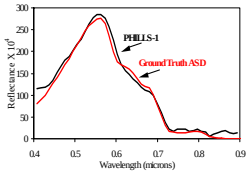
Pattern
Recognition /
Classification



Spectral
Identification




Georectification




Atmospheric
Removal

# 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**

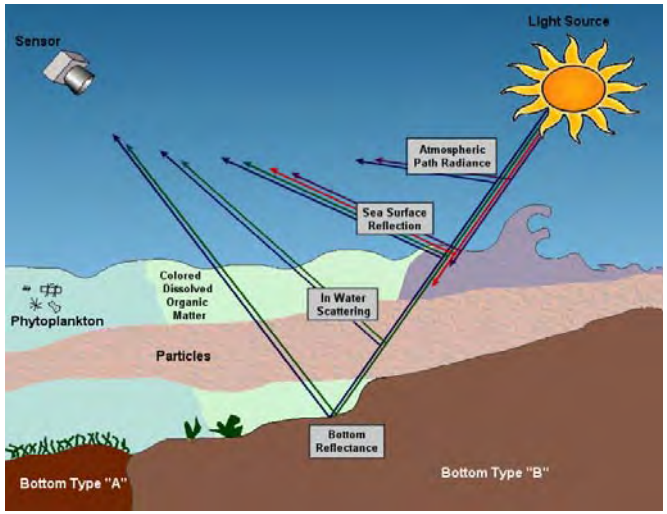
# The NRL HICO Program

## HICO: Hyperspectral Imager for the Coastal Ocean

**HICO is an Office of Naval Research sponsored program to develop and operate the first Maritime Hyperspectral Imaging from space**

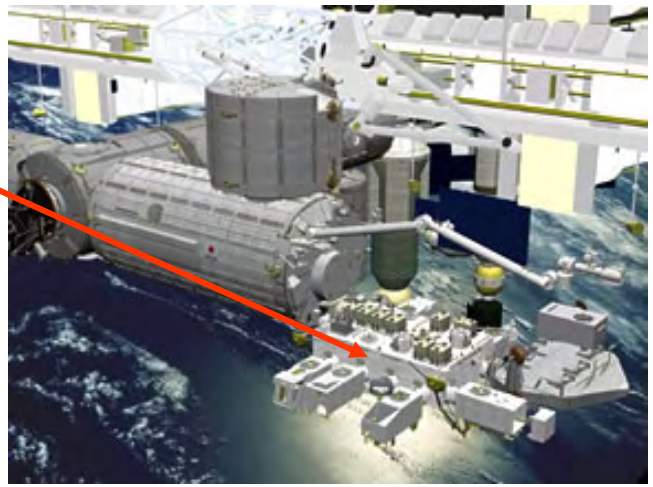
**As a Maritime Hyperspectral Imager, HICO must have:**

- **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

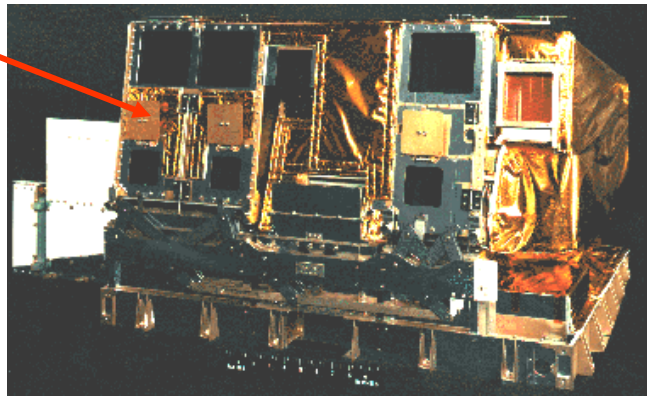
- **In the Spring of 2007, a combined payload of HICO and RAIDS (HREP) was manifested for the Japanese Experiment Module – Exposed Facility (JEM-EF) on the International Space Station**



Graphic of JEM-EF on 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**



RAIDS

***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

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

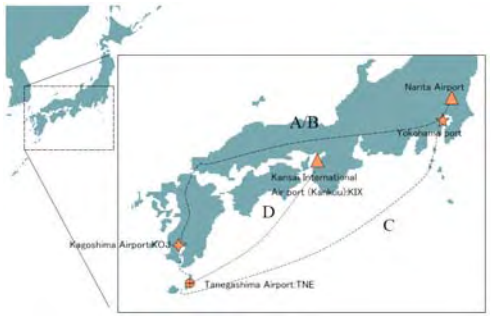
# HICO Additional / Derived Requirements

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

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

# HICO Launch to Space Station

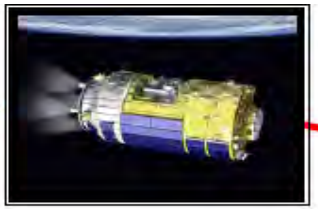
## Launch from Tanegashima Island Launch Site




Launch

1st Stage Separation

2nd Stage Separation



HTV Free Fly

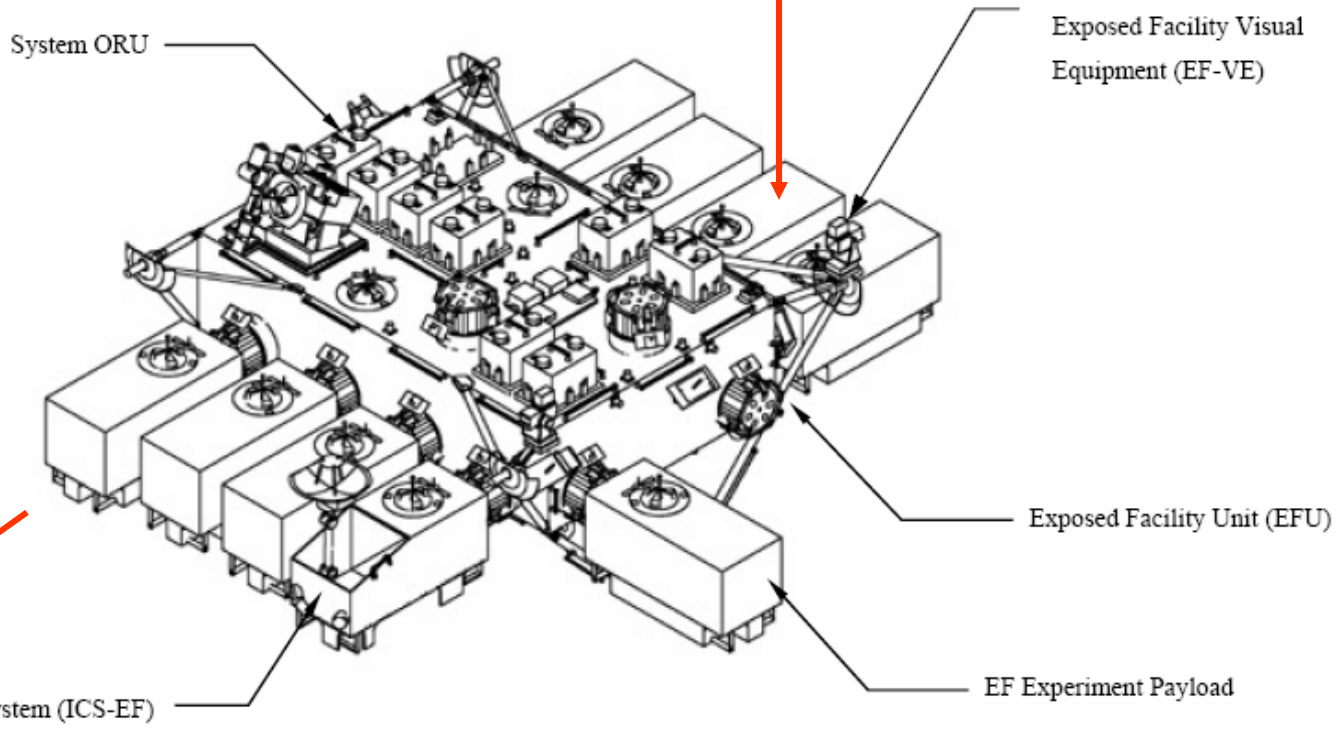
HTV Ready to Berth

HTV Berth

HTV Re-Entry (Burn Down)

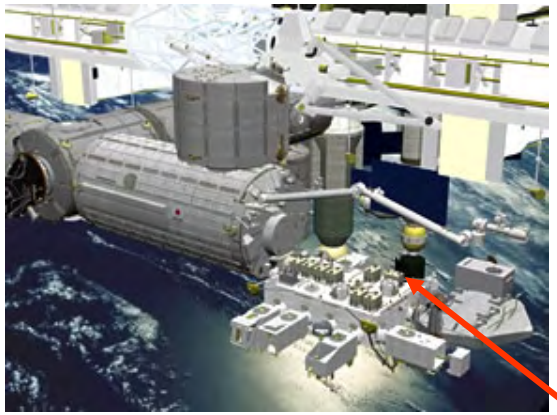
# HICO Location on Space Station

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

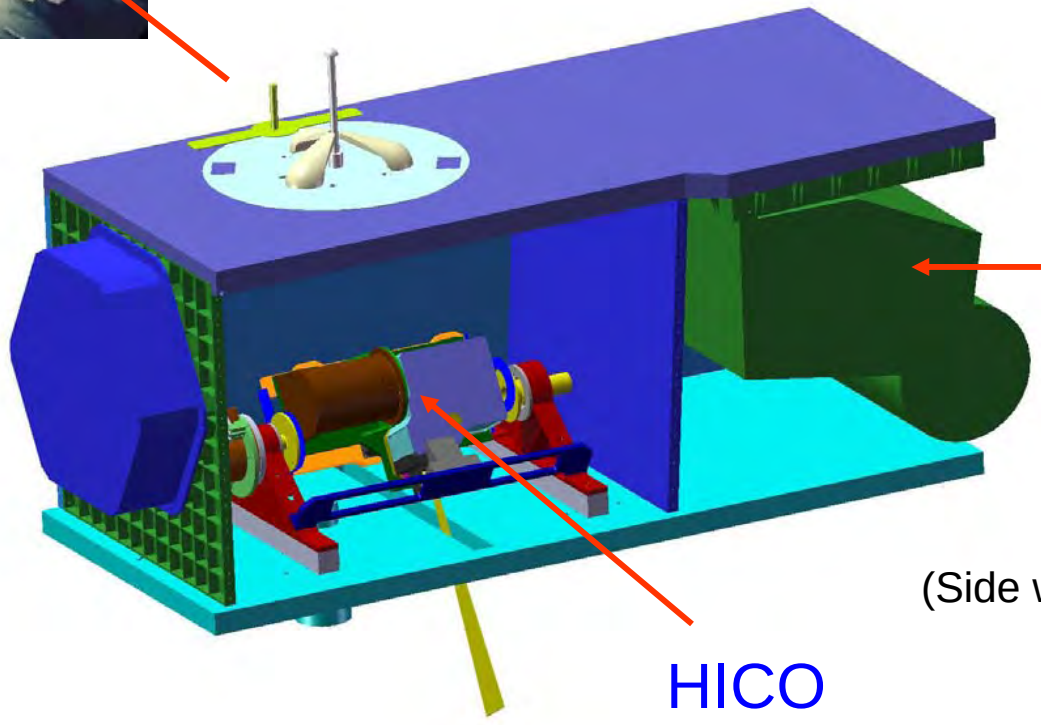



**Space Station velocity direction**

# HICO – RAIDS Combined payload

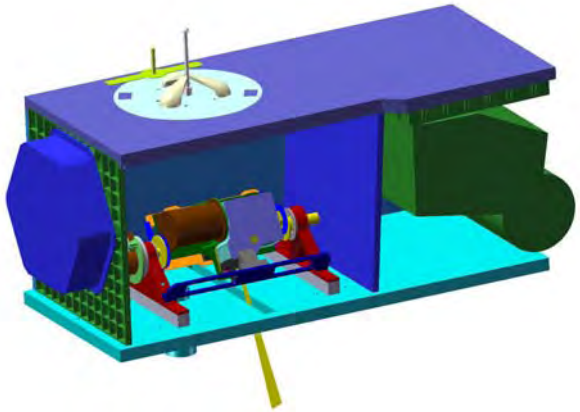


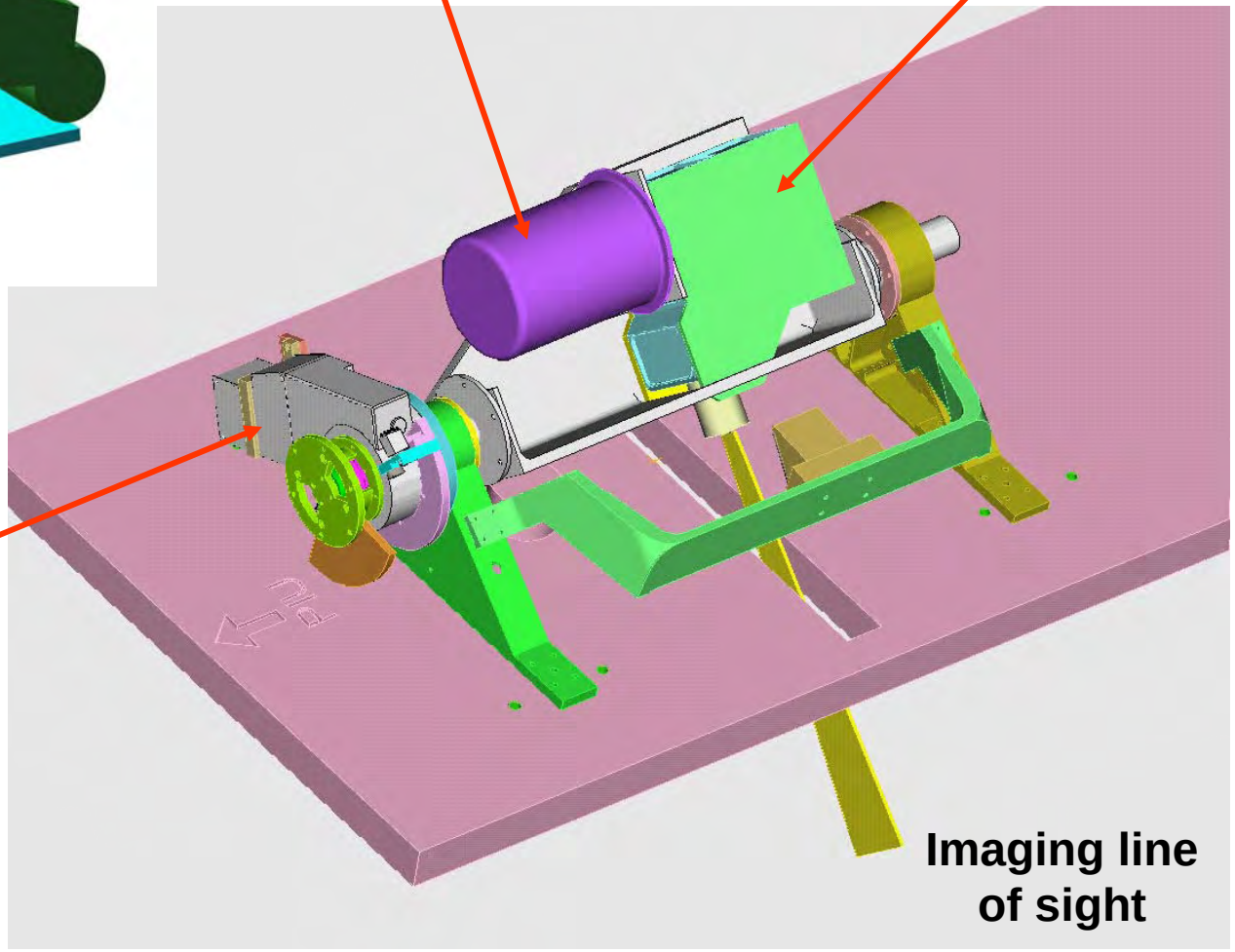
**The HICO - RAIDS combined payload will be attached to the Japanese Experiment Module – Exposed Facility (JEM-EF)**




(Side wall not shown)

# HICO Solid Mechanical Model





# HICO Spectrometer

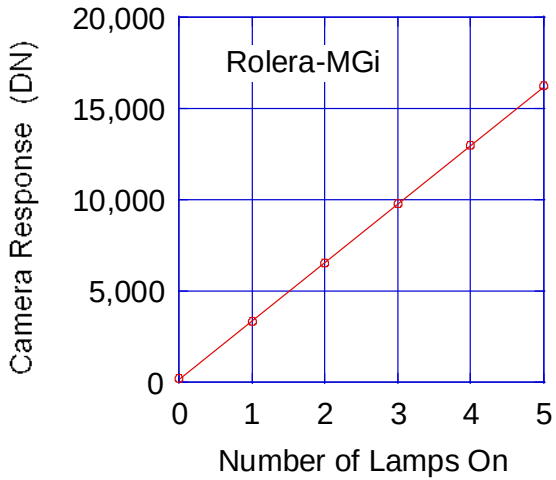
- Brandywine Optics model 3035 Spectrometer for spectral dispersion
  - commercially-available
- All-reflective Offner grating spectrometer
- High-efficiency grating
- Athermalized

**Two Brandywine model 3035 Spectrometers on an Optical table**

# HICO Camera

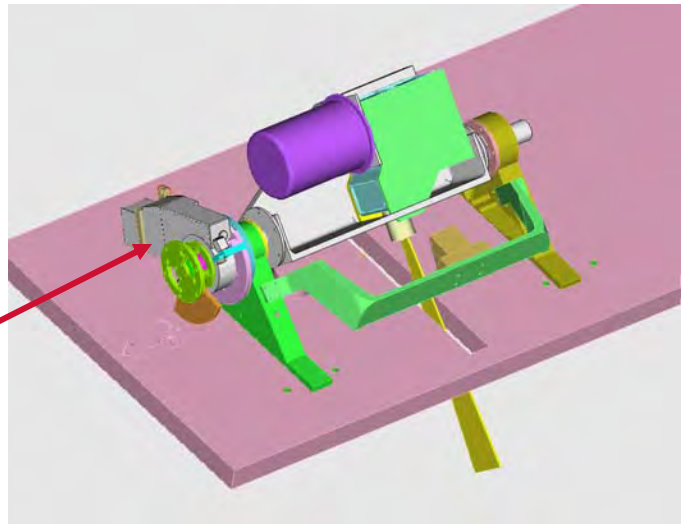
- QImaging Rolera-MGi camera
  - commercially-available
- Science grade
- Back-side illuminated CCD
  - high quantum efficiency
- Confirmed linearity in our laboratory
- Confirmed planned HICO operation
  - read noise level
  - electron well depths
  - readout speed

Rolera MGi camera



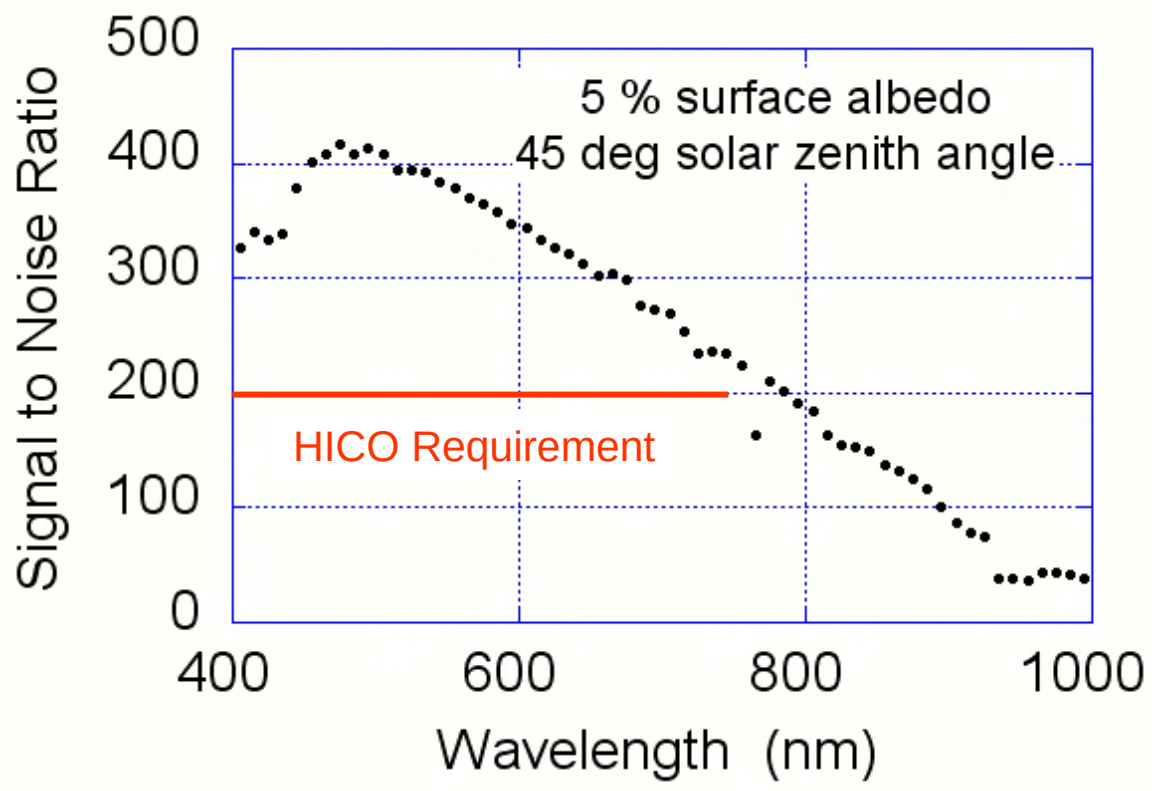
# Rotation Stage to Point Line of Sight

- 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 from space**
- **HICO is manifested for the International Space Station – Launch July 2009**

The HICO program is well under way!