Overview of the HICO / HREP Program

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Hyperspectral Environmental Characterization of the Coastal Zone

- Product retrievals use the spectral content of water-leaving radiance to identify and quantify the contents of the water column, identify the bottom type, and classify land areas

Coastal ocean scene
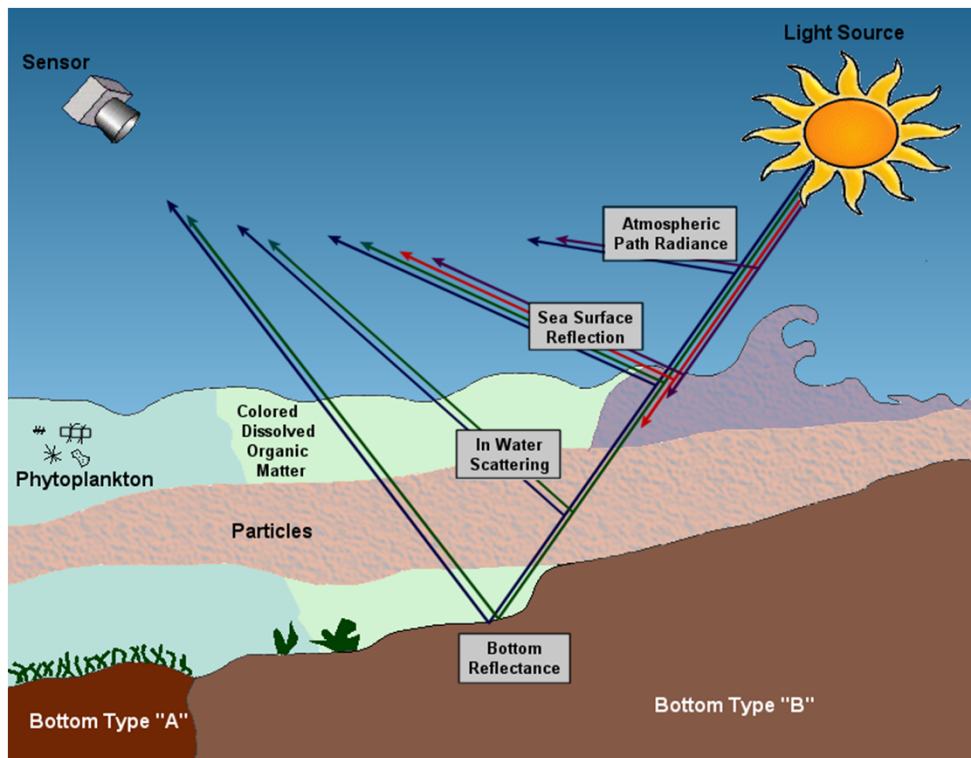
- In-water products
  - water optical properties
    - absorption $a(\lambda)$
    - scattering $b(\lambda)$
    - in-water visibility
  - bottom type
  - chlorophyll concentration
  - Colored Dissolved Organic Matter (CDOM)
  - Total Suspended Sediment (TSS)
  - bathymetry
- Land products
  - vegetation classification maps
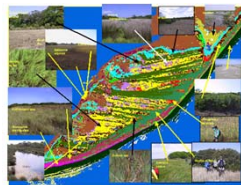 - soil classification maps
  - trafficability

NRL Airborne Coastal Environmental Hyperspectral Program

- 20+ years end-to-end development of airborne environmental hyperspectral imaging
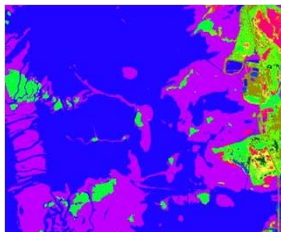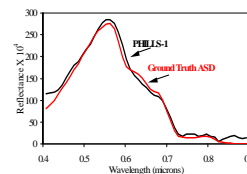

Sensor Performance Modeling
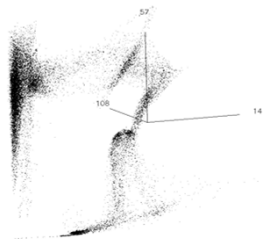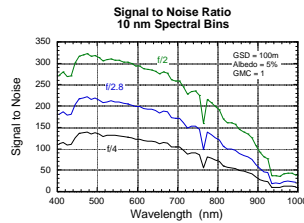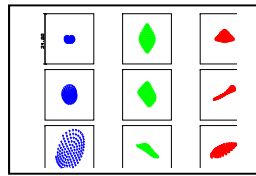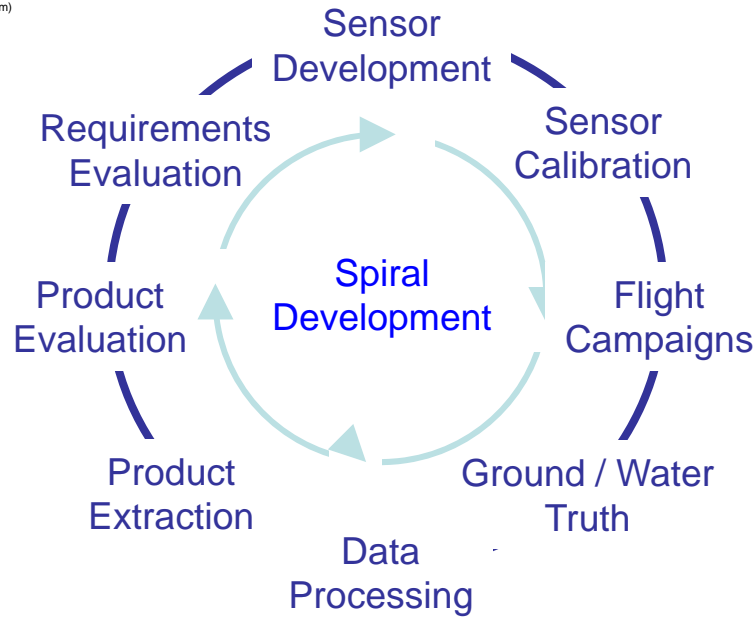
Nonlinear Manifold Analysis

PURSUIT Pattern Recognition / Classification

ORASIS Spectral Identification
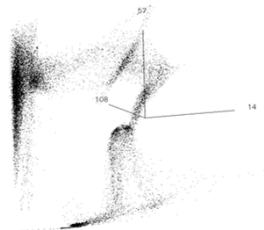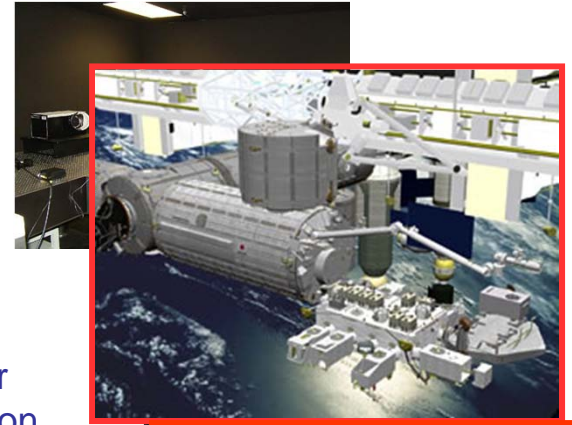
TAFKAA Atmospheric Removal Algorithm

Geolocation

Spiral Development

Sensor Development

Sensor Calibration

Flight Campaigns

Ground / Water Truth

Data Processing

Product Extraction

Product Evaluation

Requirements Evaluation
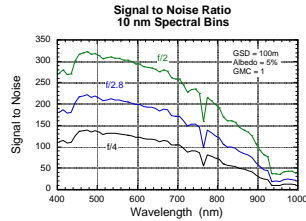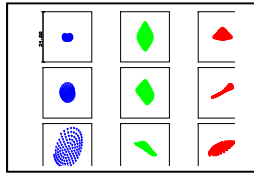
Hyperspectral Imaging from Space is a Natural Next Step

- Space provides repeat access to coastal types worldwide

Sensor Performance Modeling

Nonlinear Manifold Analysis

PURSUIT Pattern Recognition / Classification

ORASIS Spectral Identification

Sensor Development

Requirements Evaluation

Sensor Calibration

Product Evaluation

Spiral Development

Product Extraction

Data Processing

Truth

TAFKAA Atmospheric Removal Algorithm

Volcanic coast

Mangrove coast

Geolocation

Hyperspectral Imager for the Coastal Ocean (HICO)

The HICO opportunity

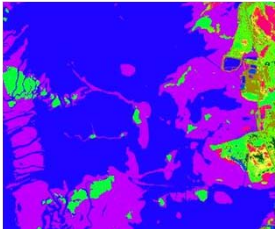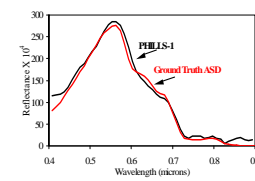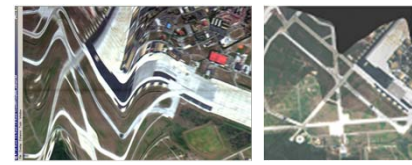- Office of Naval Research sponsored HICO as an Innovative Naval Prototype (INP)
  - demonstrate new ability to meet naval needs
  - demonstrate ways to reduce cost and schedule of a space payload
- Space Test Program provided the launch to the International Space Station

HICO program requirements

- Launch and operate the first spaceborne coastal Maritime Hyperspectral Imager (MHSI) optimized for coastal environmental characterization
  - high signal-to-noise ratio and full coverage of water-penetrating wavelengths
  - large scene size and moderate spatial resolution appropriate for the coastal ocean
- Demonstrate scientific and naval utility of maritime hyperspectral imaging from space
  - bathymetry, water optical properties, bottom type, terrain and vegetation maps
  - demonstrate ways to reduce cost and schedule
- Serve as a pathfinder for future spaceborne hyperspectral imagers

HICO based on 20+ years of airborne hyperspectral imaging

- Proven imager architecture
- Vetted imager performance requirements
- Starting point for product algorithms

HICO Program and Pathfinder Opportunity

- Summer 2006: Space Test Program asked if HICO could be ready for September 2009 launch to the ISS Japanese Kibo module – Exposed Facility
- Winter 2006-2007: HICO accommodation study for ISS
- March 2007: HICO manifested on Space Station ISS

HICO flight imager

Beginning of HICO Space Station project

- June 2007: Preliminary Design Review
- November 2007: Critical Design Review
- July 2008: HICO Test Readiness Review
- September 2008: HICO delivery for payload integration

Project start to sensor delivery in 16 months

- September 10, 2009: Launched to Space Station and activated September 24
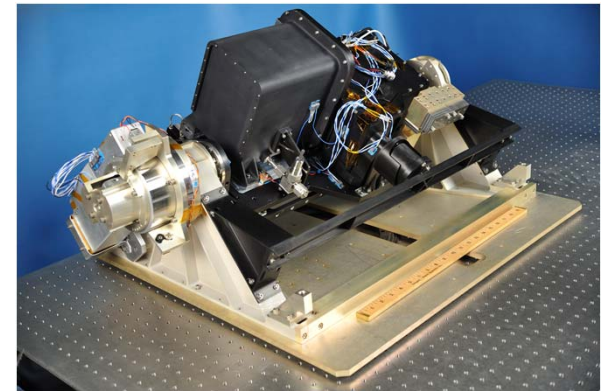
HICO image of Bosporus Strait, October 11, 2009. Scene approximately 42 x 190 km.

# HICO INP Demonstrates Significant Cost and Schedule Savings

- HICO built using COTS components where possible
- Demonstrated a significant goal of the ONR Innovative Naval Prototype program

Brandywine Optics Model 3035 spectrometer (two shown)

QImaging Rolera-MGi camera in hermetic enclosure (NRL TacSat heritage)
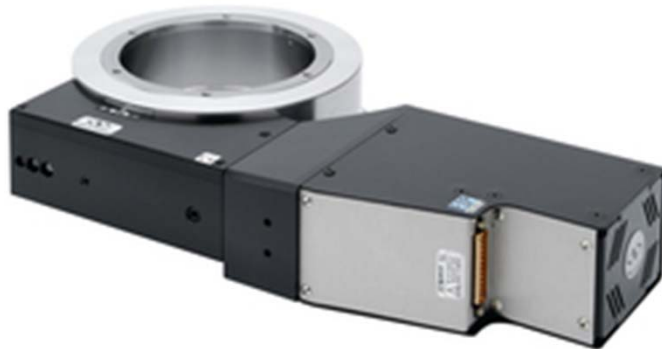
Newport Research model RV120PEV6 rotation stage to point line of sight
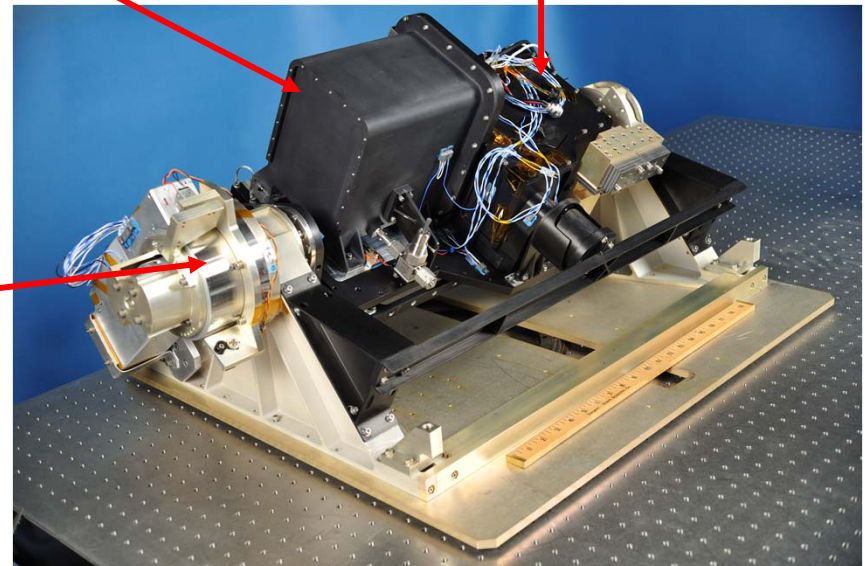
HICO Performance Specifications Based on Airborne Experience

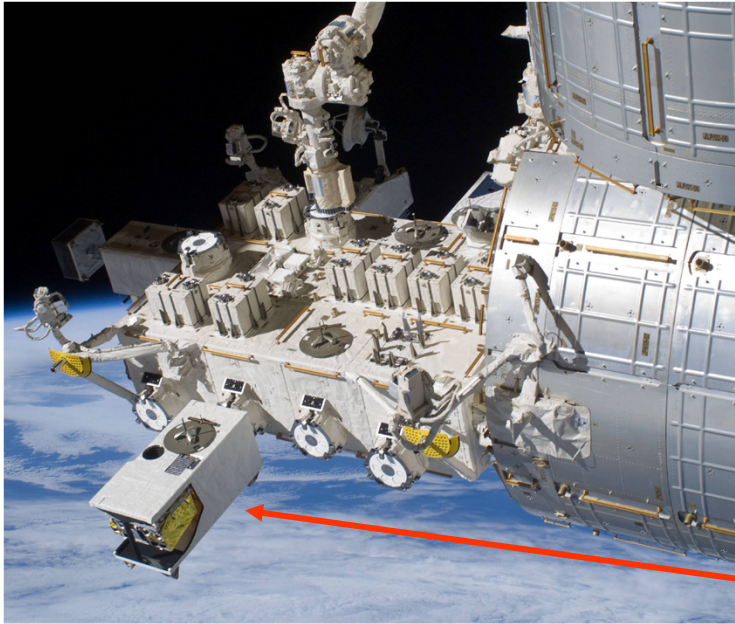| Parameter	HICO Performance	Rationale
Architecture	Offner grating spectrometer, silicon FPA	Airborne heritage
Spectral Range	400 to 900 nm	Water-penetrating wavelengths plus Near IR for atmospheric correction
Spectral Readout	1.9 or 5.7 nm	Resolve coastal spectral features
Signal-to-Noise Ratio for water-penetrating wavelengths	> 200 to 1 for 5% albedo (10 nm spectral bins)	Provides adequate Signal to Noise Ratio after atmospheric removal
Polarization Sensitivity	< 5% (430-900 nm)	Insensitive to scene polarization
Ground Sample Distance at Nadir	92 m	Adequate for selected coastal ocean features
Scene Size	42 x 192 km	Capture the scale of coastal dynamics
Cross-track pointing	+ 45 to - 30 deg	Increase scene access frequency
Scenes per orbit	1 maximum	Data transmission constraints

Solid Model of HICO

Envelope (mm)	X	Y	Z
	885	525	425
Mass (kg)	43		

Camera hermetic enclosure

Spectrometer

Lens

Optics deck

FLIGHT DIRECTION

Z

HREP coordinate system

Rotation mechanism

Viewing slot

Coordinate System1

X

Y

Z

HICO coordinate system

Lens shield assembly
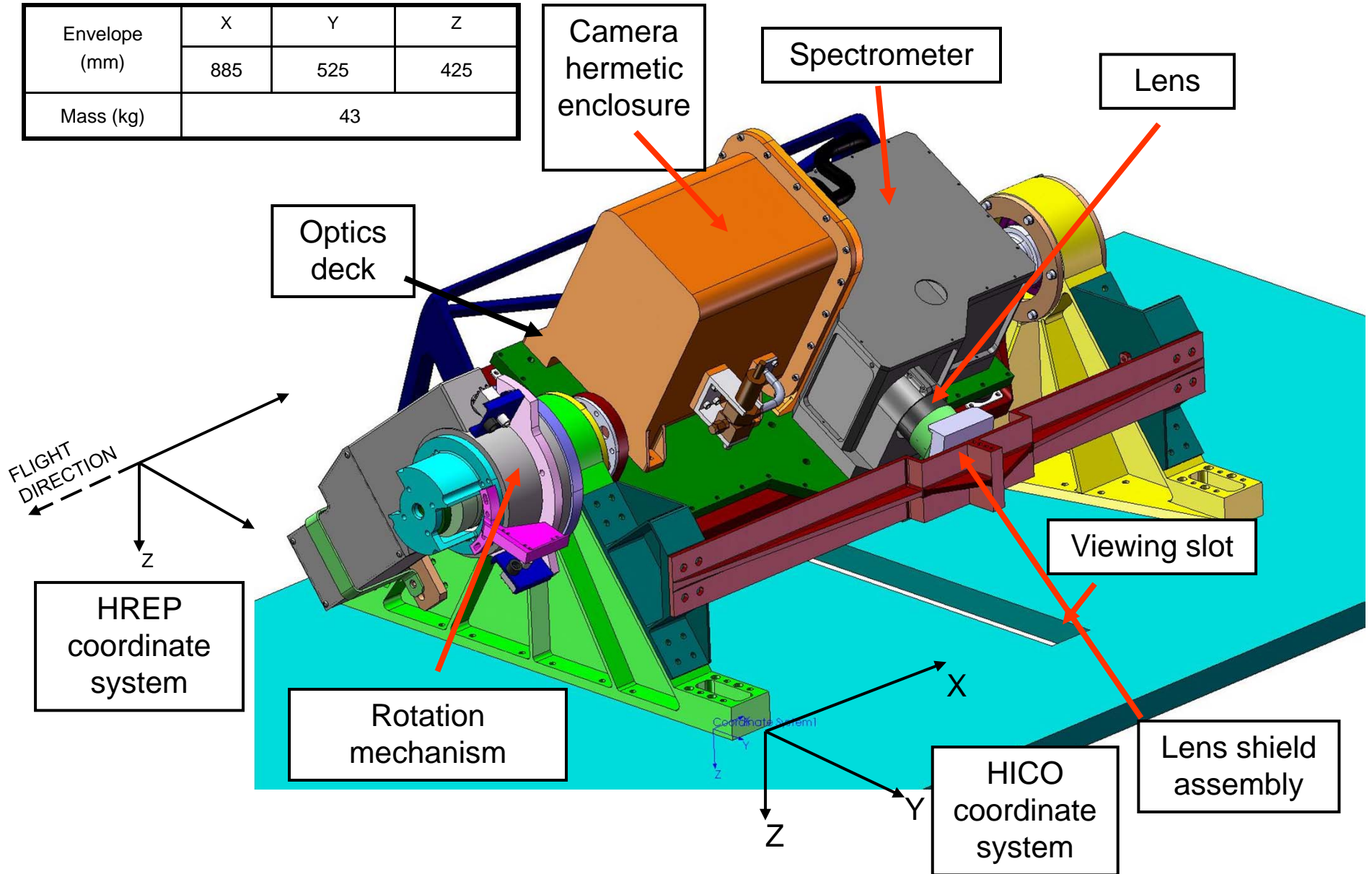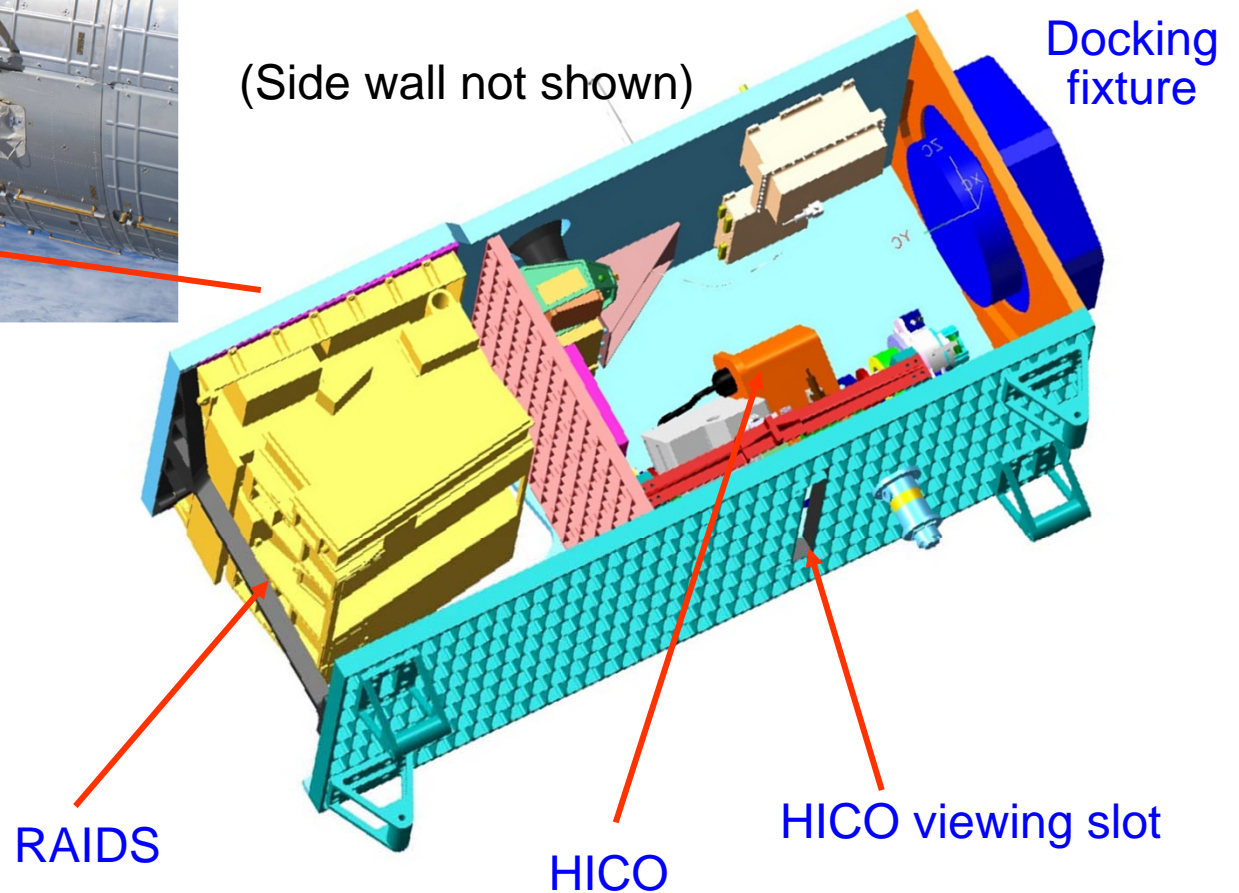
The HICO Flight Instrument
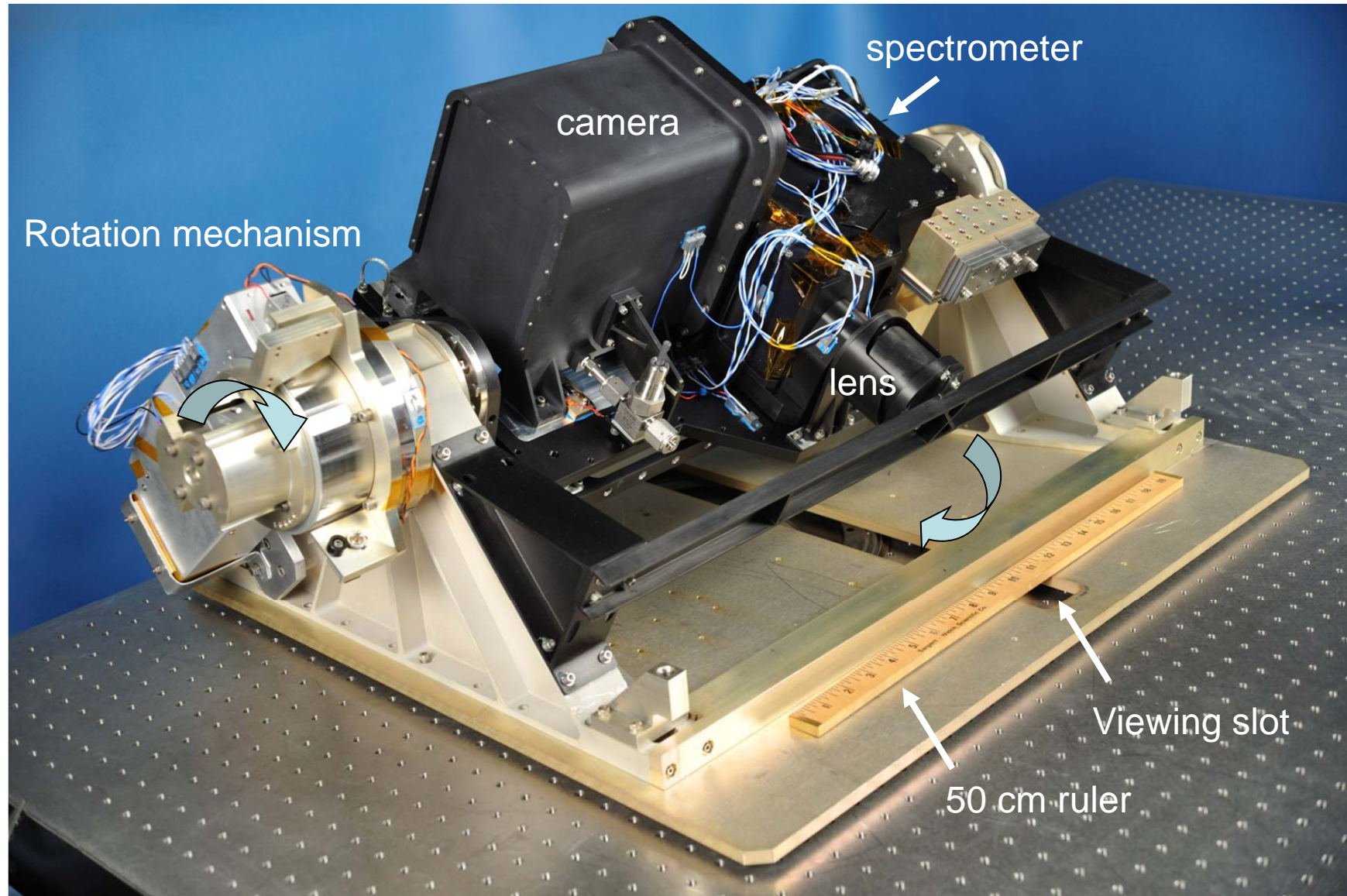
HICO – RAIDS Experiment Payload

Photograph courtesy NASA

The HICO - RAIDS Experiment Payload
(HREP) is attached to the
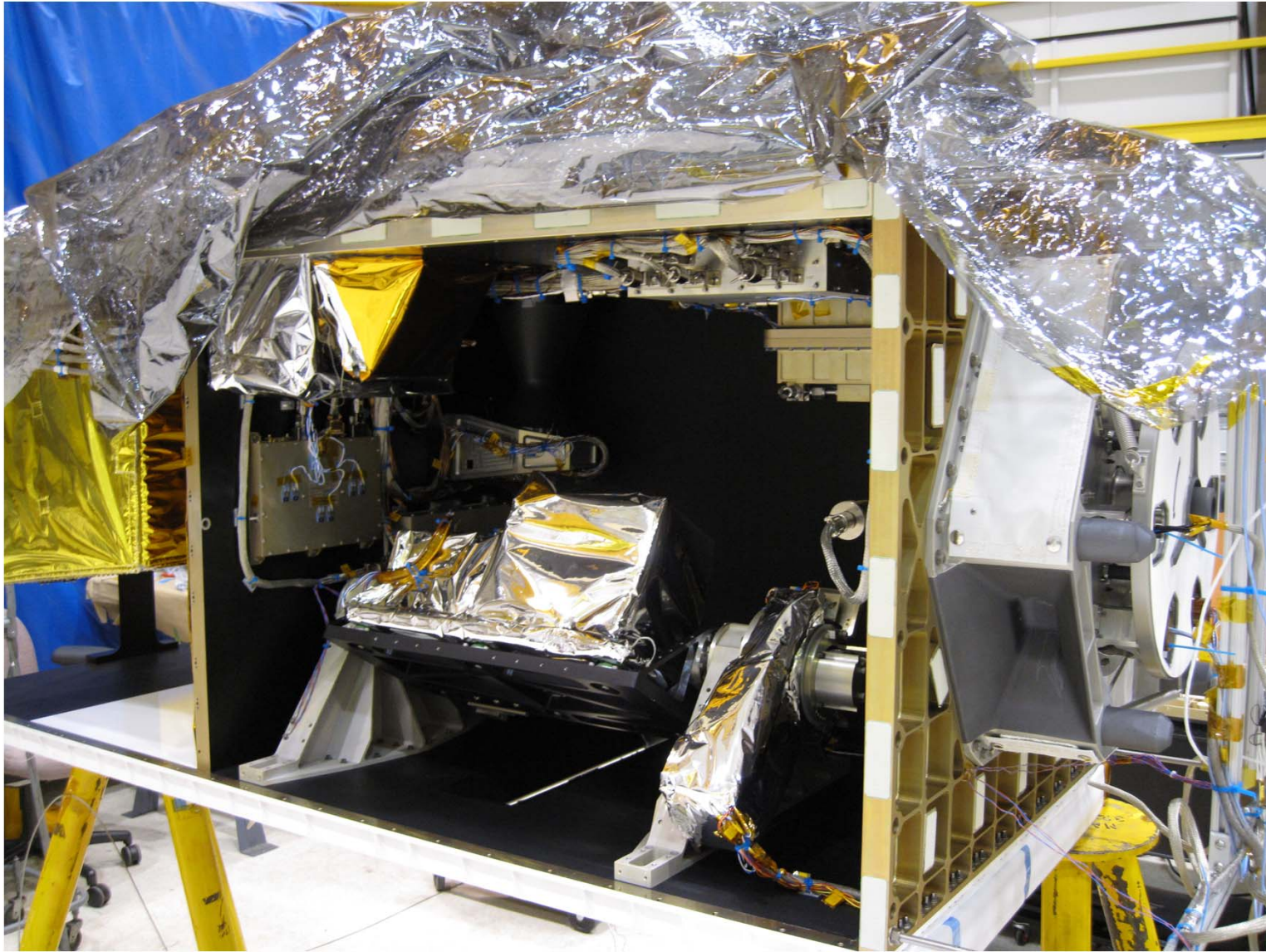Japanese Kibo module – Exposed Facility

(Side wall not shown)

Docking fixture

RAIDS is a limb scanner
for atmospheric temperature
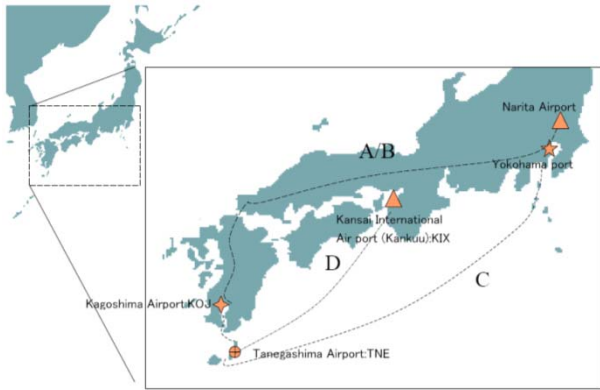and chemistry

RAIDS

HICO

HICO viewing slot

Blanketed HICO Inside the HREP Structure

HREP Launch and Robotic Attachment

Launched from Tanegashima Space Center, Japan, September 10, 2009, on Japanese HTV
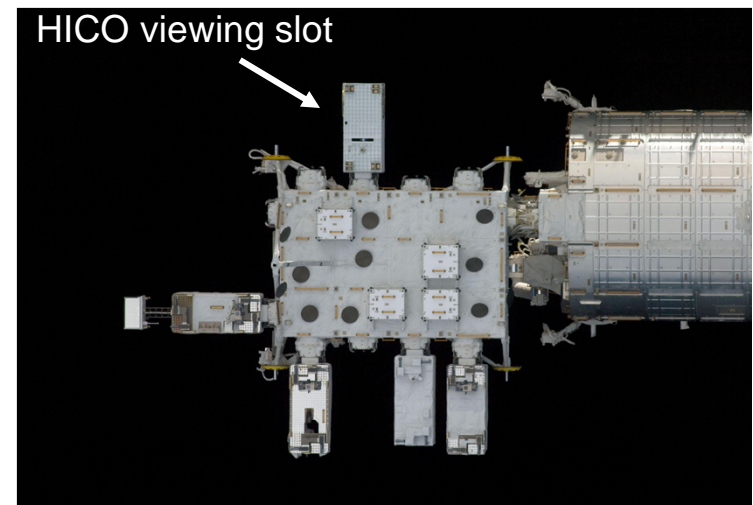
HTV payload module carrying HREP docked to Space Station September 17

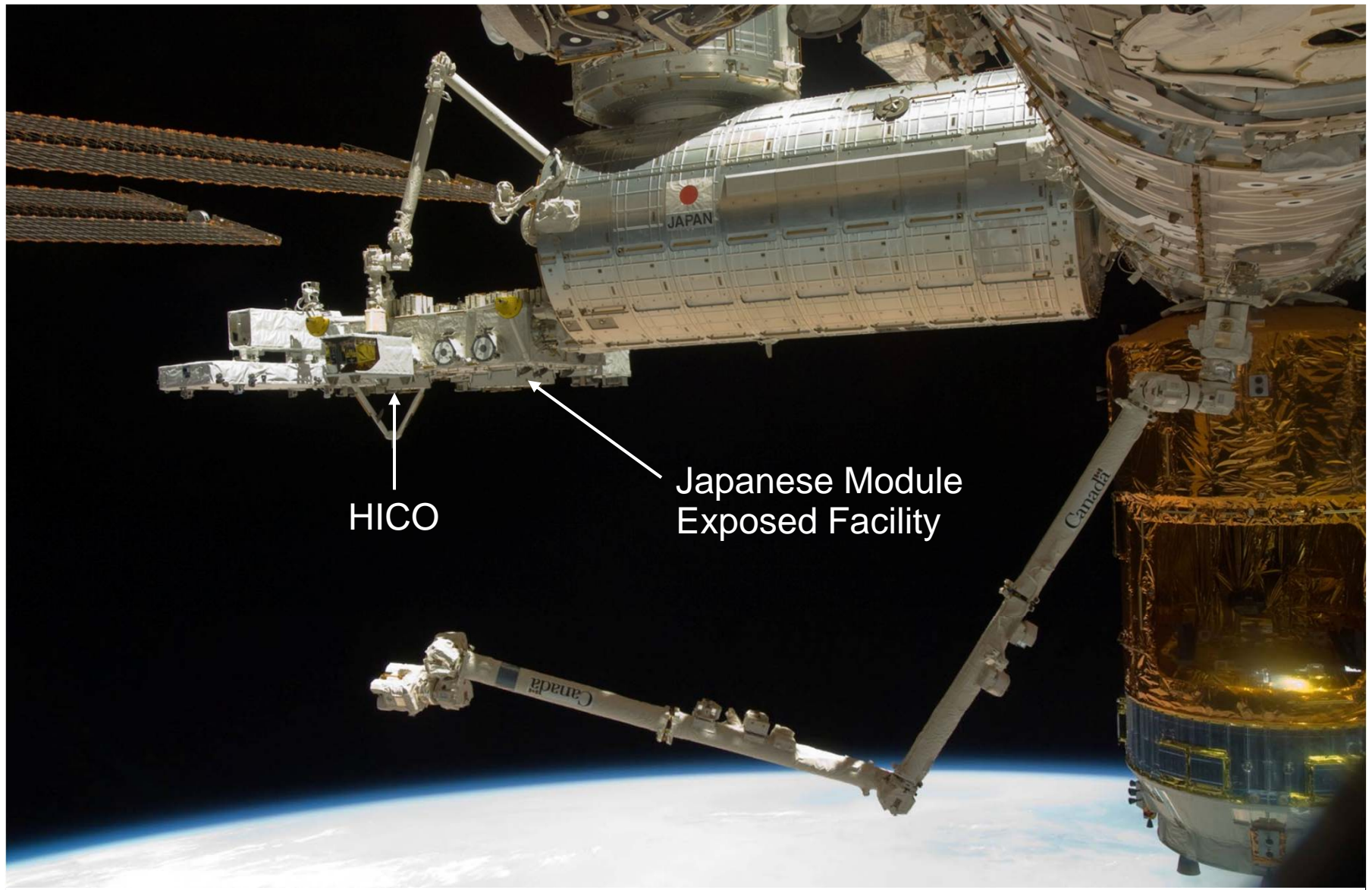HREP on Japanese Remote Manipulator arm

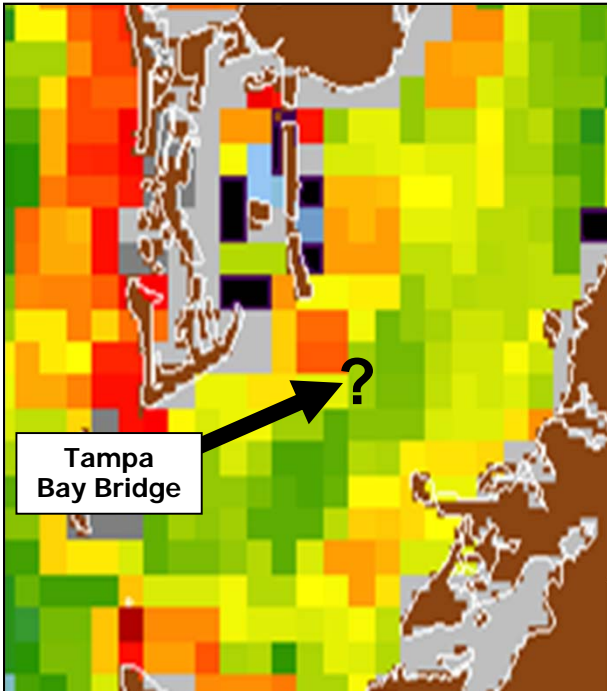HREP docked to Japanese Exposed Facility September 24

HICO viewing slot

Photographs courtesy NASA

HICO Docked to the Japanese Kibo Exposed Facility
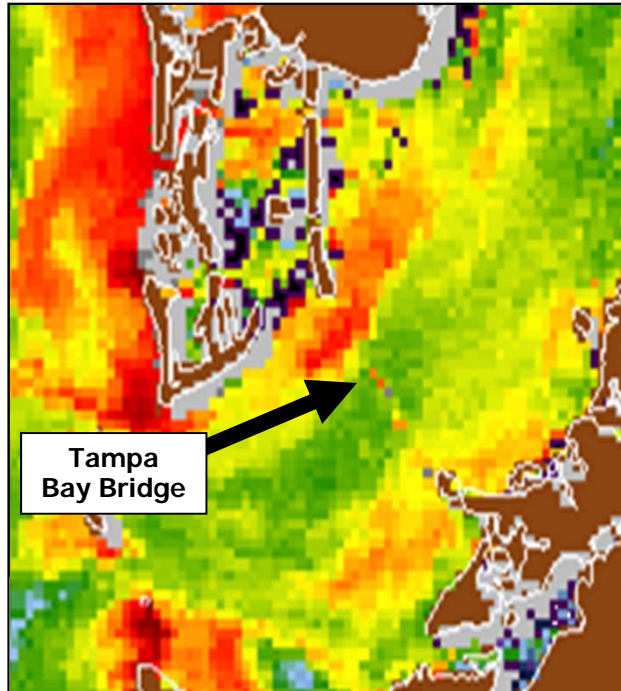

HICO

Japanese Module Exposed Facility

Inter-Satellite Comparison of Spatial Scale

- MODIS, MERIS, HICO data of Tampa Bay, Florida, October 20, 2009
  - Scene size approximately 25 x 30 km
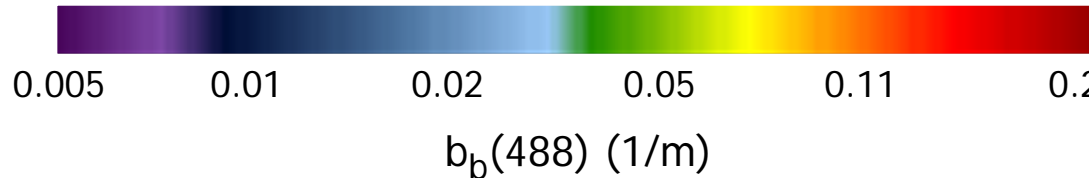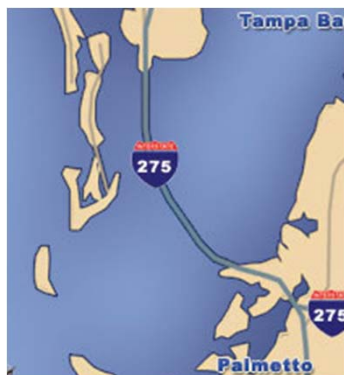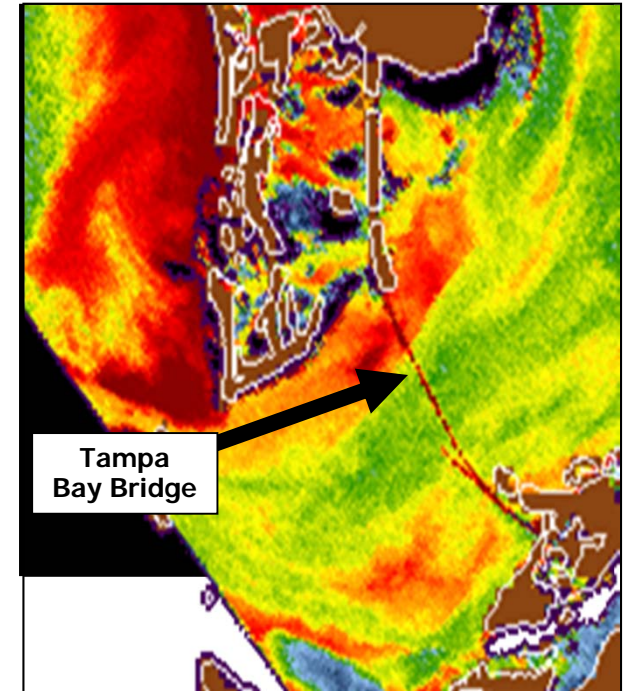- Processed to optical backscatter coefficient b_b at 488 nm wavelength

MODIS Aqua (1 km) at 1915 GMT

MERIS (300 m) at 1556 GMT

HICO (95 m) at 1524 GMT

Tampa Bay Bridge

Tampa Bay Bridge

Tampa Bay Bridge

0.005   0.01   0.02   0.05   0.11   0.25

$b_b(488)$ (1/m)

From Bob Arnone, NRL

- Small ground sample distance images (HICO) are better in resolving complex coastal features and monitoring coastal processes.
- Derived backscattering for all three sensors are consistent.

HICO High Signal to Noise Ratio for Dark Water Scenes
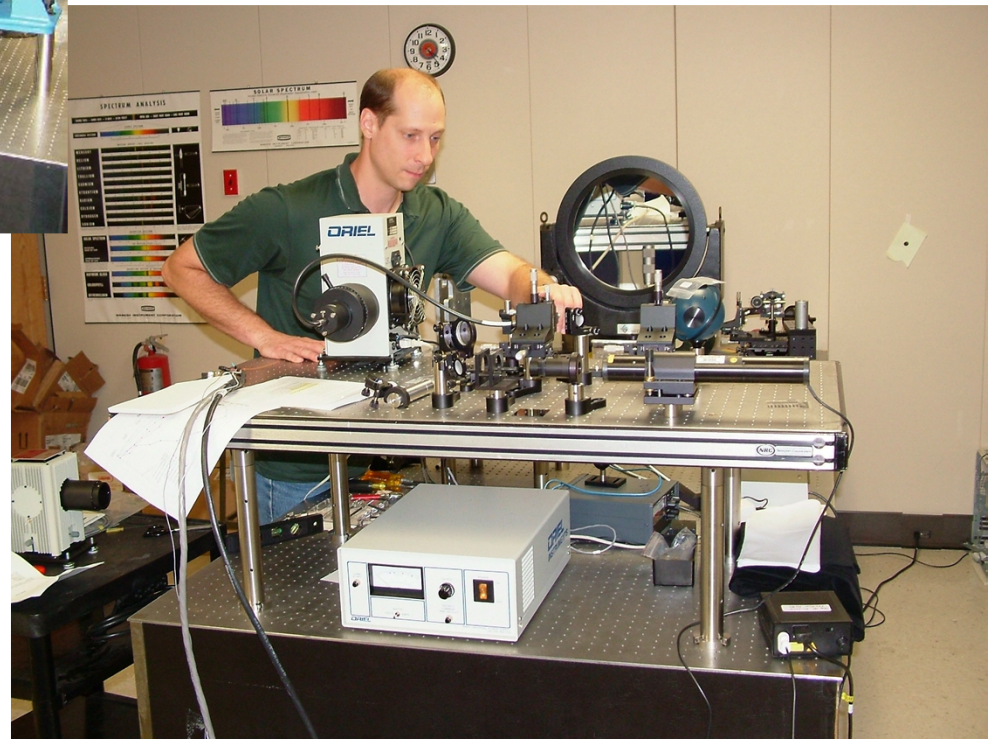
Pusan, South Korea, 18 November 2009

HICO Calibration and Alignment at NRL

Integrating sphere radiometric sources standardized using a NIST-traceable lamp

Optical collimator system for alignment and focus

HICO Commanding and Data Center at NRL

- HICO command scripts generated by science team based on orbit simulations
- Command scripts sent from NRL Payload Operations Control Center (POCC) to Huntsville Operations Support Center (HOSC) to Space Station
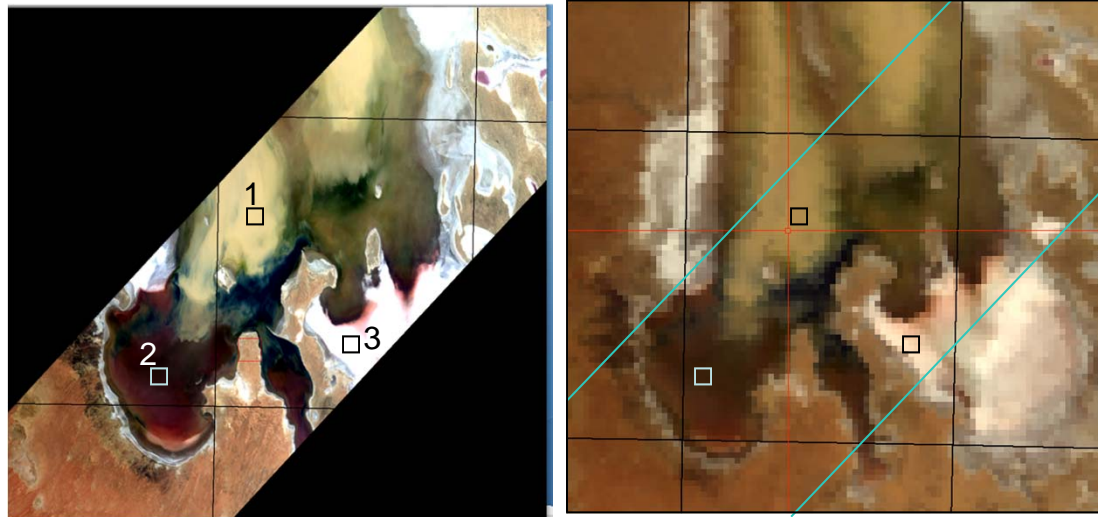- Image and housekeeping data from Station are collected by the HOSC, sent to the NRL POCC

NRL Payload Operations Control Center
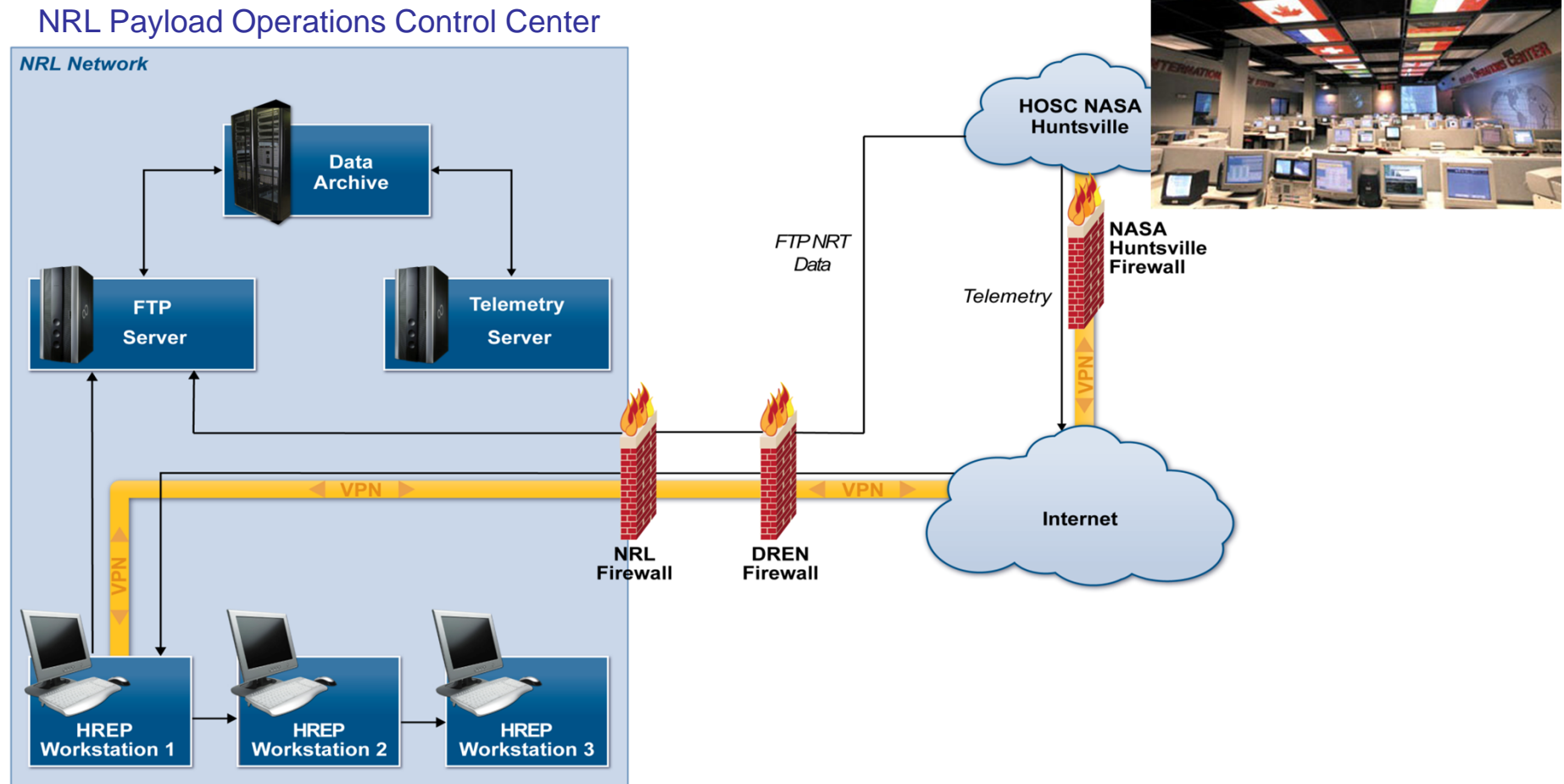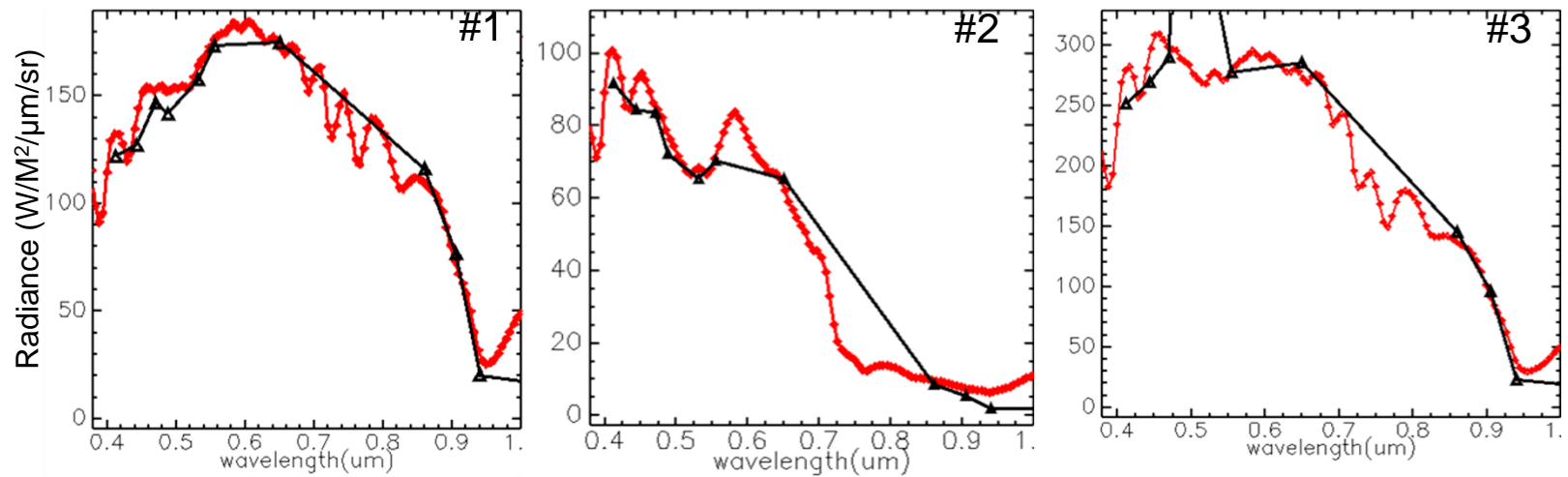
Vicarious Calibration of HICO

Lake Eyre, Australia   HICO   Terra MODIS

HICO   Terra MODIS

Ocena Products Using Look-Up-Tables

General Look-Up-Table Method

- Compute modeled water-leaving radiance for many (all expected) combinations of water depth, bottom type, and in-water parameters
- Store modeled spectra in look-up table
- For each water pixel in the scene, search the look-up table spectra to find the best match to the pixel spectrum
- The model parameters for the look-up table spectrum are assigned to the image pixel
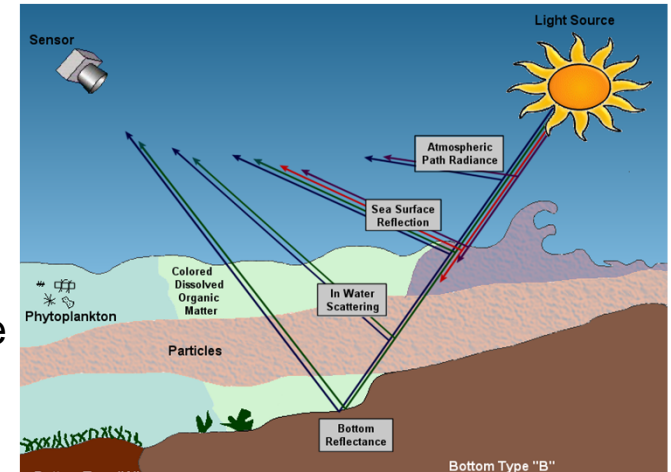
Application of Look-Up-Table Method

- Parameters that are varied
  - Chlorophyll A
  - Other accessory pigments
  - CDOM – slope and amount
  - Suspended sediments – type and amount
  - Water depth – range to 30 m, spacing increasing with depth
  - Bottom type – many available, down selected for particular locations
  - Phase function
  - Turn on or off, Raman, Chl and CDOM fluorescenece

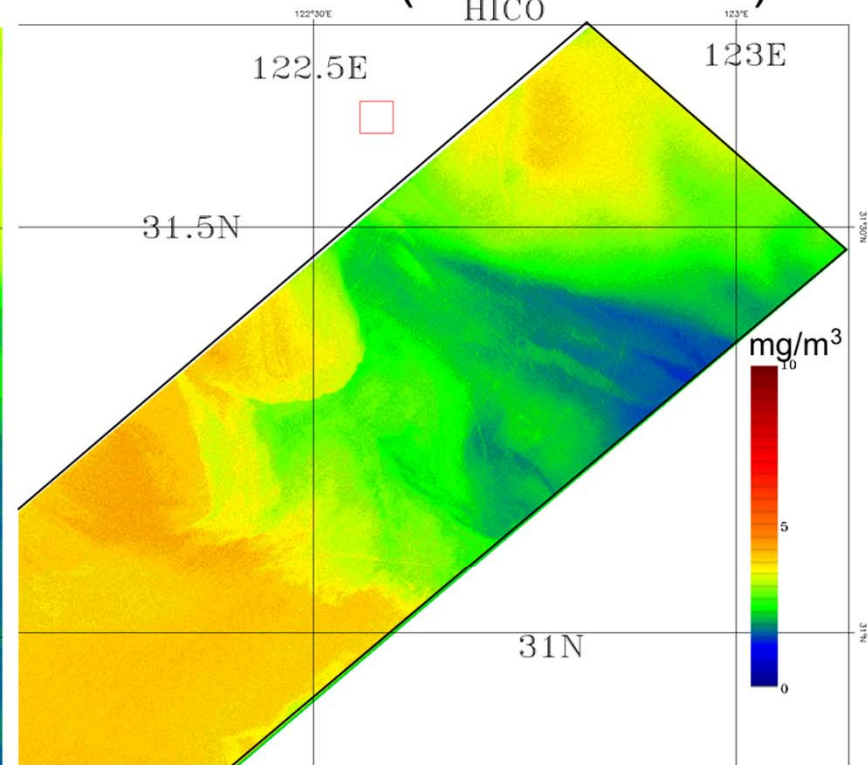- How to determine best match is an ongoing research issue
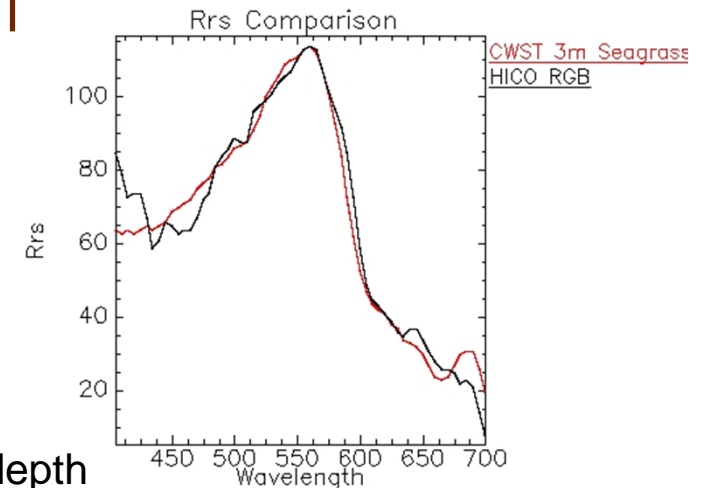
HICO Product Retrievals Using Multispectral Aalgorithms
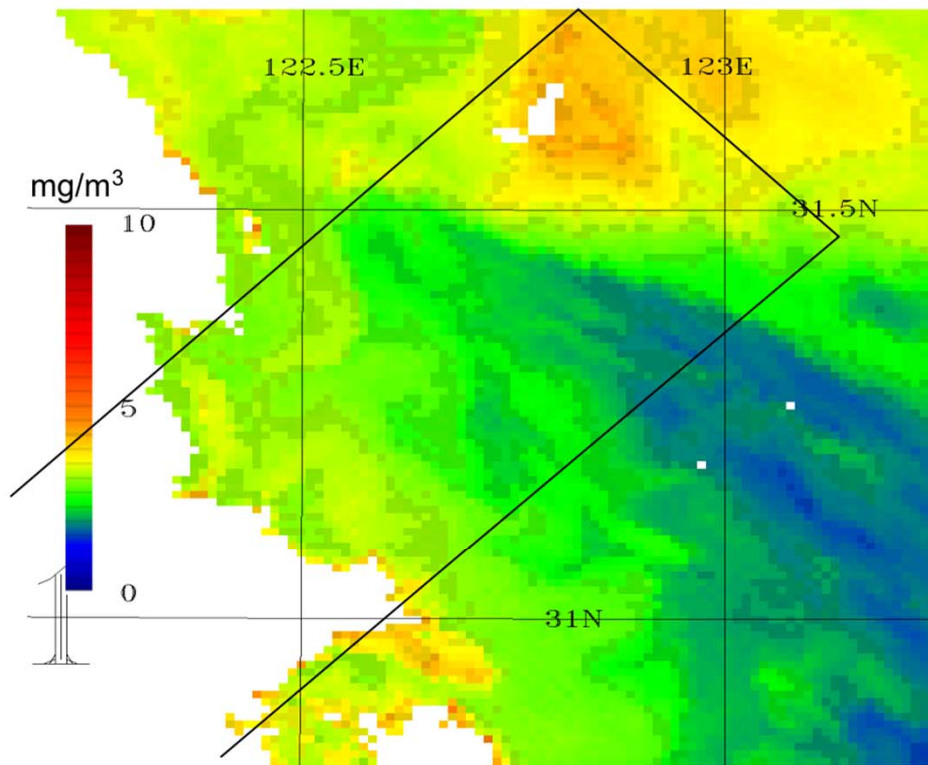
Summary

- HICO launched to the International Space Station on September 10, 2009
- Now using HICO coastal product retrievals to demonstrate the Naval utility of coastal hyperspectral environmental products from space
- Ready to distribute HICO data to the broader oceanographic community