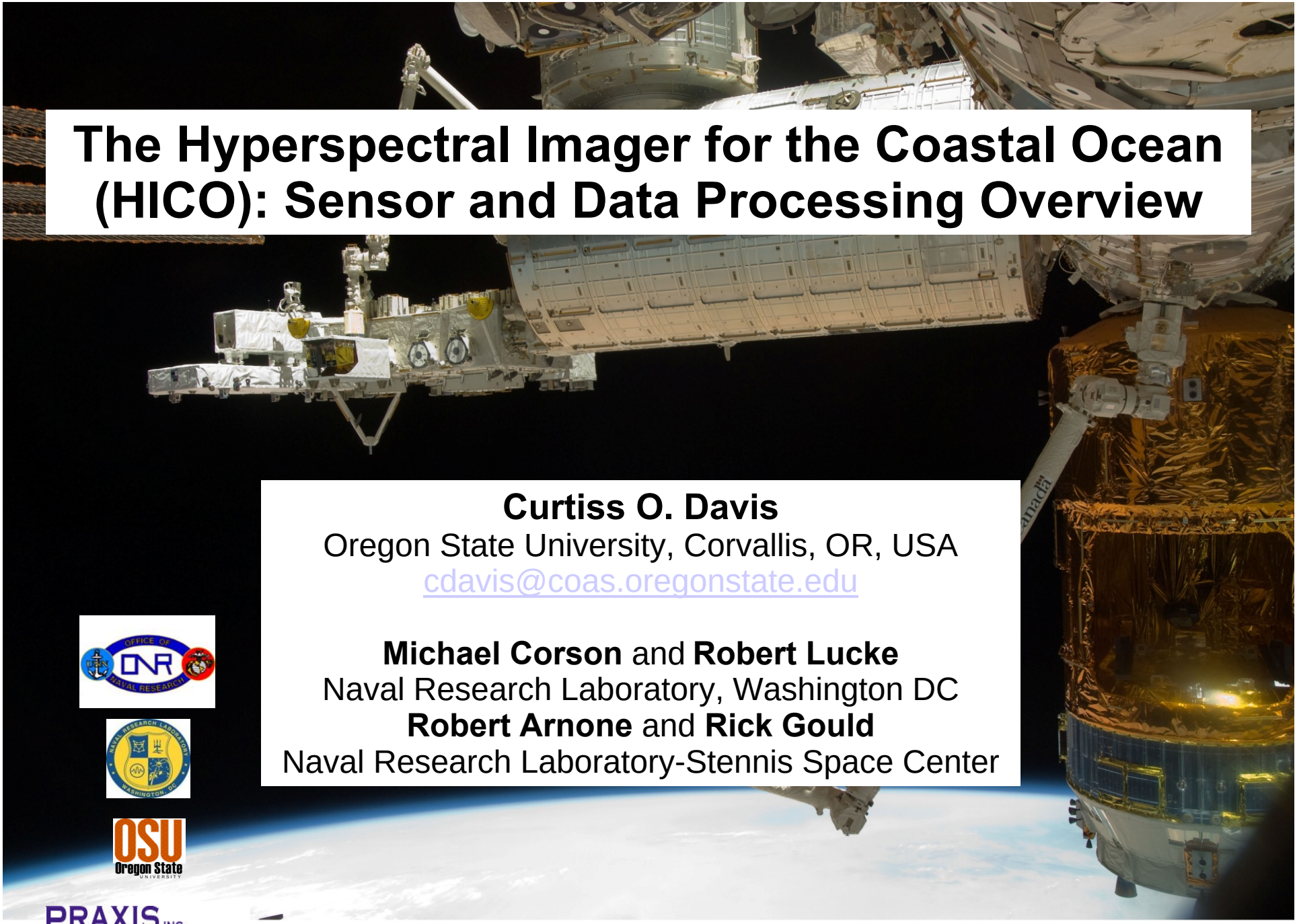

The Hyperspectral Imager for the Coastal Ocean (HICO): Sensor and Data Processing Overview

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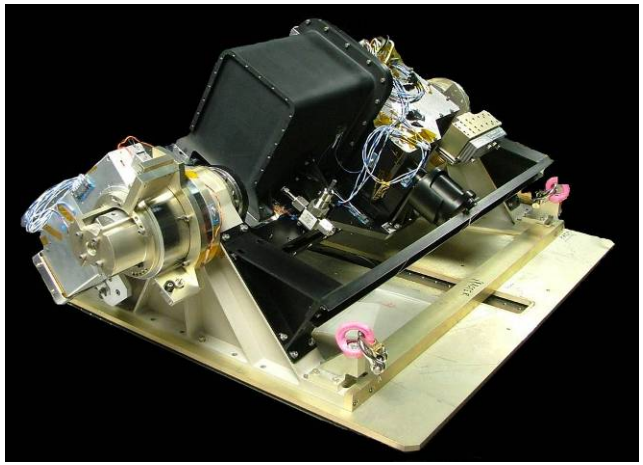
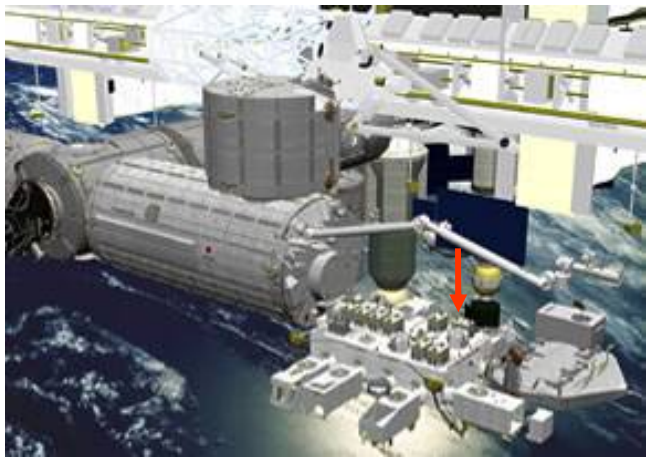
Hyperspectral Imager for the Coastal Ocean (HICO)

- Sponsored as an Innovative Naval Prototype (INP) of Office of Naval Research
- Supported by the Space Test Program for Integration and Launch
- Additional support from NASA and JAXA for launch and integration onto the Japanese Experiment Module Exposed Facility on the International Space Station (ISS)
- September 24, 2009: HICO installed on ISS Japanese Module Exposed Facility
- The HICO sensor:
  - first spaceborne imaging spectrometer designed to sample coastal oceans
  - samples coastal regions at <100 m (380 to 1000 nm: at 5.7 nm bandwidth)
  - has high signal-to-noise ratio to resolve the complexity of the coastal ocean





Left, *HICO, before integration into HREP.* ***Right*** *red arrow shows location of HREP on the JEM-EF.*

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
  - terrain and vegetation maps
- As a Naval Innovative Prototype (INP) demonstrate new and innovative ways to develop and build the imaging payload
  - reduce cost
  - reduce schedule
- Serve as a pathfinder for future spaceborne hyperspectral imagers

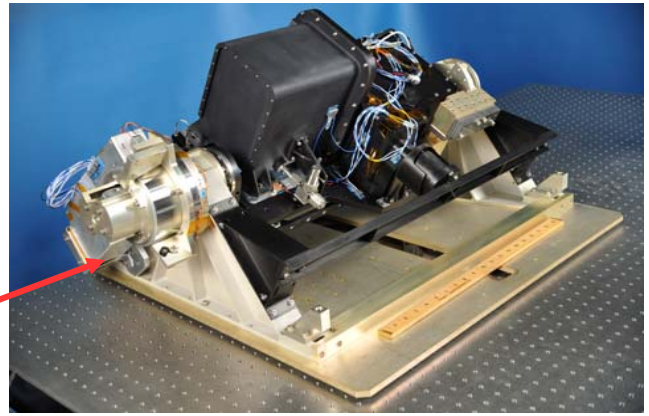
HICO Development Timeline

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

Beginning of HICO Space Station project

- June 2007: Preliminary Design Review
- November 2007: Critical Design Review
- May 2008: HICO imager delivery
- July 2008: HICO Test Readiness Review
- September 2008: HICO delivery to HREP payload

Project start to sensor delivery in 16 months

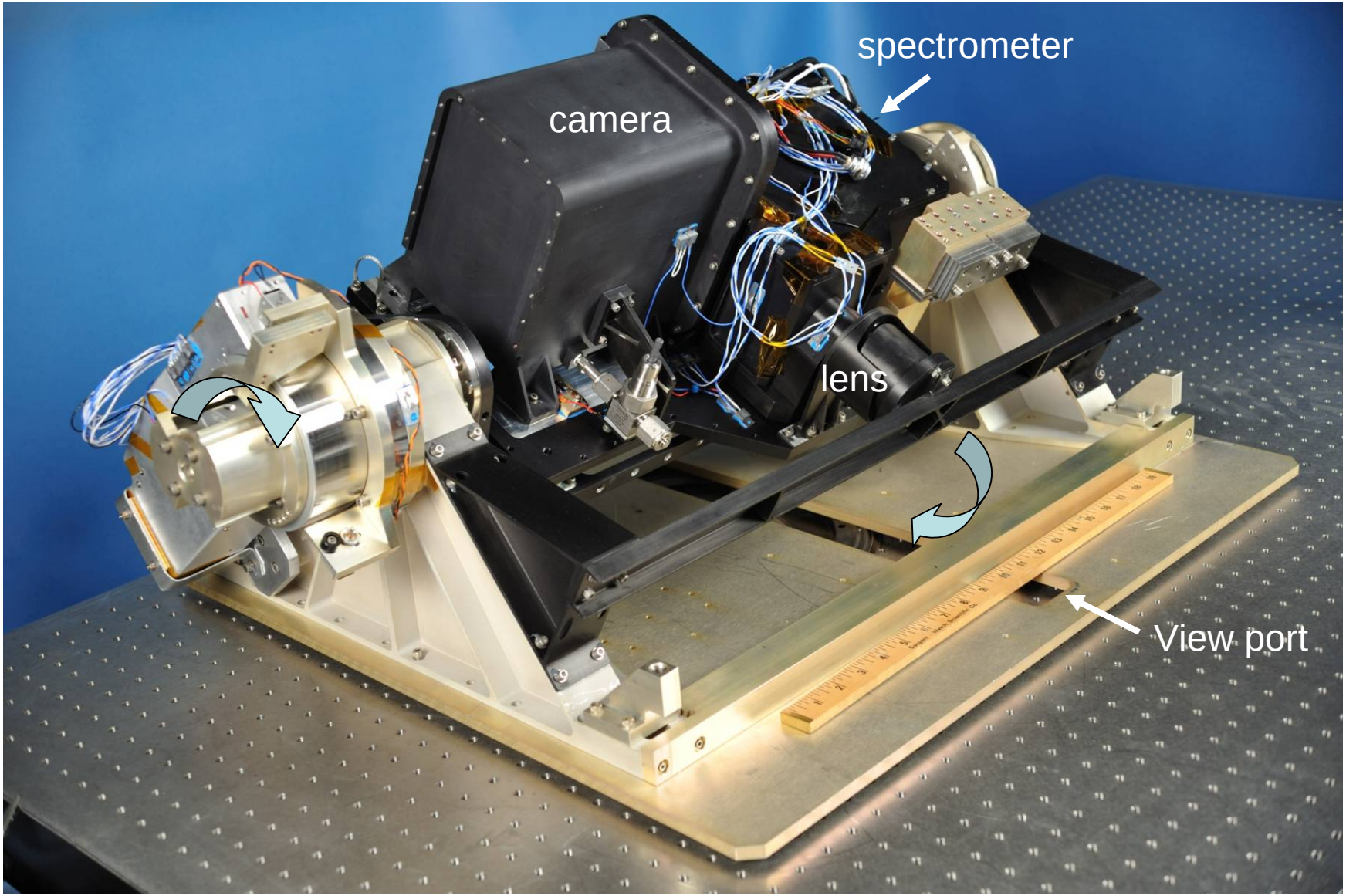


HICO flight imager

- September 10, 2009: Launch to Space Station
- September 24: HREP installed on Japanese Experiment Module and activated

HICO image of Hong Kong, October 2, 2009. Scene approximately 42 x 192 km

HICO Flight Sensor - Stowed position

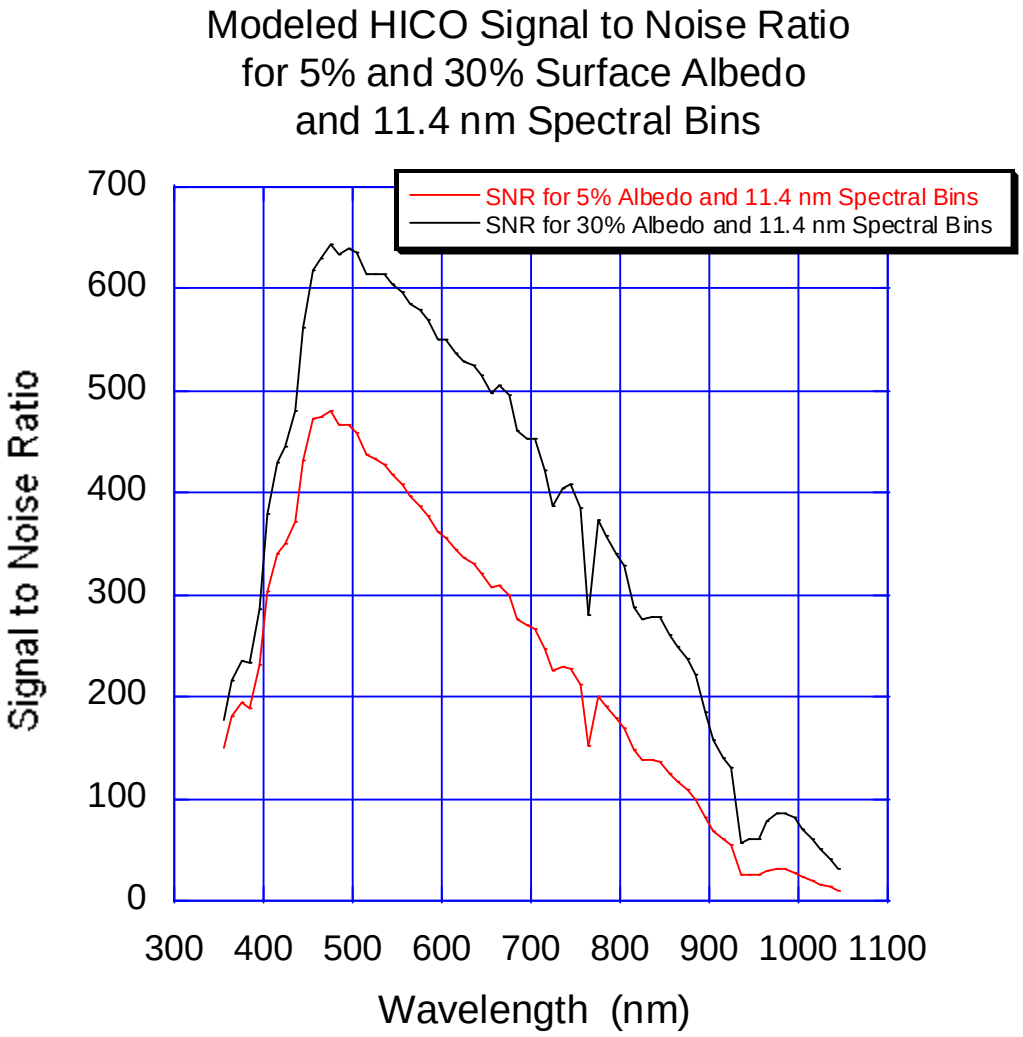


HICO meets Performance Requirements

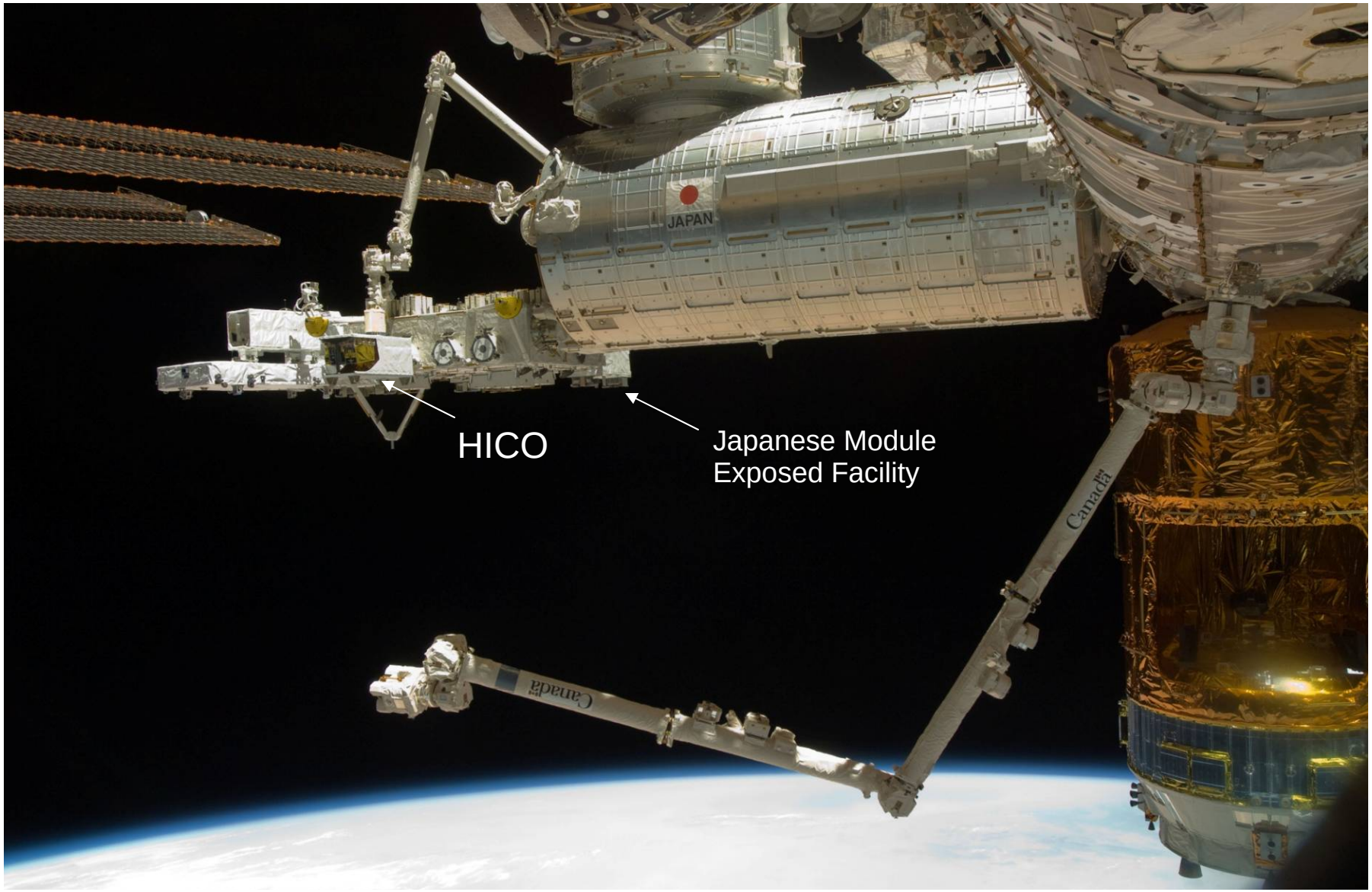
Parameter	Performance	Rationale
Spectral Range	380 to 960 nm	All water-penetrating wavelengths plus Near Infrared for atmospheric correction
Spectral Channel Width	5.7 nm	Sufficient to resolve spectral features
Number of Spectral Channels	102	Derived from Spectral Range and Spectral Channel Width
Signal-to-Noise Ratio for water-penetrating wavelengths	> 200 to 1 for 5% albedo scene (10 nm spectral binning)	Provides adequate Signal to Noise Ratio after atmospheric removal
Polarization Sensitivity	< 5% (430-1000 nm)	Sensor response to be insensitive to polarization of light from scene
Ground Sample Distance at Nadir	92 meters	Adequate for scale of selected coastal ocean features
Scene Size	42 x 192 km	Large enough to capture the scale of coastal dynamics
Cross-track pointing	+45 to -30 deg	To increase scene access frequency
Scenes per orbit	1 maximum	Data volume and transmission constraints

Radiometry

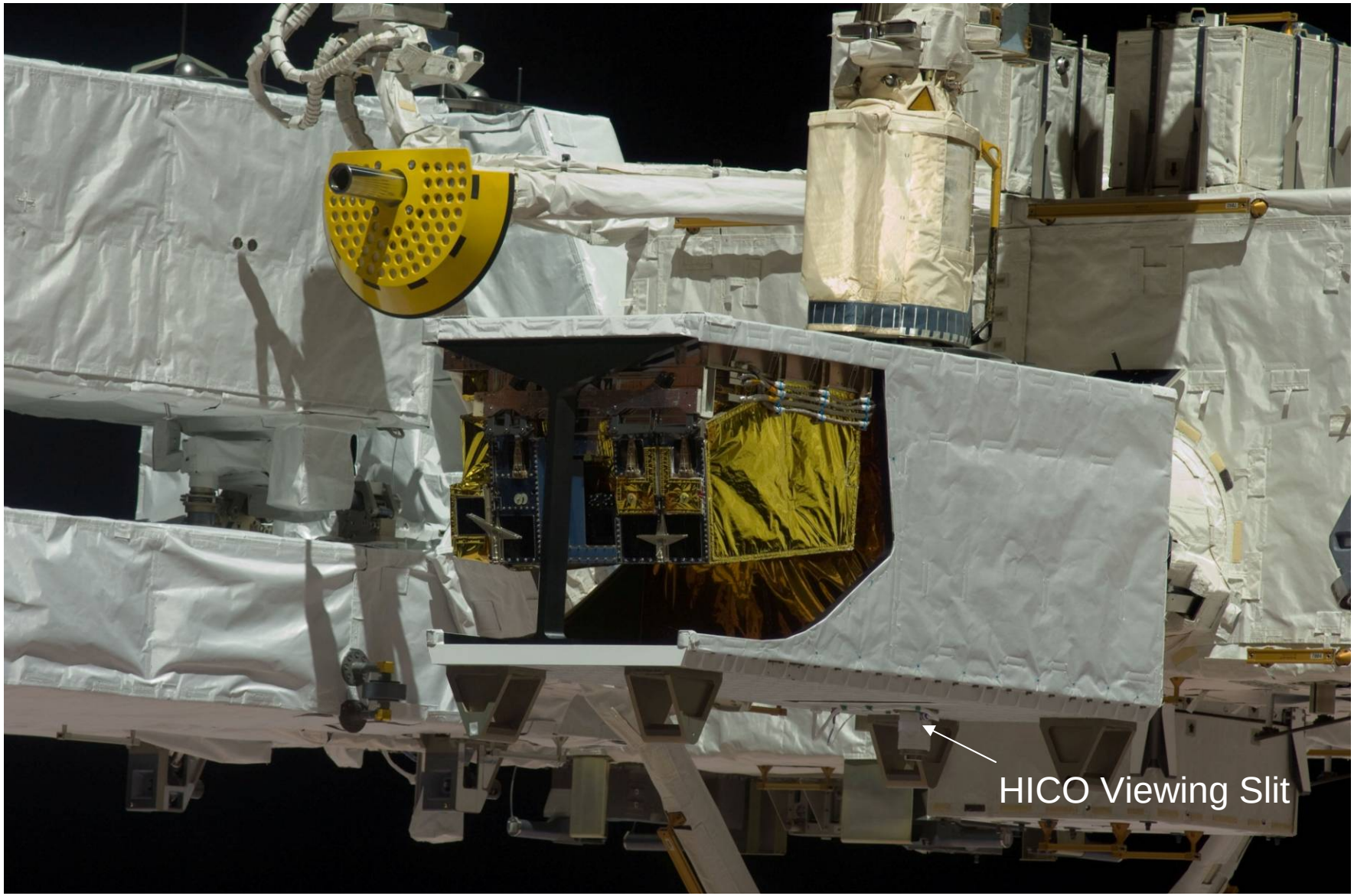
- Use Model to Predict SNR for Ocean Scene from Orbit



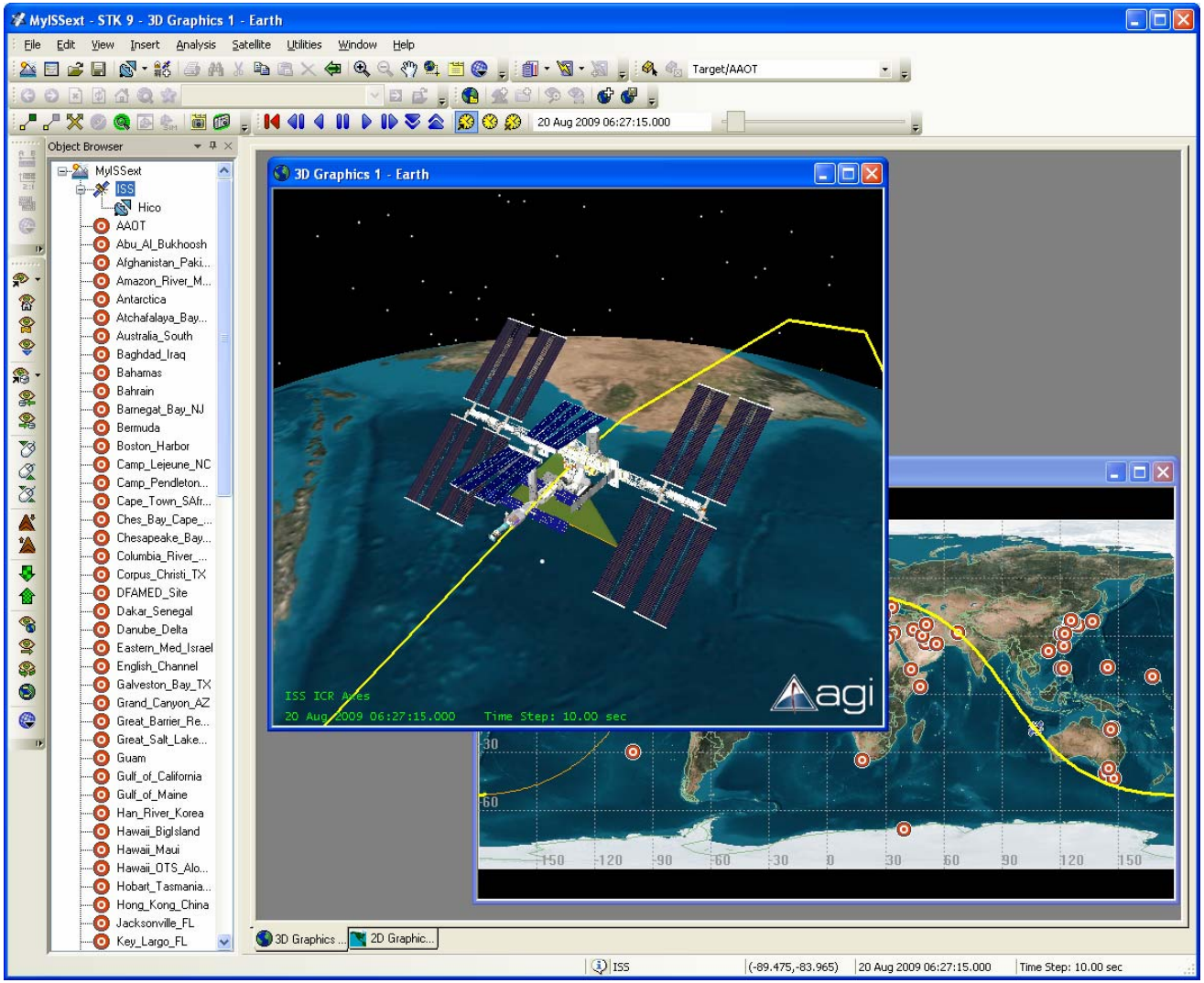
HICO on Japanese Module Exposed Facility



HICO docked at ISS



Mission Planning with Satellite Tool Kit (STK)



Combines scene locations,
ISS attitude, ISS ephemeris, HICO pointing and constraints to produce list of all possible observations in particular time period

Constraints include:

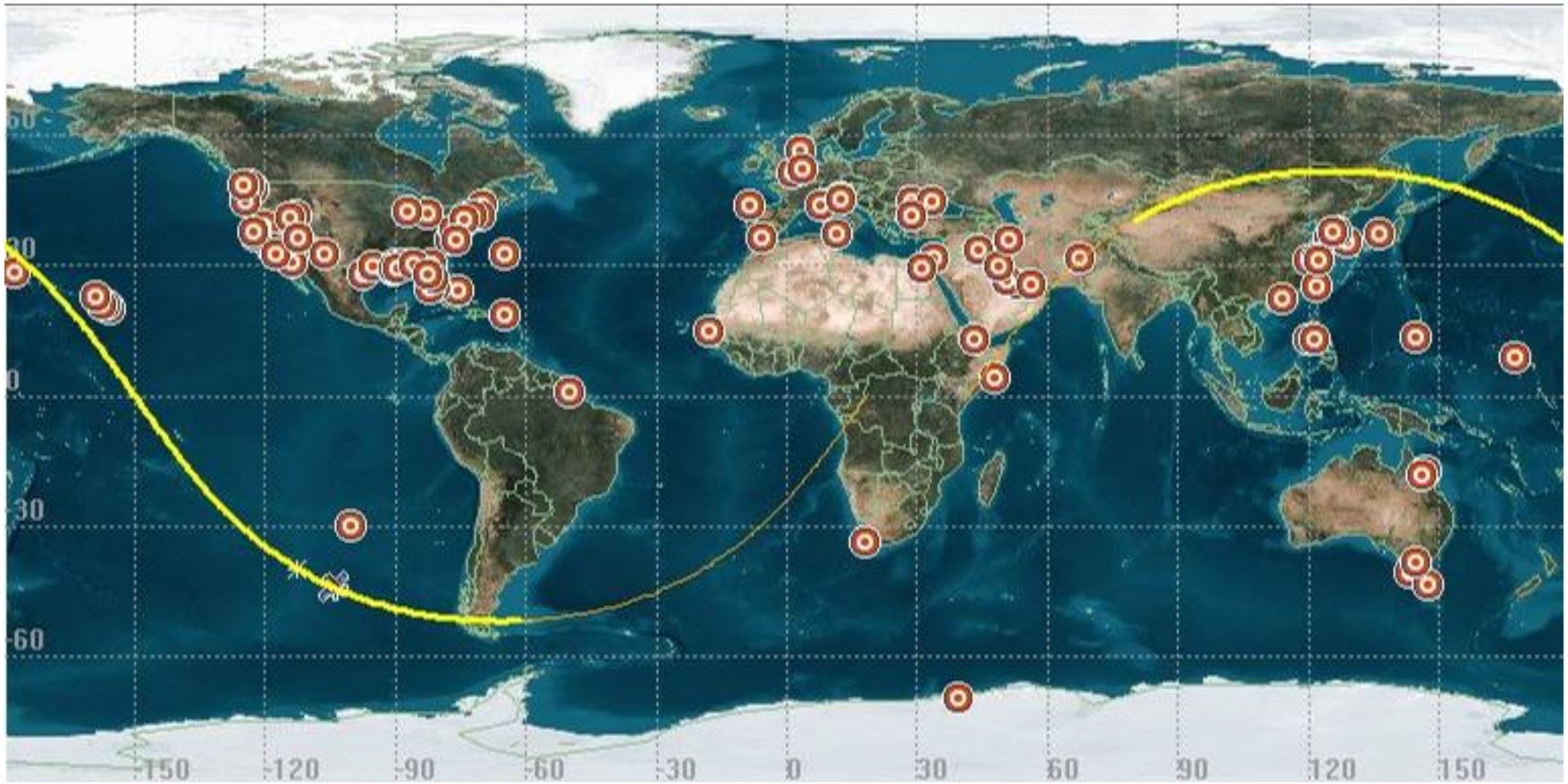
- Targets in direct sun
- Angle from ISS z-axis to Sun <= 140°
- Sun specular point exclusion angle = 30°
- Sun ground elevation angle >= 25°

HICO Image Locations

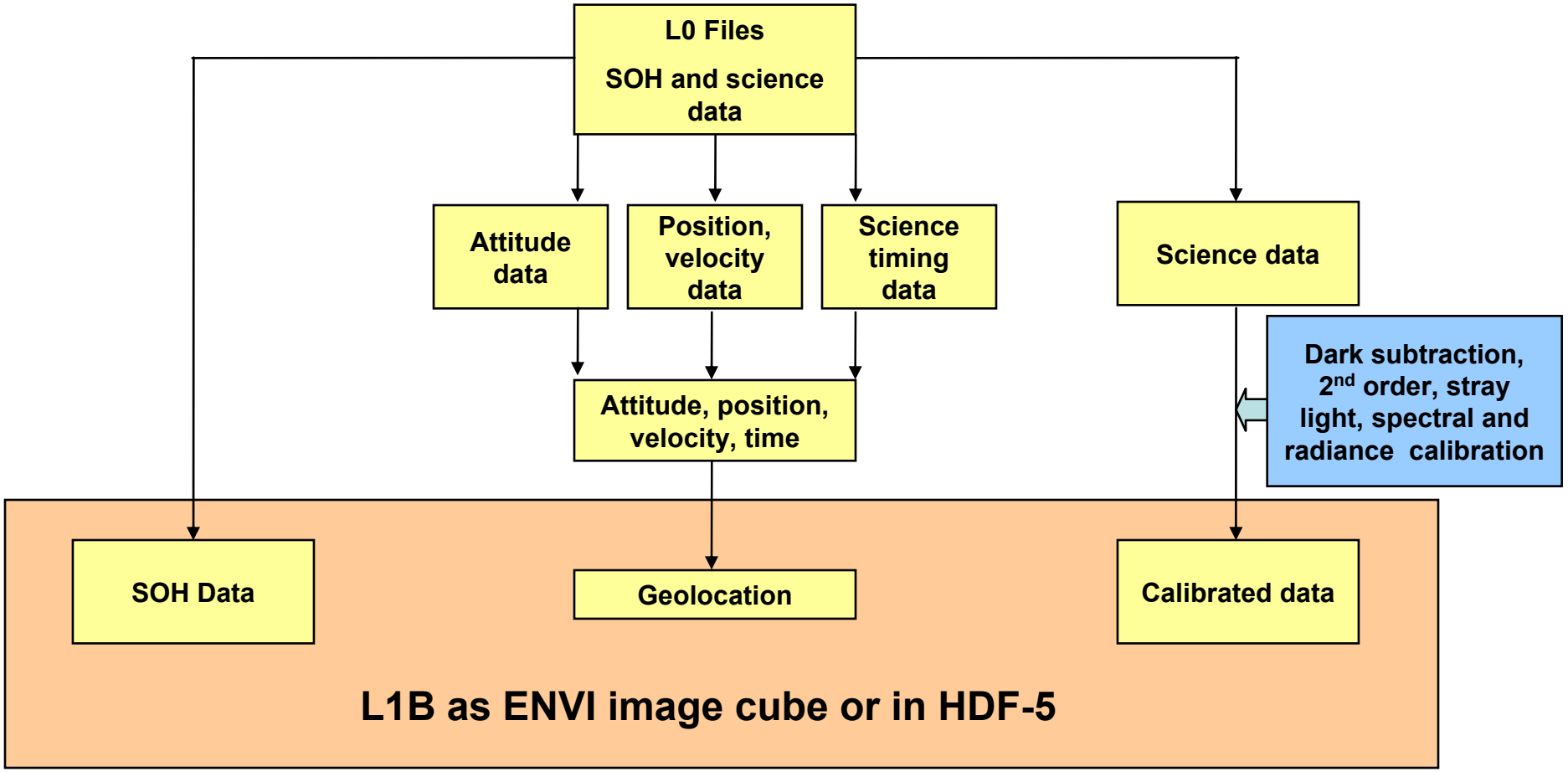
Locations chosen based on:

1. Location – within latitude limits of ISS orbit
2. Type – ocean, coast, land
3. Use – CalVal, Science, Navy, etc

- Currently ~150 locations identified
- New sites can be added which may mean fewer observations of each site due to “competition” between sites



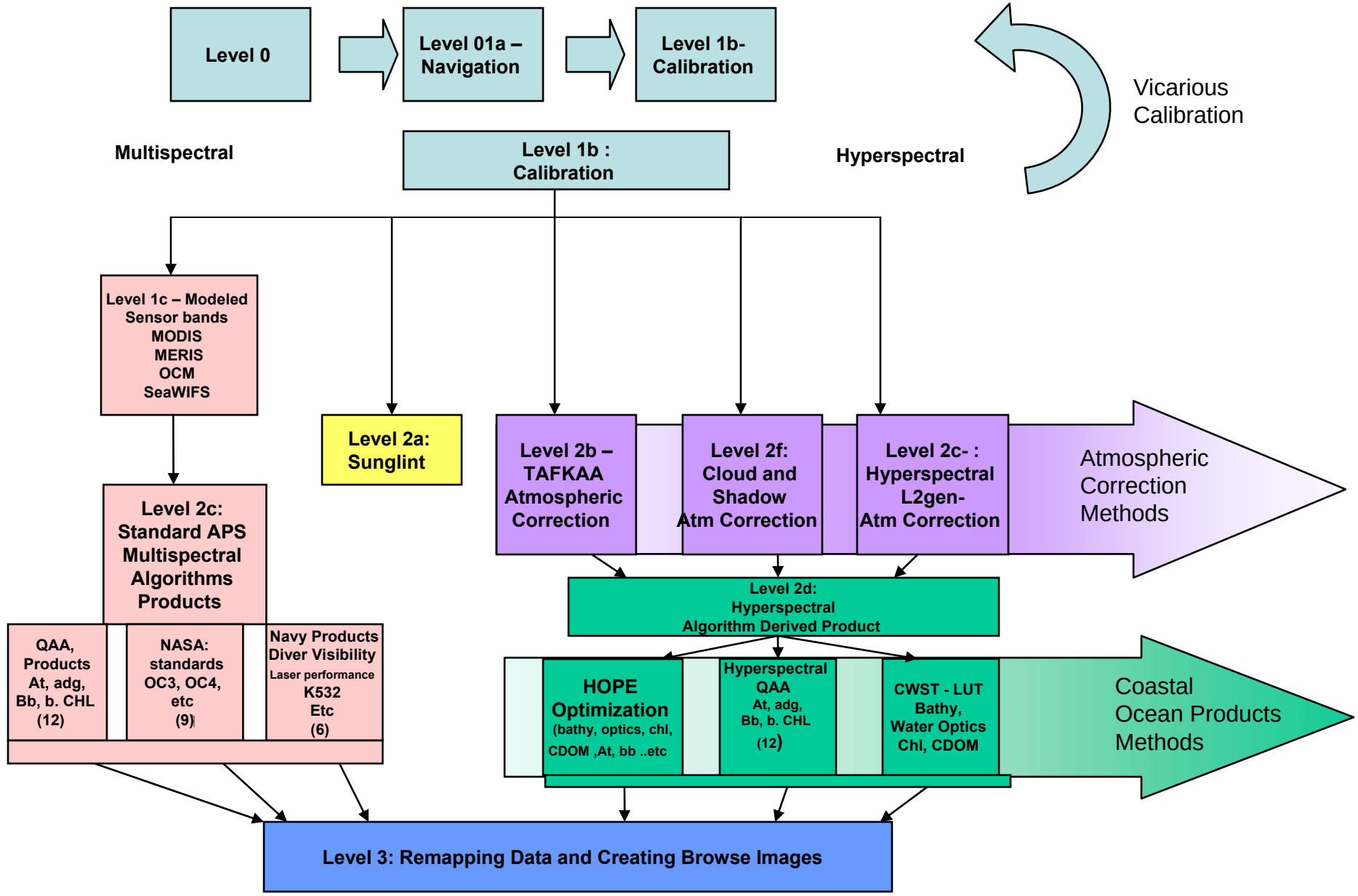
L0 to L1B File Generation



APS: Automated Processing System

- Individual scenes are sequentially processed from the raw digital counts (Level-1) using standard parameters to a radiometrically, atmospherically, and geometrically corrected (Level-3) product within several minutes.
- It further processes the data into several different temporal (daily, 8-day, monthly, and yearly) composites or averages (Level-4).
  - HICO repeat may preclude this normal processing
- Additionally, it automatically generates quick-look ``browse'' images in JPEG format which are stored on a web.
  - PNG, TiFF/GeoTiFF, World File side-car file
- Populates an SQL database using PostgreSQL.
- It stores the Level-3 and Level-4 data in a directory-based data base in HDF format. The data base resides on a 20TB RAID array.
  - APS format in netCDF (v3, v4), HDF (v4, v5).
  - HICO data also available as an ENVI image cube

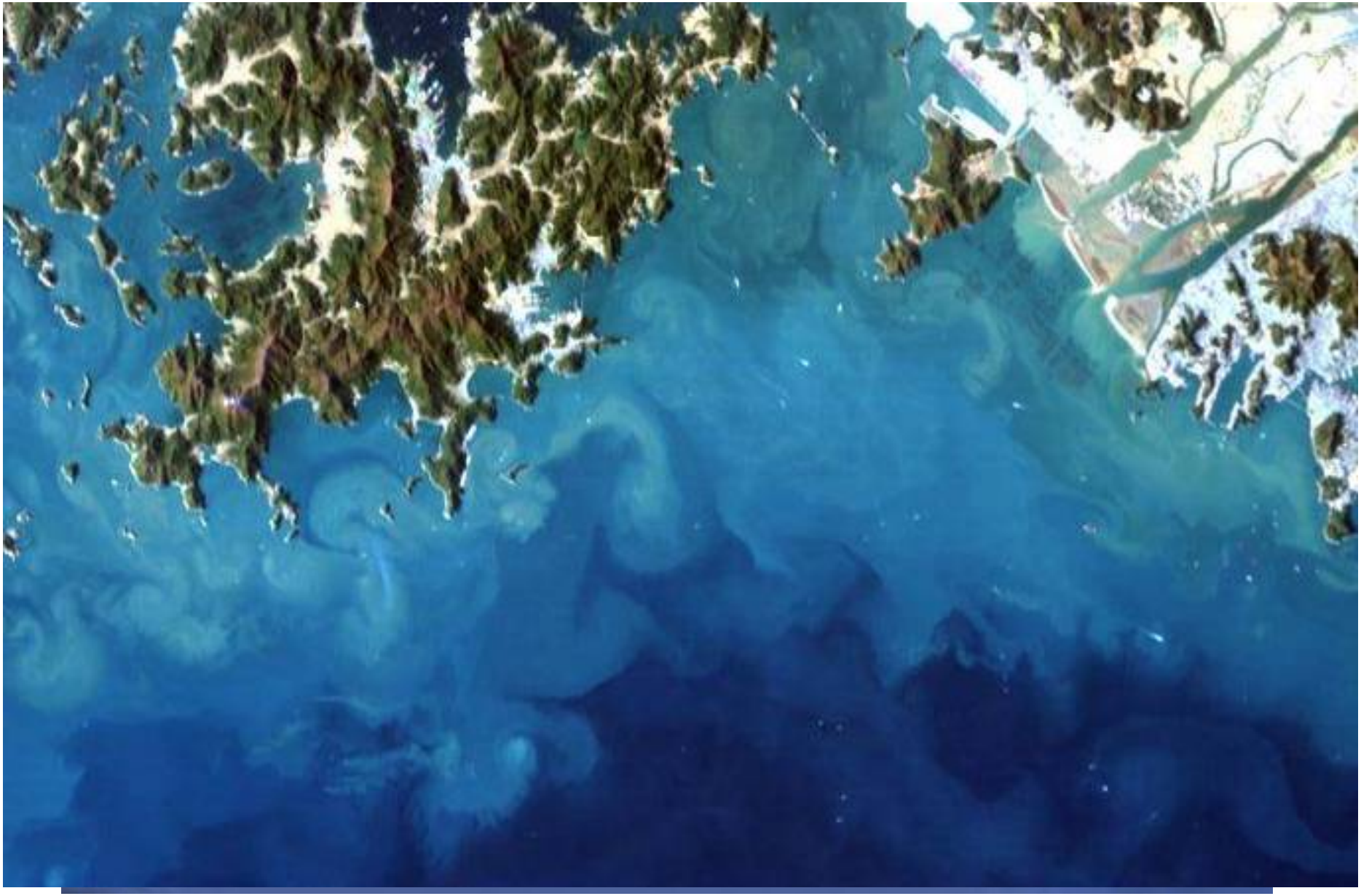
HICO Processing Activity in APS



HICO Image
Hong Kong : 10/02/09

HICO Image
Chesapeake Bay: 10/09/09

HICO Image
Pusan, South Korea: 11/18/09



Relative Bathymetry of Han River Area Mud Flats

HICO Image off
Korean Peninsula

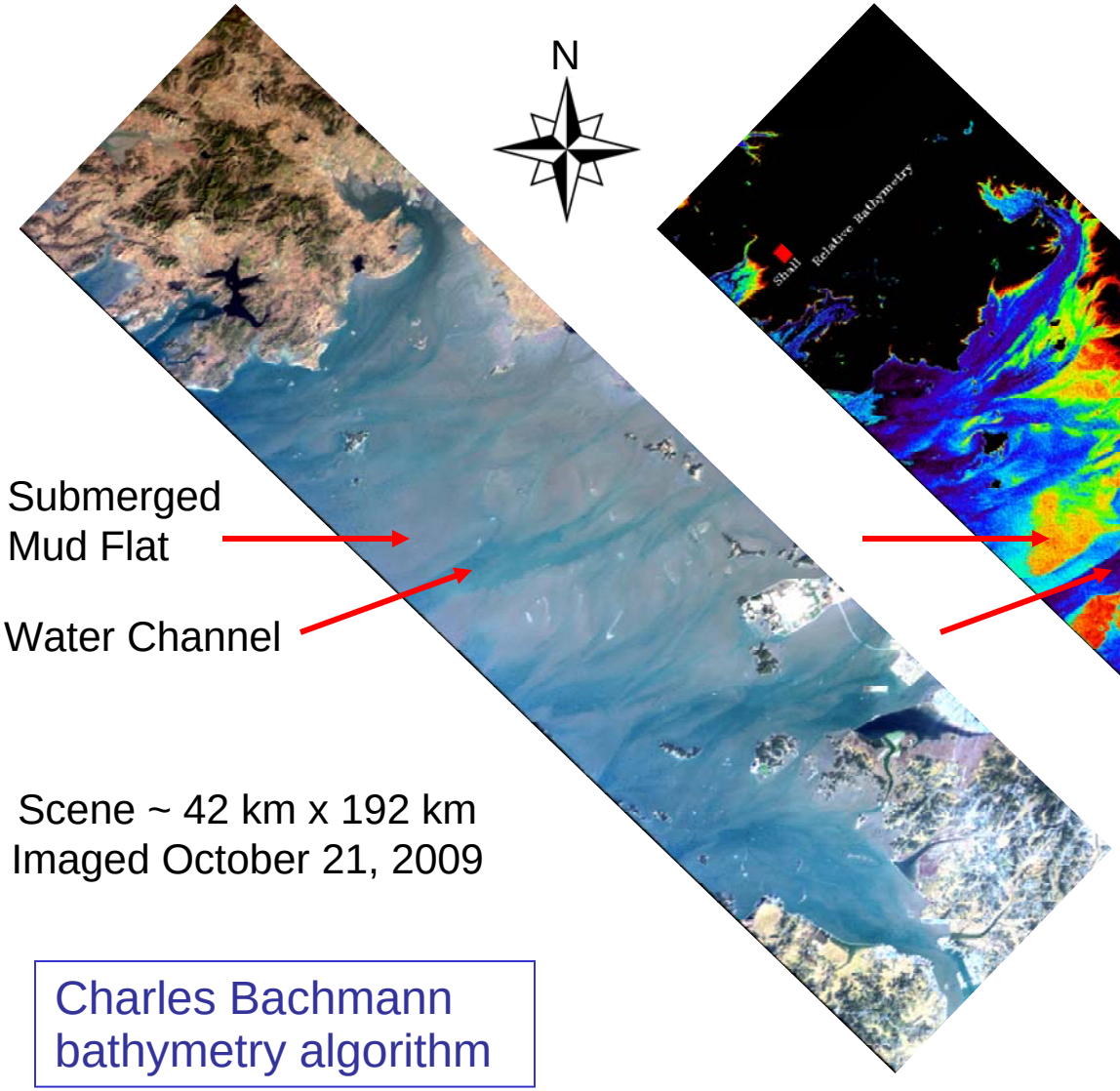
Relative Bathymetry Map
Retrieved from HICO Image

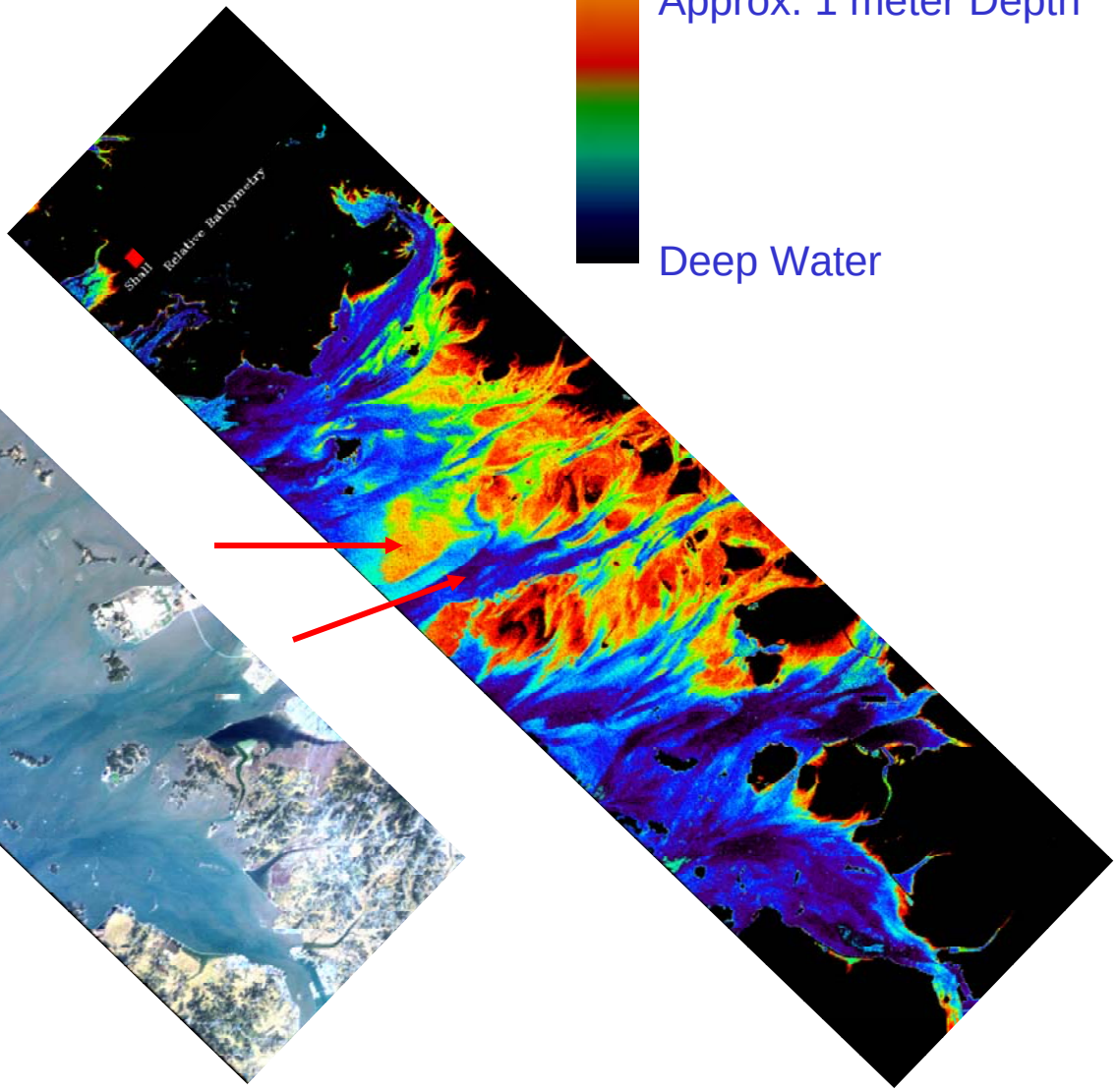
N

Shallow Water

Approx. 1 meter Depth

Deep Water





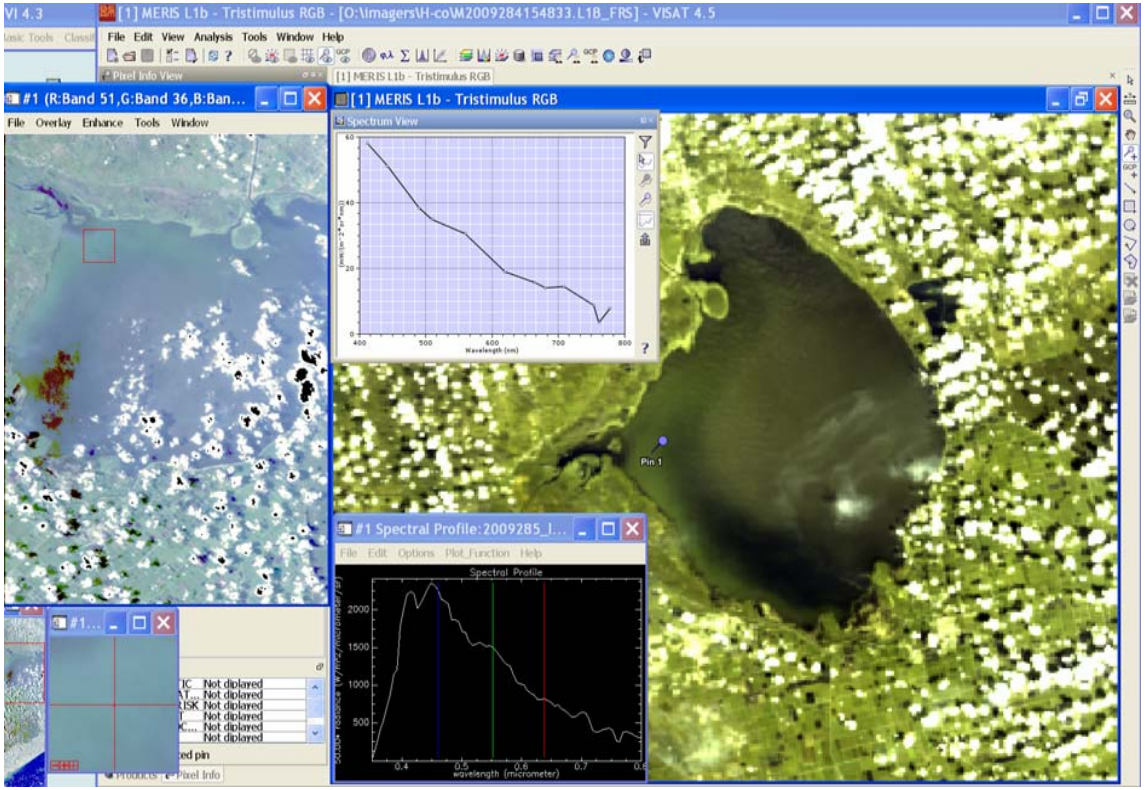
Submerged
Mud Flat

Water Channel

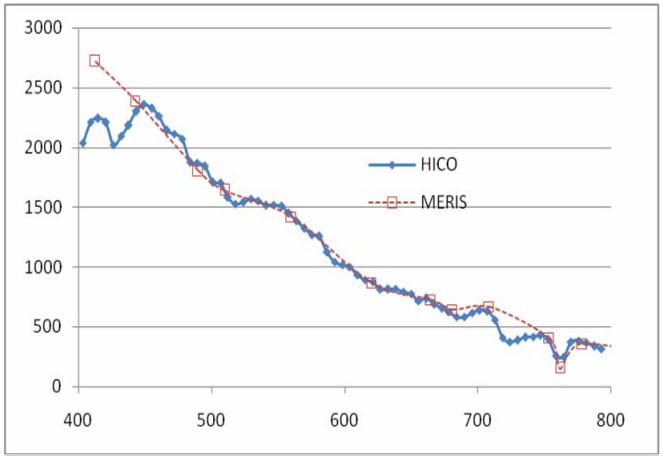
Scene ~ 42 km x 192 km
Imaged October 21, 2009

Charles Bachmann
bathymetry algorithm

Comparison of HICO and MERIS

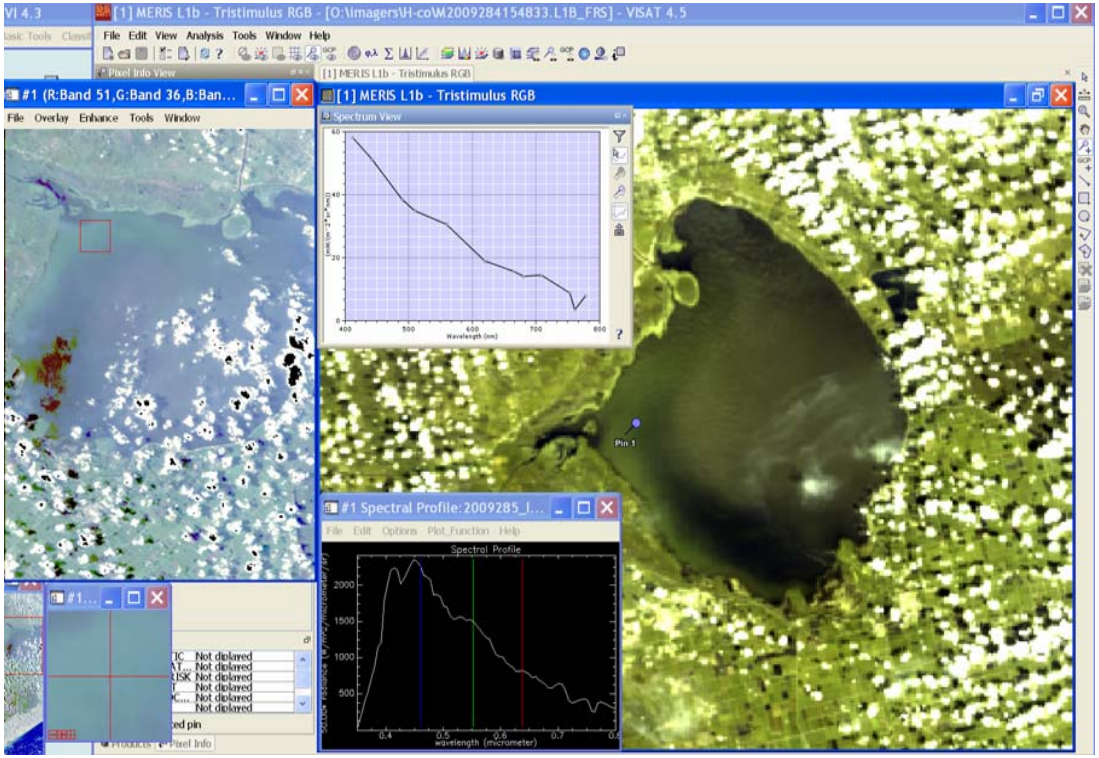


Lake Okeechobee

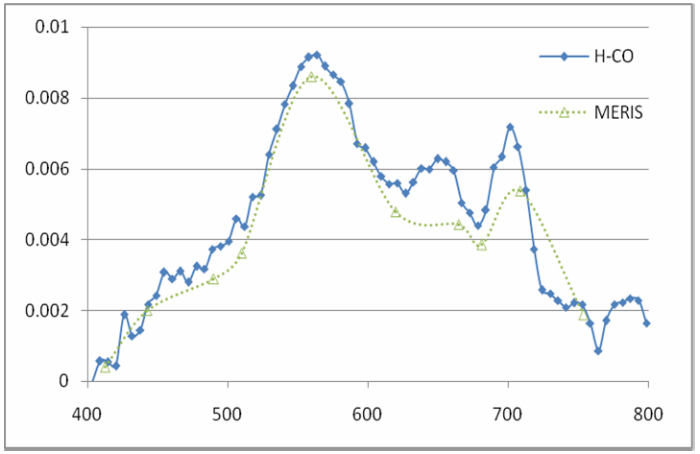


At Sensor Spectra Comparison

Comparison of HICO and MERIS



Lake Okeechobee

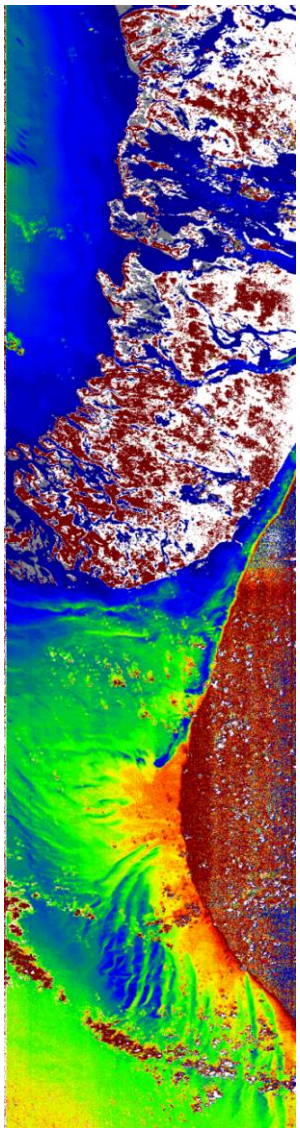


Reflectance Spectra Comparison

Ping Lee Cloud/Shadow and HOPE algorithms

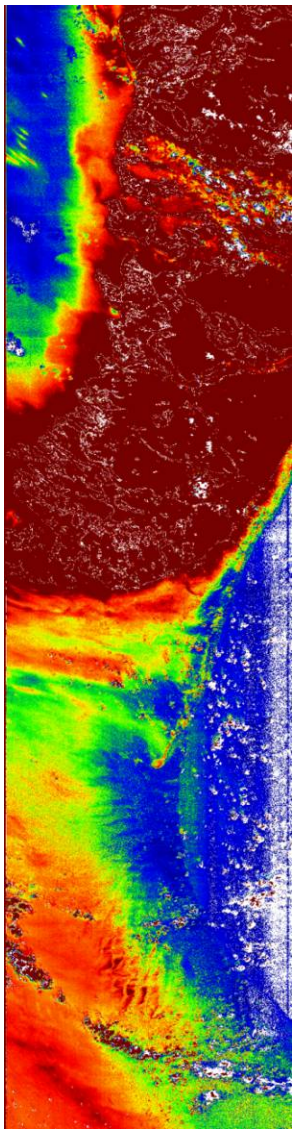
HICO Image
Bahamas: 10/22/09

Radiance



Bathymetry

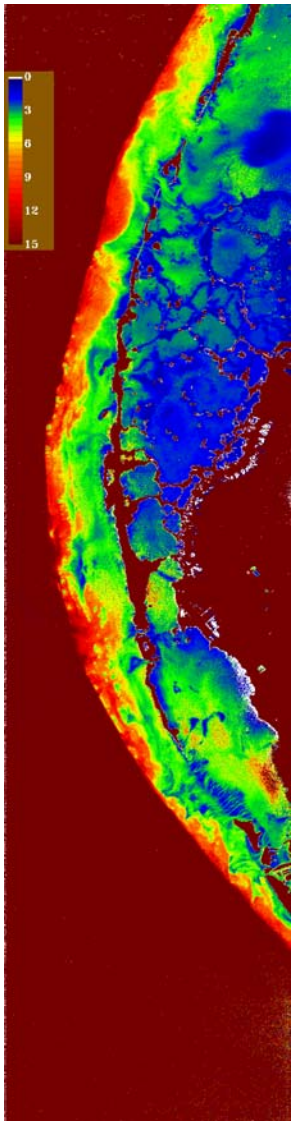
Ping Lee
HOPE
Algorithm



Absorption

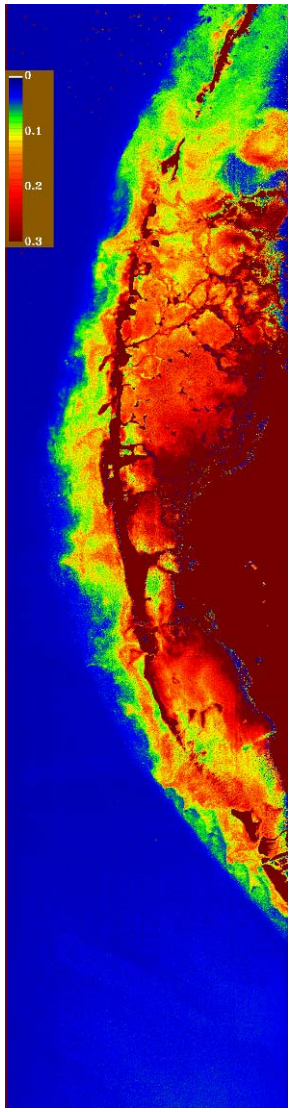
HICO Image
Key Largo, Florida: 11/13/09

Radiance



Bathymetry

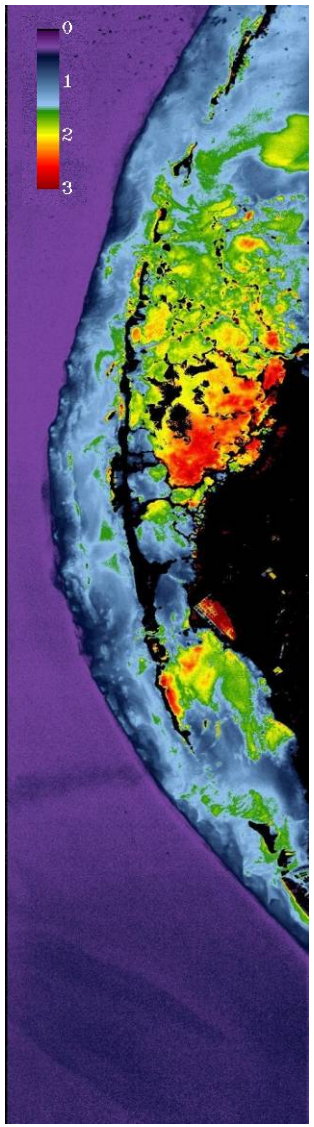
Ping Lee
HOPE
Algorithm



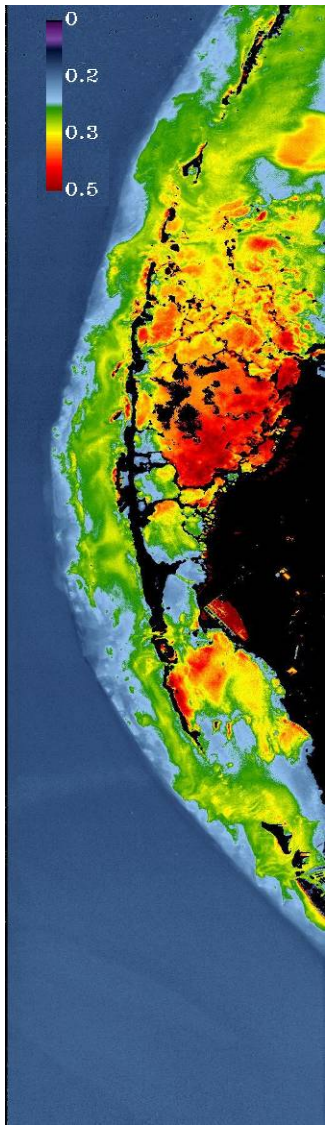
Absorption

Selected HICO APS Data Products
Key Largo, Florida

Radiance



chl_02



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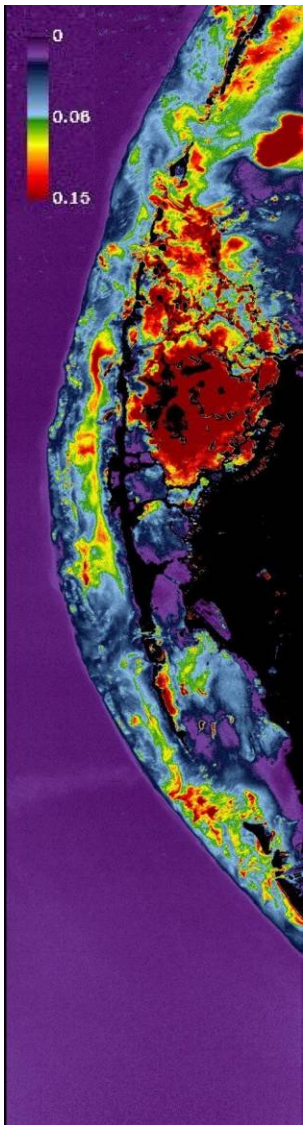

bb_551

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- Ellen Bennert
- Karen Patterson
- Dan Korwan
- Marcos Montes
- Robert Fusina
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- David Lewis
- Ronnie Vaughn
- Theresa Scardino
- Adam Lawson
- Alan Weidemann

Academic

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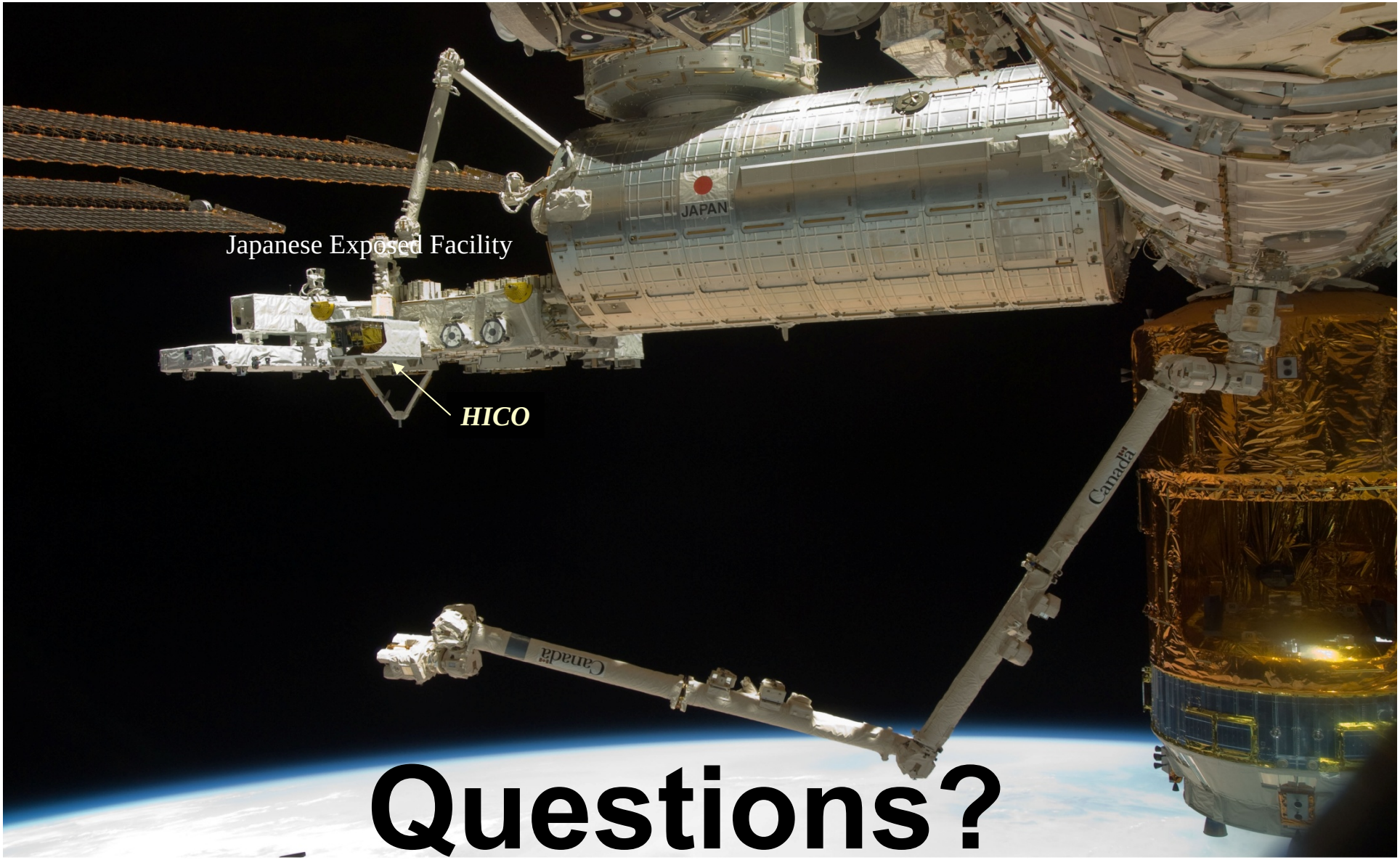
- Jasmine Nahorniak, OSU
- Nick Tufillaro, OSU
- Curt Vandetta, OSU
- Ricardo Letelier, OSU
- Zhong-Ping Lee, MSU

Special thanks to our sponsors the Office of Naval Research, the Space Test Program, and to NASA and JAXA who made this program possible.

HICO Next Steps and future Directions

- Publication on HICO instrument design and calibration completed and in review at NRL.
- Automated end-to-end processing of all HICO data with APS is working.
  - We are evaluating the results in preparation for routine processing and distribution of data.
- Developed HICO Web site at OSU to be made public in next month.
  - Web site will be portal for data requests and distribution (stay tuned)

HICO Docked on the Space Station



Questions?