NRL - 0205 Coastal Ocean Imaging Spectrometer (COIS)

DoD Space Experiment Review Board
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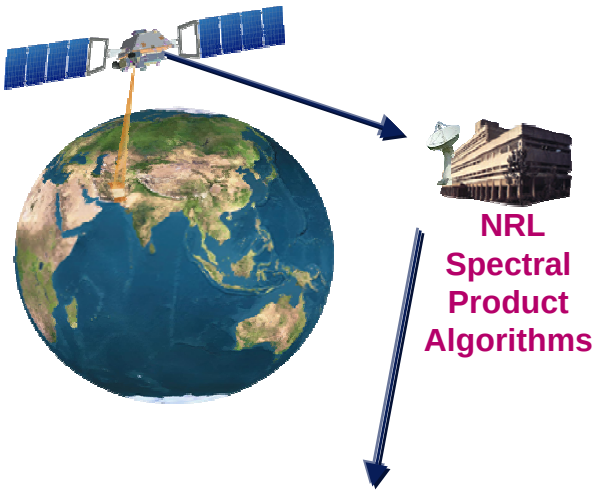
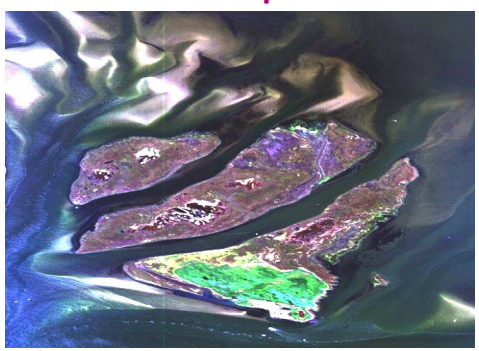
NRL - 0205 Coastal Ocean Imaging Spectrometer (COIS) Concept

Collect two Hyperspectral Earth Image Scenes (20 Km x 100 Km) Per Orbit (30 scenes per day)



Littoral Battlespace Model



Objective: Develop and Demonstrate the Application of Space-based Hyperspectral Imagery (HSI) for Characterization of the Battlespace.

- Collect Visible Near-Infrared (VNIR) Hyperspectral Data.
- Process and compress the data on board.
- Compile Multi-year Seasonal Hyperspectral Database for 50 (global) Littoral sites for seasonal analysis and geophysical model development.
- Additional tasking for Air Force, Army, NIMA and NOAA.
- Technology demonstration of high performance CMOS FPA & Gflop class processor.

Description: COIS is a hyperspectral imaging payload designed to image, process and store 20 km x 100 km images of VNIR (0.4-1.0 µm, 60 bands) HSI data at 20 m GSD. Collect and downlink an average of two scenes per orbit.

- Gimbaled imager with15 cm aperture TMA telescope, and Offner design grating spectrometer, advanced CMOS FPA.
- Processing performed onboard using NRL's ORASIS algorithm on a fast parallel processor; compressed data downlinked at 10 Mbs.
- 400 to 600 km orbit, sun synchronous, 1030 – 1330 equatorial crossing time.

NRL - 0205 Coastal Ocean Imaging Spectrometer (COIS) Justification

Military Relevance - HSI from Space is a Transformational Approach to Characterization of the Battlespace (NSSA, Integrated Spectral Architecture (ISA), Aug 22, 2002).

- Supports Navy-Marine Corps Amphibious Strike, Special Warfare (SEALS) And Minewarfare;
  - Bathymetry, bottom type, in-water optical properties, hazards to navigation, beach and terrain trafficability products.
- Develop HSI battlefield target detection techniques;
  - Cueing and detection of medium size facilities, camouflage, terrain categorization, BDA.
- Supports **many** mutual requirements of Departments of Commerce (NOAA), Interior, Agriculture and NASA
  - Coastal bathymetry, pollution monitoring, fisheries, land cover, land use, crop assessment, resource management, illicit crops, geologic mineral identification.

Need for Spaceflight -

- The repeat seasonal coverage of 50 widely dispersed global targets (many in foreign sovereign or territorial waters) over a three year period can not be accomplished (economically or practically) with airborne systems.

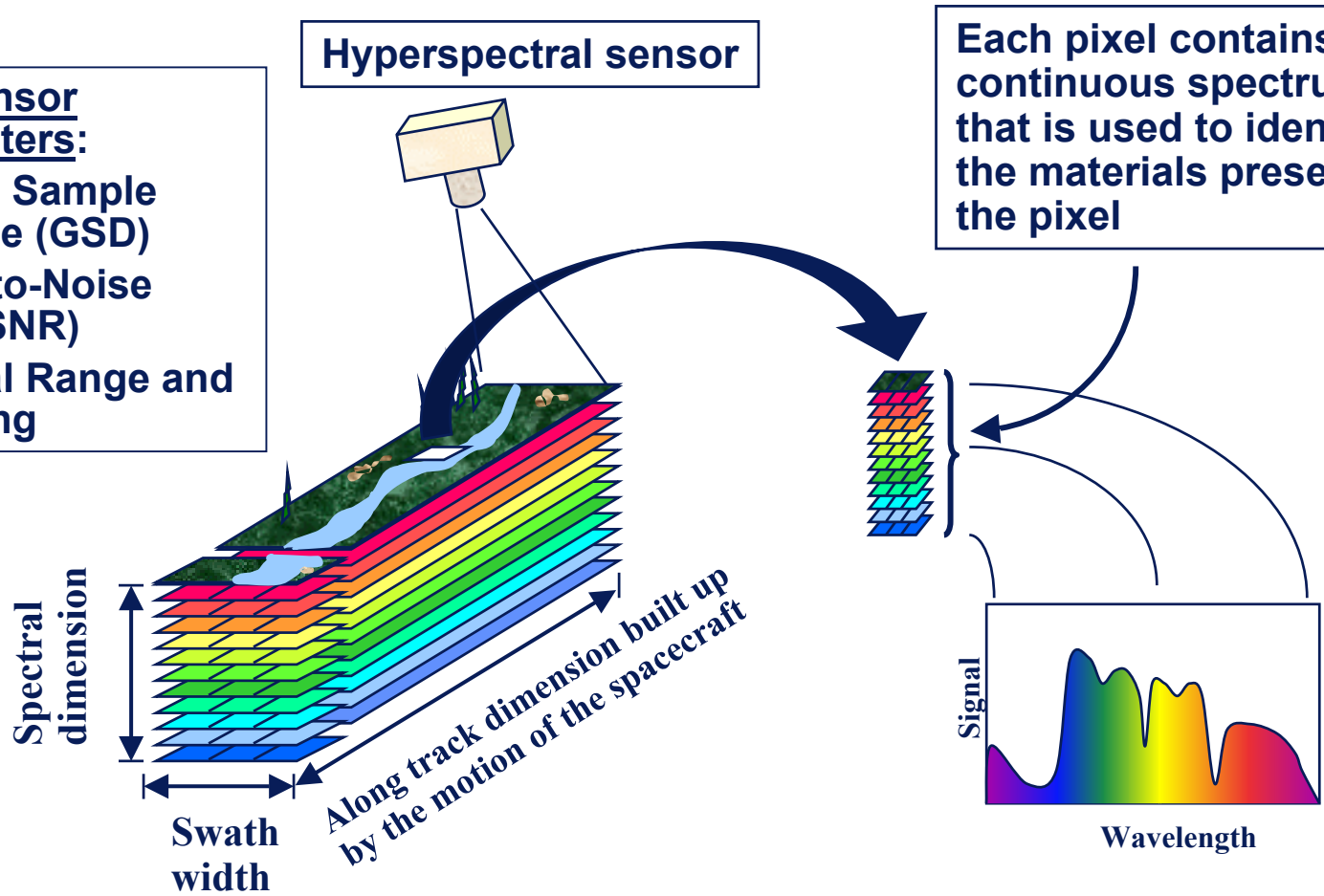
Comparison to Alternatives -

- Aircraft Flight Data and Techniques are the heritage and basis for this experiment; but global airborne collection would be impractical. HSI is ready now for transition to space.
- Previous Government attempts at spaceborne HSI collection have either failed (Warfighter I, NEMO) or lacked radiometric quality and coverage (HYPERION). The COIS STP payload experiment would serve as risk reduction for future operational space HSI programs outlined in the ISA in the technology areas of large format FPAs, Gflop class onboard parallel processors and onboard processing algorithms.

Hyperspectral Imaging Concept

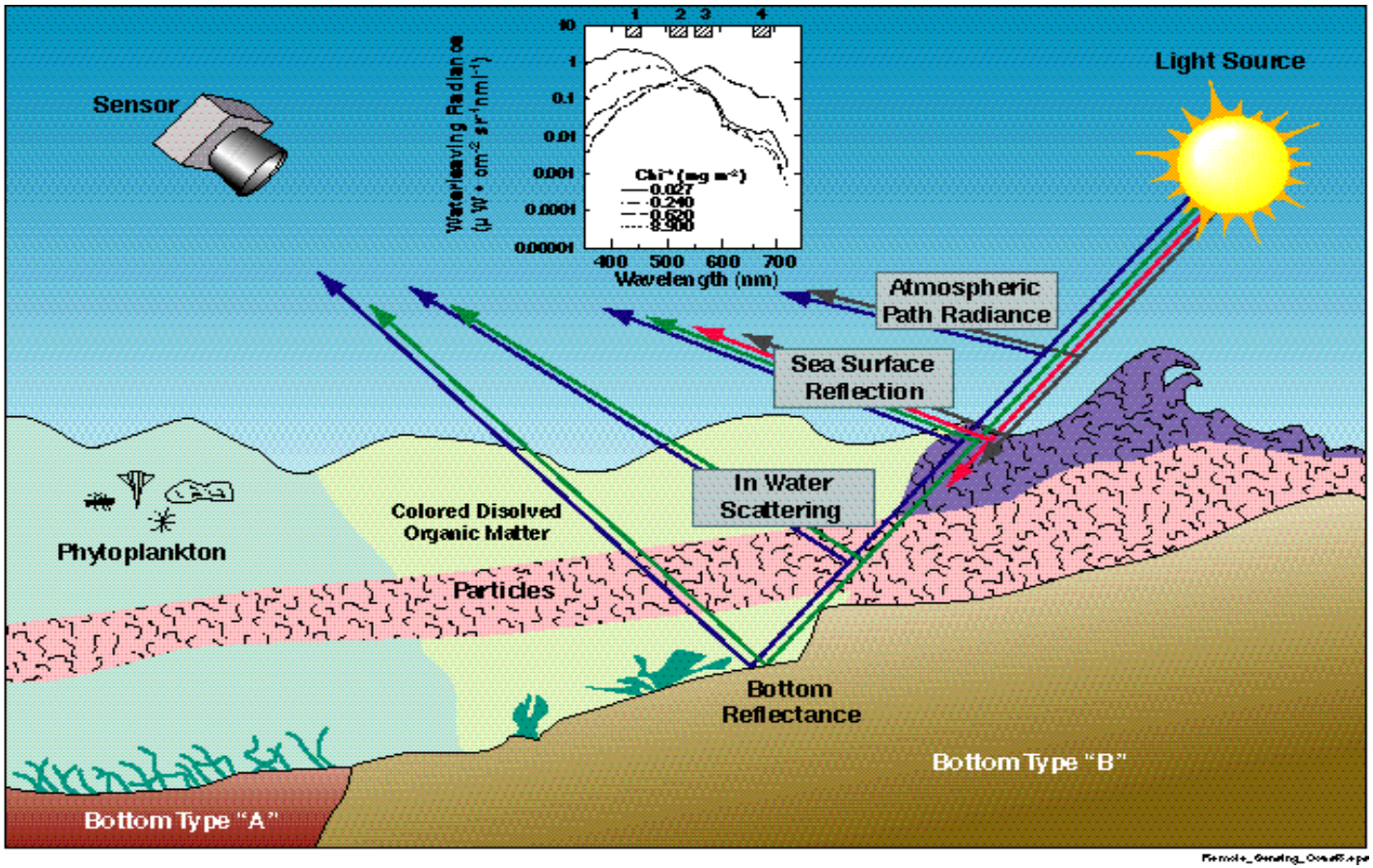
Key Sensor Parameters:

- Ground Sample Distance (GSD)
- Signal-to-Noise Ratio (SNR)
- Spectral Range and Sampling



In the visible and near-infrared liquids and solids are identified by their spectral absorption and scattering of solar radiation.

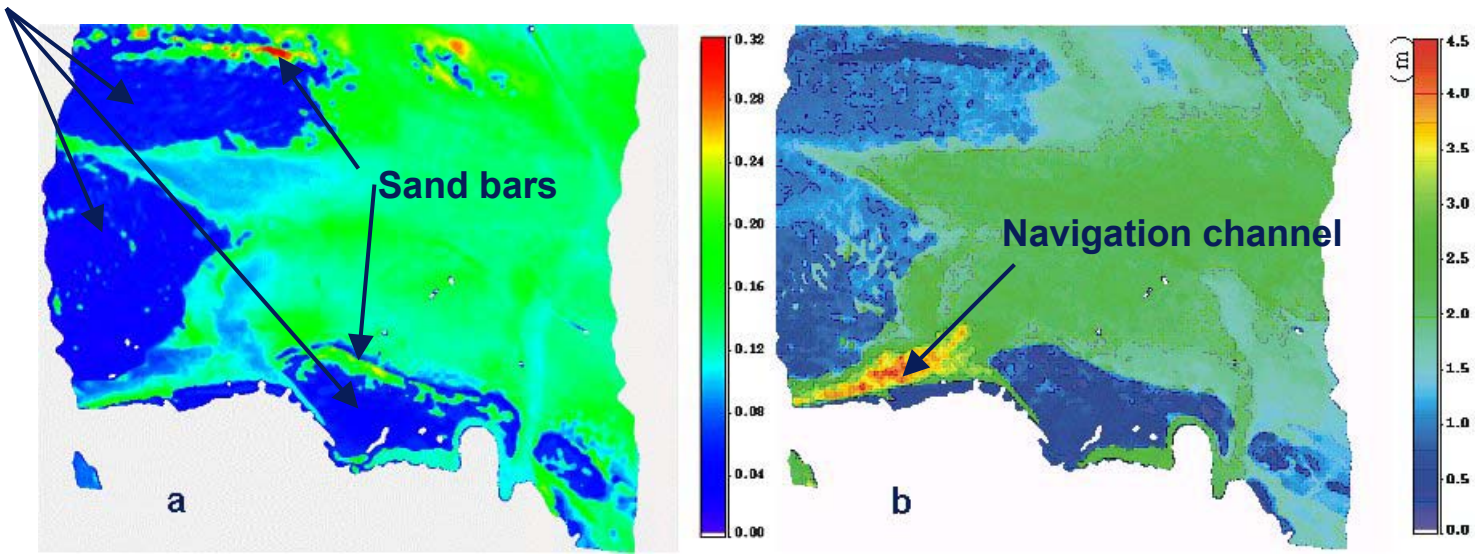
Resolving the Complexity of Coastal Optics Requires Hyperspectral Remote Sensing



Visible radiation is the only part of the Electromagnetic Spectrum that penetrates the water. Extensive studies using shipboard measurements and airborne hyperspectral imaging have shown that hyperspectral imaging is the only tool available to resolve the complexity of the coastal ocean from space.

Applications

- **Naval Requirements for characterization of the littoral battlespace:**
  - **Bathymetry, bottom type, water clarity, hazards to navigation, beach and shore trafficability.**
  - **Hyperspectral imaging is the only way to do this from space.**
- **Army and Air Force requirements for hyperspectral imaging for military target detection.**



a) Bottom type and b) bathymetry derived from an AVIRIS image of Tampa Bay, FL using automated processing of the hyperspectral data.

NRL - 0205 Coastal Ocean Imaging Spectrometer (COIS) Summary of Data Application

- **Demonstration of the use of Spaceborne Hyperspectral Imaging to meet Naval Requirements for characterization of the littoral battlespace[1-5]:**
  - **Bathymetry, bottom type, water clarity, hazards to navigation, beach and shore trafficability.**
  - **Time series data set for coastal ocean model development and validation.**
- **Pathfinder for Noble EYE and future spaceborne hyperspectral systems[6-7]:**
  - **Army, Air Force and Naval Space Command will use COIS data for TPED development and training for battlespace characterization and large target detection.**
  - **Technology demonstration for focal planes and on-board processing.**

1. NPOESS: Integrated Operational Requirements Document, 10 Dec 2001.
2. USSOCOM: Critical METOC Thresholds for SOF Operations, (Manual No. 525-6), October 1996.
3. Marine Corps Intelligence Activity (MCIA): Generic Intelligence Requirements Handbook (GIRH), 2d Edition, (Publication MCIA-1540-002-95), March 1995.
4. Navy METOC Spectral Sensing Conference, Navy METOC E.O. Roadmap, December 2001.
5. Commander Fleet Forces Command, Fleet METOC Requirements Conference Prioritized List of Fleet METOC Concerns, January 2002.
6. NSSA: Integrated Spectral Architecture Study (Classified).
7. Naval Space Command: Final Report - Naval Needs Utility Assessment, Hyperspectral Technology Assessment in Support of Naval Requirements, January 2002.

NRL - 0205 Coastal Ocean Imaging Spectrometer (COIS) Detailed Overview

Flight Data -

- Proposed as Free Flyer or as a Secondary Payload, three year duration.
- Orbit - 500 km (± 100 km), 1030 - 1330 Sun synch, 97.4 ˚ Inclination.
- Gimbaled imager on Earth facing deck.
- Payload Envelope - 92 X 61 X 110 cm; Mass - 72 kg ; Power - 90 watts.
- Downlink data rate: at least 10 Mbps.

Status -

- Capitalize on previous Navy/DoD $80M investment, mature CDR-level design, available flight optics and other existing hardware components.
- Onboard processing and product algorithms tested and validated in ongoing science programs at NRL.
- System requirements and design based on 10 yrs extensive HSI experience at NRL.

Priority -

- #2 in 2002 NAVY SERB and DoD SERB.

Requested STP services -

- Spacecraft / Experiment Integration
- Launch Services
- Launch Integration
- First year Operations

Funding -

- Total Cost: $ 64 M
- Estimate to Complete $ 39 M including
  - Complete, calibrate and characterize sensor
  - On-board processor and data storage
  - 2-axis pointing system
  - Management Reserve
  - Three years Operations and data products.

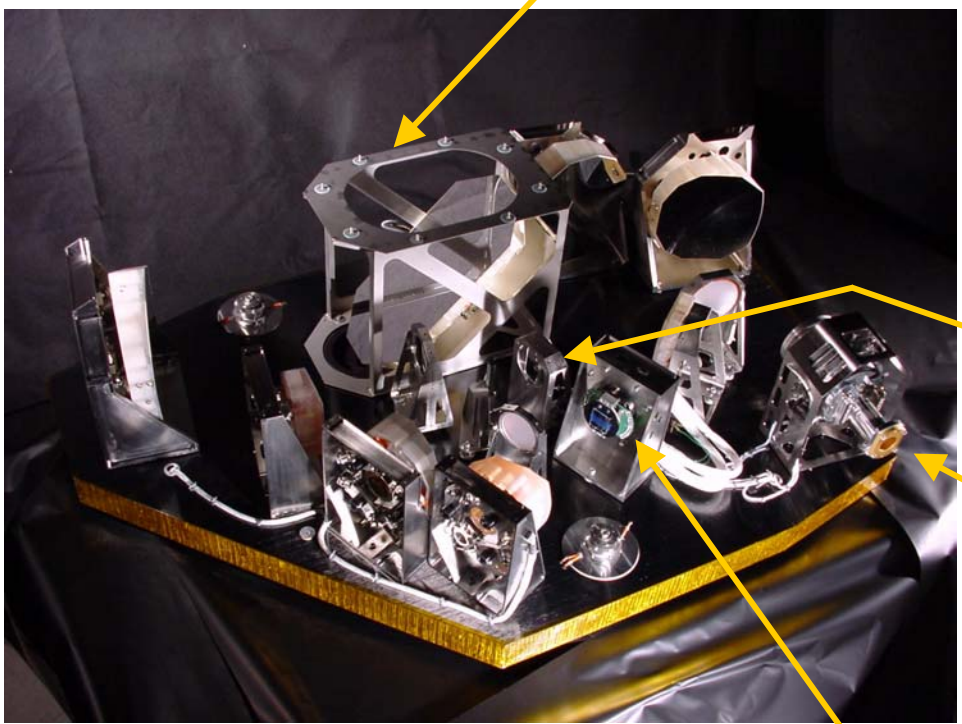
	Prior	Current	Fy03	FY04	FY05	FY06	FY07
Requested Budget	17	3.6	9.2	18.5	10.5	3	2.5
Actual or Programmed	17	3.6	1	1	1	1	1

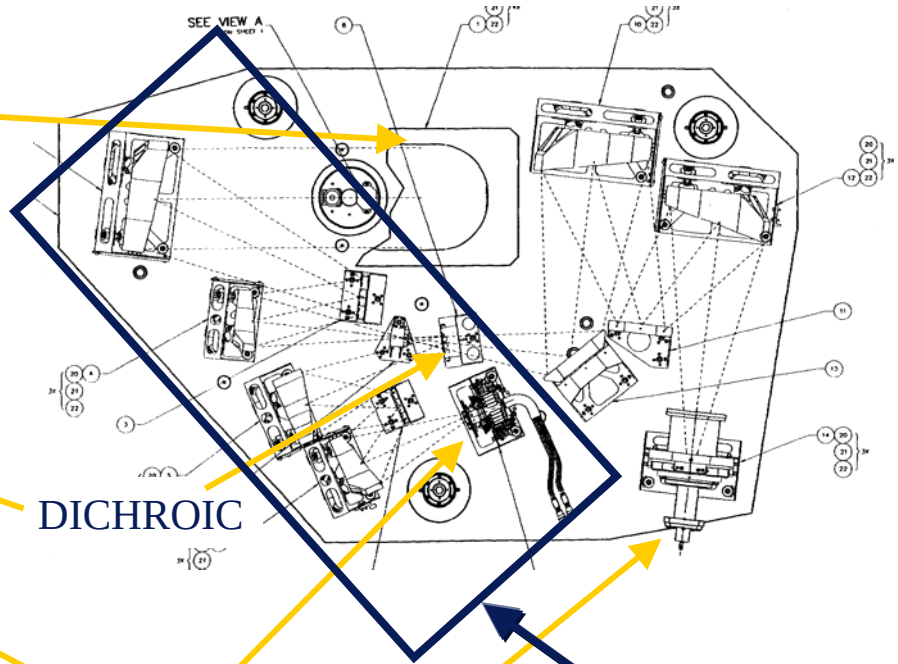
Note * Notional launch late FY-05

COIS Sensor Flight Hardware at NRL

Two Full sets of Flight Spare Mirrors & gratings at NRL

Support for Baffle & Cover Mechanism





DICHROIC

SWIR FPA in Dewar

VNIR FPA
(EM FPA)

VNIR COIS, as outlined, is a much smaller package for integrating into an STP flight opportunity

- **Engineering Model at NRL for Mechanical Testing (Pictured).**
- **Flight Unit is now at NRL.**

NRL - 0205 Coastal Ocean Imaging Spectrometer (COIS)
Flight Mode Suitability

Flight Mode	% Experiments Objectives Satisfied
* Shuttle	0 %
* Shuttle Deployment	0 %
Shuttle Deployment with Propulsion	30 %
* International Space Station	30 %
"Piggyback" Free-flyer on EELV	100 %
Dedicated Free-Flyer on EELV	100 %

How important is it to retrieve your flight hardware for analysis or reflight?

Payload retrieval not required.

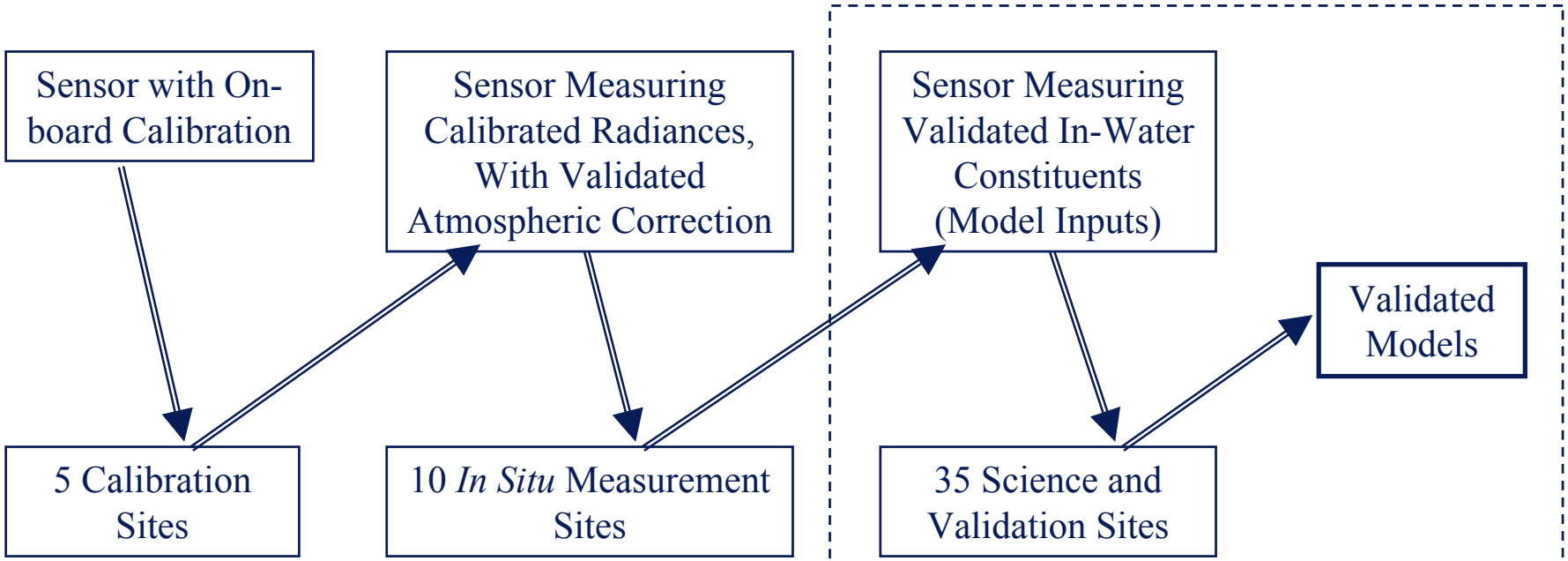
(* Shuttle and ISS orbits do not provide global coverage and consistent sun angles)

Backup

COIS Standard Littoral Products

- NRL Tafkaa atmospheric and glint correction algorithms:
  - Produces surface reflectance, $\rho(\lambda) = \pi\ L/E_d$, where L is the water leaving radiance (corrected for glint over the ocean) and E_d is the surface downwelling irradiance
  - Atmospheric Correction of land scenes
    - Assumes a Lambertian surface
    - Includes bright targets
    - Includes elevations above sea level
- Ocean algorithms:
  - Water clarity K_d(490 nm)
  - Phytoplankton chlorophyll and Colored Dissolved Organic Matter (CDOM)
  - Suspended sediments
  - Bathymetry
  - Bottom type and reflectance
- Beach and coastal products
  - Terrain categorization and vegetation classification
  - Trafficability

Littoral Ocean Data Validation and Model Development



Observations of the calibration sites fix the radiance calibration and validate the atmospheric correction model.

Observations of sites with extensive ground truth provide validation of the algorithms for the in-water constituents (chlorophyll, sediments, etc.) that will be used as input to the coupled physical, bio-optical models.

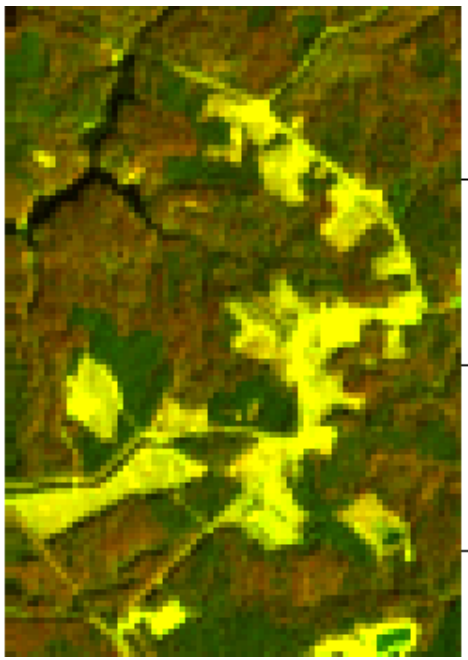
The validated products now become the "ground truth" for the model validation. The process of model validation is an iterative one, comparing repeated observations with model predictions.

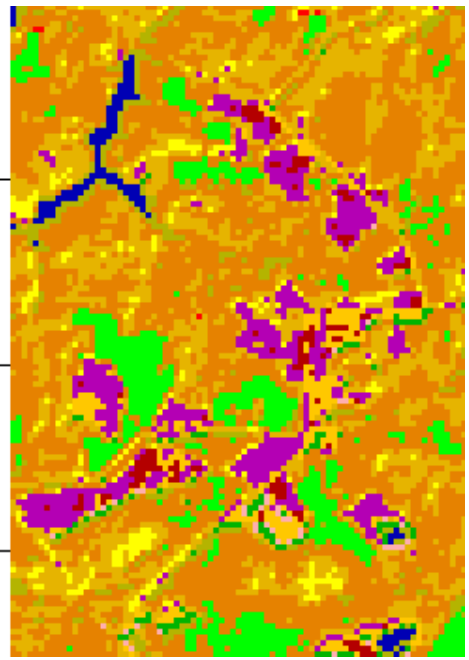
Comparison of Hyperion and AVIRIS data

Hyperion November 2001

Left: RGB, Right: vegetation classes

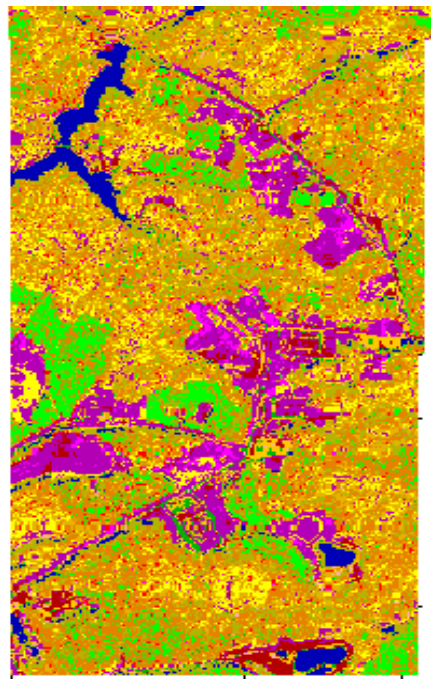
loblolly pine
autumn deciduous 1
autumn deciduous 2
autumn deciduous 3
field





AVIRIS November 1999

Left: RGB, Right: vegetation classes



Hyperion is a NASA technology demonstration which provides a limited amount of low SNR, 30 m Ground Sample Distance (GSD) hyperspectral data. It does not include the 0.4 to 0.45 μm wavelength range which is critical for ocean measurements. By comparison, COIS is designed to provide AVIRIS like high SNR, 20 m GSD data. This will provide much better detail and far better water penetration than Hyperion.